Gender Gap in Computer Science Programs from Costa Rican Public Universities

Are Women Really Becoming Extinct?

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Abstract—**There is evidence that women tend to be underrepresented in computer science programs (CS) in many countries. Based on this fact, we analyzed the gender situation in Costa Rica finding that this situation also applies to the four public universities in the country. Furthermore, similar to the case of the U.S., the percentage of women graduating from CS programs from such universities is decreasing. Based on previous studies, we attempt to explain the gender gap in Costa Rican public universities, and present recommendations to reduce it.**

Keywords-Gender; computer science programs; public universities; Costa Rica

I. INTRODUCTION

According to Jofré [1], "[a] milestone for women [in Costa Rica] was to achieve equality with men in terms of university diplomas, situation that occurred 33 years ago. What has happened afterwards is somehow curious: the relationship men/women came back to the 60s, but reversed. In fact in those years, 36% of the university diplomas were granted to women, yet in 2010 a similar percentage corresponded … to men." Nevertheless more women are graduating from the university system in Costa Rica in present years, the percentage of women graduated from computer science (CS) programs[1] is low and appears to be decreasing [2]. There is also evidence that women in Costa Rica tend to graduate more from education and social sciences programs [3], and not so much from basic sciences and engineering (BS&E) programs, and particularly, not from CS programs.

The low representation of women in CS programs is not particular of Costa Rica. Camp [4] referred to the situation in which the percentage of women diminishes along the academic

trajectory as the "shrinking pipeline." Furthermore, this author also reported a reduction across time in the number of bachelor degrees in CS granted to women in the U.S.

Camp et al. [5] indicates that the "incredible shrinking pipeline" in women´s graduation in CS programs is a trend likely to continue. Cohoon [6] and Katz [7] report decreasing percentages of women graduating from CS, while such percentage has increased for other BS&E programs in the U.S. Related to this situation, Clarke [8] indicates that an unusual situation can be observed in CS. While there has been a notable increase in the number of women in professions traditionally dominated by men, such as law and medicine, women are still underrepresented in CS, similar to other engineering disciplines. Nevertheless different from other engineering professions, the participation of women in CS programs has been falling progressively in the last 20 years.

Studies reporting the low participation of women in CS programs have focused on other countries: Australia [9,10], Canada [11], Greece [12], Israel [13], and Germany [14]. All the previous studies put CS at an interesting perspective regarding other fields, including BS&E. As Misa [15], claims: "[t]here´s no way of putting it except to say that computing is unique to all the professional fields" (p. 4).

In Costa Rica, studies on gender differences have focus on specific universities or CS departments, presumable due to the fact that gender data for CS programs has been hard to obtain [16]. In a pioneering work, Chavarria [17] presented the first study on gender considering the careers at the Universidad de Costa Rica, the largest public university in Costa Rica. Several years later, this researcher along with Marin and Barrantes [2] studied the CS undergraduate and graduate programs at the main campus of the Universidad de Costa Rica (UCR). Similarly to authors in other countries, they conclude that women are underrepresented in the CS undergraduate program in terms of admission, and consequently, also in terms of graduation. In addition, there is a decreasing trend in women´s

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[1] Computer related study programs in Costa Rican universities have several different names. For the sake of simplicity, they are referred in this paper to as computer sciences programs.

participation in the undergraduate program across time. Although women are also underrepresented in the graduate program, the male to female rates for this program are very similar across time. Based on their results, these authors propose the intriguing question of whether women might become extinct from CS programs in Costa Rica.

In this paper we attempt to answer this question considering public universities in Costa Rica. We focus on public universities for three reasons. First, public universities as social mobilizers should promote gender equality. Second, private universities in Costa Rica offer fewer degrees in BS&E than public universities. We use graduates in these programs as a comparison to CS graduates in this work, similar to the papers of Cohoon [6] and Katz et al. [7]. Finally, there are significantly less public than private universities in Costa Rica, which simplifies the analyses.

We gathered graduation data for this research, including undergraduate and graduate diplomas, for the time period 2001 to 2009 [2] from the "Consejo Nacional de Rectores" (CONARE) [3] [18,19,20,21]. We were only able to collect graduation data yet not admission data, which are not reported by CONARE.

The specific objectives of this research are:

- To measure the gender gap in the CS programs of the public universities in Costa Rica;
- To relate the previous gap to all public university (APU) and to BS&E programs from public universities;
- To determine differences in the gender gap considering the individual CS programs of the public universities;
- To determine whether the gender gap in public universities is improving or worsening across time;
- To explain the gender gap found and propose possible recommendations to reduce it.

This research is important not only from a social, but also from an economic perspective. Costa Rica has experienced in recent years an increase in new ICT jobs due to the installation in the country of several high-tech multinational corporations such as IBM, Intel and HP. These organizations provide well-paid positions to new graduates. Therefore, under-representation of women in CS programs deprives them from having access to such jobs. Furthermore, the industry often complains about the lack of qualified professionals for ICT jobs. By increasing women participation in CS programs, more workforce would be available [2,6].

II. GENDER DIFFERENCES IN THE GRADUATES OF PUBLIC UNIVERSITIES

Costa Rica has a pretty much balanced gender population. According to the last census carried out in 2011, women represent 51% and men 49% of the total population [22]. The gender distribution according to the 1984, 2000 and 2011 censuses shows little variation in the population distribution by gender (see Table I).

TABLE I. POPULATION GENDER DISTRIBUTION (1984, 2000 AND 2011)

Year	Total Population	Female population		Male population	
		Total	*%*	*Total*	*%*
1984	2,416,809	1,208,593	50.0	1,208,216	50.0
2000	3,810,179	1,907,565	50.1	1,902,614	49.9
2011	4,301,712	2,195,524	51.0	2,106,188	49.0

Source: INEC [22]

To analyze the gender gap in the CS programs of Costa Rican public universities, we used the tunneling approach depicted in Fig. 1. In this approach, the first level of analysis considers the graduates from APU programs. Within this level, we consider as the second level of analysis only the graduates from BS&E programs. CS programs are a subset of this last type of programs, and therefore they make the third level of analysis. Finally, CS programs are divided into the four individual programs corresponding to each of the four public universities: Instituto Tecnológico de Costa Rica (TEC), Universidad de Costa Rica (UCR), Universidad Estatal a Distancia (UNED), and Universidad Nacional (UNA).[4]
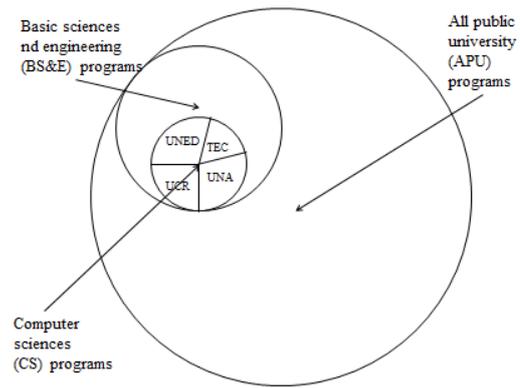

Figure 1. Tunneling approach for gender analysis of public university programs

A. Gender Differences in the Graduates of APU, BS&E and CS Programs

Table II presents the percentage of women graduated from APU, BS&E, and CS programs for the period 2001-2009. As this table shows, on average 61% of the graduates from APU programs in this period were women, meanwhile, when BS&E programs are considered during the same period, only 30% of the graduates were women. Women graduated from CS programs, on average, show a similar behavior to BS&E programs (27%).

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[2] This is the last year for which university graduation data were available at the time of writing this paper.

[3] This organization is in charge of coordinating public universities in Costa Rica.

[4] In 2008 another public university was created in Costa Rica: the Universidad Técnica Nacional. However, this is not considered in the analyses.

TABLE II.   PERCENTAGE OF WOMEN GRADUATED FROM PUBLIC UNIVERSITIES (2001-2009)

Year	Percentage of women graduated		
	All programs	BS&E programs	CS programs
2001	58.4	28.4	28.8
2002	60.2	28.5	29.5
2003	61.4	27.6	28.9
2004	61.4	29.1	28.3
2005	60.9	32.3	28.5
2006	61.2	31.5	30.2
2007	62.4	30.2	22.6
2008	60.8	30.1	23.1
2009	60.1	29.7	21.4
Mean	60.8	29.7	26.8
Std. dev.	1.1	1.5	3.4
Min	58.4	27.6	21.4
Max	62.4	32.3	30.2

Source: Data taken from [18,19,20,21]

Given the balanced gender distribution in the population in Costa Rica (see Table I), the expected percentage of women graduating from the previous three types of programs would be 50%. Therefore, this expected percentage of women graduated can be used as a benchmark to measure the gender gap. In the case of APU programs, there is an average positive gap of 10.8%, which means that women are overrepresented when all the programs are considered in the public universities. However, in the case of BS&E and CS programs there are average negative gaps of 20.3% and 23.2%. This situation implies that women are underrepresented from these two last programs.

Paired comparisons of the percentage of women graduated from APU programs versus women graduated from BS&E programs, and the percentage of women graduated from BS&E programs versus women graduated from CS programs can be used to test statistical differences between these three levels of gender analysis.[5] These paired comparisons are presented in Table III. As this table shows, the paired comparison of the time series between the APU and BS&E programs is statistically different at a 95% level of confidence, yet the comparison of the series for BS&E and CS is not statistically different at this same level. Due to the fact that the same data is used at most twice in a comparison and that a type I error rate of 5% is considered in the previous tests, the composite

error rate[6] for these paired comparisons is not greater than 9.75% [23].

TABLE III.   COMPARISON OF PERCENTAGE OF WOMEN GRADUATED FROM APU, BS&E AND CS PROGRAMS FROM PUBLIC UNIVERSITIES (2001-2009)

Year	Paired comparisons	
	APU vs. BS&E	BS&E vs. CS
2001	30.0	-0.4
2002	31.7	-1.0
2003	33.8	-1.3
2004	32.3	0.8
2005	28.6	3.8
2006	29.7	1.3
2007	32.2	7.6
2008	30.7	7.9
2009	30.4	8.3
Mean	31.04	2.90
Std. dev.	0.53	1.29
t value	58.41	2.25
Prob > |t|	<0.0001	0.0545

Fig. 2 depicts the data in Table II. As shown in this figure, whereas the percentage of women graduated from APU programs and from BS&E programs remain relatively stable across time, a notable reduction in the percentage of women graduated in CS programs can be observed from 2006, year corresponding to the maximum percentage of women (30.2%), to 2009, year corresponding to the minimum percentage (21.4%).[7] These results are similar to the ones reported in the U.S. by Cohoon [6], for the period 1971-2000, and by Clarke [8], for the period 1966 to 2006. According to these authors, the percentage of women graduated from BS&E programs have steadily increased, with the exception of CS programs which started to decline at the end of 1984 in that country.

Table IV presents the linear regression equations for the time series depicted in Fig. 2. As shown in this table, only the equation associated with the CS series presents a negative coefficient, reflecting a decrease of almost 1 percentage point annually.[8] Incidentally, this is the best fit linear equation, and it is able to explain 63% of the variation in the data.

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[5] This is done computing first the difference between the percentages of graduation for each of the two levels and then computing the mean for such differences. A *t* test can later be used to determine whether this average is statistically different from 0. The null hypothesis in this case implies that the respective values in the two time series are equal. Therefore, rejecting this hypothesis at a type I error rate of α will provide evidence that the two time series are statistically different with a confidence level of 1- α.

[6] Composite error refers to the possible error induced by using the same set of data more than once in several statistical tests [23].

[7] CS programs also present the greater standard deviation for the percentage of women graduated (see Table 2).

[8] Although the linear regression models do not have a very good fit, as reflected by the low R^2 values associated to most programs, these models are not used to forecast values, but simply to present the linear tendency reflected by the actual values in each time series.
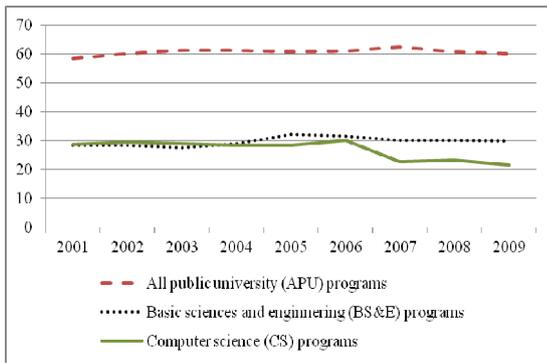
Figure 2. Percentage of women graduated from public universities (2001-2009)

TABLE IV.   LINEAR TENDENCIES FOR TIME SERIES CORRESPONDING TO APU, BS&E AND CS PROGAMS

Programs	Linear regression equation	R^2
APU	y = 0.1733x+59.889	0.1795
BS&E	y = 0.2942x+28.230	0.2880
CS	y = -0.987x+31.733	0.6325

B. Gender Differences between CS Programs

Table V presents the percentage of women graduated from all CS programs in the public universities, as well as from the individual CS programs from each of these universities. It can be observed from these data that more men than women graduated from these individual programs. In descending order according to the mean percentage for the period 2001-2009, the CS programs correspond to the UNED, UNA, UCR, and TEC. It is interesting to note that the two extreme programs, corresponding to the UNED and the TEC, have particular characteristics. The UNED is a distance learning university, which appeals more to women, particularly heads of household. On the other hand, the TEC is a university specializing in engineering and technology programs, and tends to attract fewer women. Clarke [8] hypotheses that after being established at their beginnings under a wide variety of disciplinary cultural influences, i.e. in departments such as mathematics, physics, and electrical engineering and located in liberal arts, science and engineering colleges, nowadays CS programs have become independent departments predominantly under engineering colleges. This focus in discipline and association with engineering reduced the number of women interested in CS programs and made the proportion of women in these programs similar to those in engineering.

TABLE V.   PERCENTAGE OF WOMEN GRADUATED FROM CS PROGRAMS FROM PUBLIC UNIVERSITIES (2001-2009)

Year	CS programs				
	All CS	UNED	UNA	UCR	TEC
2001	28.8	16.7	35.0	28.9	15.5
2002	29.5	33.3	31.5	29.7	24.8
2003	28.9	30.0	32.9	29.9	19.1
2004	28.3	36.8	30.6	34.2	15.3
2005	28.5	37.0	32.2	28.0	21.5
2006	30.2	43.5	37.7	30.9	17.5
2007	22.6	35.7	25.0	23.4	15.9
2008	23.1	25.0	22.8	23.8	22.2
2009	21.4	27.0	21.3	28.3	11.6
Mean	26.8	31.7	29.9	28.6	18.2
Std. dev.	3.4	8.0	5.6	3.3	4.1
Min	21.4	16.7	21.3	23.4	11.6
Max	30.2	43.5	37.7	34.2	24.8

As stated before, under a balanced gender distribution in the Costa Rican population, the expected percentage of women graduating from each of these individual CS programs would be 50%. Therefore, average negative gaps of 18.3%, 20.1%, 21.4% and 31.8% are found for the UNED, UNA, UCR and TEC CS programs, respectively. It is important to note that the TEC CS program not only has the largest gap, but also it is the only program whose mean percentage is below the average percentage for all CS programs.

Similar to the previous case, paired comparisons were made to test the statistical difference between the percentage of women graduated from all CS programs and the percentage of women graduated from the UNED CS program and then pairwise between each individual CS program in descending order of mean percentage of women graduated. These comparisons are presented in Table VI. As this table shows, only the paired comparison of the UCR and TEC series is statistically different at a 95% level of confidence. Similar to the previous case, the composite error rate for these paired comparisons is not greater than 9.75% using a type I error rate of 5% [23].

TABLE VI. COMPARISON OF PERCENTAGES OF WOMEN GRADUATED FROM ALL CS PROGRAMS AND INDIVIDUAL CS PROGRAMS FOR PUBLIC UNIVERSITIES (2001-2009)

Year	Paired comparison			
	All CS vs. UNED	UNED vs. UNA	UNA vs. UCR	UCR vs. TEC
2001	12.1	-18.3	6.1	13.4
2002	-3.8	1.8	1.8	4.9
2003	-1.1	-2.9	3.0	10.8
2004	-8.5	6.2	-3.6	18.9
2005	-8.5	4.8	4.2	6.5
2006	-13.3	5.8	6.8	13.4
2007	-13.1	10.7	1.6	7.5
2008	-1.9	2.2	-1.0	1.6
2009	-5.6	5.7	-7.0	16.7
Mean	-4.86	1.78	1.32	10.41
Std. dev.	2.58	2.80	1.51	1.91
t value	-1.88	0.63	0.88	5.46
Prob > |t|	0.0962	0.5434	0.4053	0.0006

Source: Data from CONARE [18,19,20,21]

Figure 3 graphically presents the data in Table V. All the time series represented in this figure show a decreasing tendency across time. This decrease is noteworthy after 2006 for the UNED, UNA and UCR CS programs, which explains the sharp decrease in the percentage of women graduated from all CS programs in the public universities.

Linear tendencies for the time series in Fig. 3 are presented in Table VII. All linear regression equations present negative coefficients, with the exception of the one corresponding to the UNED. These negative coefficients reflect decreases in the percentages of women graduated for most individual programs. In particular, the linear equation corresponding to the UNA shows the greatest decrease: 1.5 percentage points annually. This is also the equation with the best fit, explaining 53% of the variation of the time series corresponding to this university.
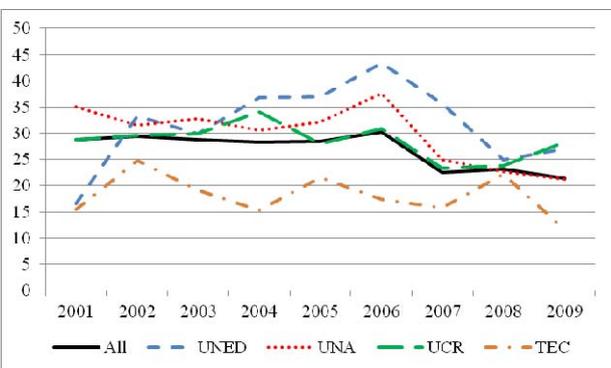

Figure 3. Percentage of women graduated from CS programs from public universities (2001-2009)

TABLE VII. LINEAR TENDENCIES FOR TIME SERIES CORRESPONDING TO ALL, UNED, UNA, UCR AND TEC CS PROGRAMS

Programs	Linear regression equation	R^2
All CS	$y = -0.987x + 31.733$	0.6325
UNED	$y = 0.5751x + 28.802$	0.0391
UNA	$y = -1.4938x + 37.354$	0.5292
UCR	$y = -0.5987x + 31.566$	0.2406
TEC	$y = -0.459x + 20.461$	0.0931

III. CONCLUSIONS, EXPLANATIONS AND POSSIBLE RECOMMENDATIONS

The previous study demonstrates that there is a considerable gender gap in the CS programs from public universities in Costa Rica, considering the percentage of women graduated in the period 2001-2009. Women are seriously underrepresented in these programs, and they are so, even more, if we consider the percentage of women graduated from all programs offered in these universities.

Since the female representation in CS programs is similar, and statistically not different, to the BS&E programs in the same universities, we might conclude that the gender gap in CS programs is just a result of the gender gap in the BS&E programs. Nevertheless, the previous perspective provides only a static view of the problem. While the percentage of women graduated from all programs and from BS&E programs from the public universities in Costa Rica remain relatively stable during the period studied, the percentage of women graduated from CS programs show a notable decrease, especially after 2006. At an average decrease of almost 1 percentage point annually, women would become extinct from the public CS programs in less than 25 years.

The situation in the four individual CS programs of each public university is not very encouraging either. Similar to the case of the percentage of women graduated from CS programs, the individual CS programs show a decrease in such averages, also especially after 2006.

In the U.S., the reduction in the proportion of women in CS is not just related to the academic programs but also to the workforce [15]. Esmenger [24] explains this masculinization process as a result of the professionalization of the computing discipline. According to this author, the professionalization of the computer field required the computer related occupations to become more formal and to acquire a higher status. Formal requirements, particularly associated with education, impose entry barriers to women considering the time they have to dedicate to raise children and support their own households. Furthermore, to increase its status, computer professionals have to separate themselves from aspects of the work that are considered routinary and mechanical, which are often associated with a feminization of the work. This is also reinforced with the fact that professionalism demands managerial authority, skill that is often associated to men and not to women. This phenomenon has made the computer profession inhospitable to women.

Therefore, the gender problem in CS programs is the result of the masculinization of the computer profession as a whole, and the feminization of low-skill computer jobs; which are both gender induced processes. To support this claim, Haigh [25] indicates that as we move up in the computer career ladder, the proportion of women is lower and the average pay is higher.

Based on Esmenger´s explanation, we hypothesize that the decrease in women participation in the public CS programs after 2006 is the result of the professionalization of the computer discipline in Costa Rica, induced by the establishment of the multinational corporations in the country at the end of the last milennium. This process began with the decision by Intel at the end of the 1990s to invest US$300 million in a period of two years and a total of US$600 million to build an assembly and testing plant in Costa Rica. According to Mata and Mata Marin [26], this decision produced "strong demonstration effects, by showing other companies Costa Rica´s advantages as an investment destination" (p. 7). Consequently, Costa Rica has become an attractive destination for foreign direct investment, particularly for ICT companies. The recent opening of a global delivery service center from IBM, with an expected investment of US$300 million and 1,000 new jobs in the country, is just another example of this ripple effect [27]. As a result of all this, Costa Rica is the fourth-largest technology-exporting country in the world, with high-tech exports accounting 39% of the country´s total exports in 2008 [28].

Jobs in multinational corporations are abundant, well paid, and have indeed contributed to professionalize the computing discipline in Costa Rica. But also, requirements for such jobs, as shown in newspaper ads, are very formal and demanding in terms of ICT knowledge and skills. Therefore, we claim they are more intimidating to women, deterring them to pursue an ICT career.

In order to find solutions for the gender gap problem in CS programs, it is necessary to realize that such gender differences are not "so much [in] formal discrimination or overt barriers to women, but rather [in] gender biases encoded in professional culture" (Misa [15], p. 7). This author proposes five possible actions to reduce such biases. The first one is to reduce the requirement of prior experience in programming, which might be a gender entry barrier. To address this issue, introductory programming courses can be restructured to demand less programming abilities and skills and focus more on conceptual aspects. Second, topics in the CS curriculum should be treated in a more gender neutral way, making women more comfortable to participate. Third, it is important to develop mentoring mechanisms for women, since they are often excluded from the existing mechanisms. Fourth, peer support can be useful. In this regard, formal group working in classes can be beneficial, particularly pair programming where two students work on a programming problem, instead of doing it alone. Fifth, reforms are needed to confront the male dominated culture of computing. This is very evident in the computing language, which shows a clear male orientation: *booting* a computer, *crashing* a process, *executing* instructions, and *killing* or *aborting* a program.

Gender biases need to be addressed in order to increase the number of female graduates in CS programs [29]. Therefore, public universities in Costa Rica need to devise strategies to reduce the gender gaps in their CS programs; otherwise, women are very much likely to become extinct from such programs.

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