Circuit Building and Control Workshop to Promote Women in Computer Engineering

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Abstract

The University of Washington Tacoma (UWT) is an urban-serving university and educates a diverse student population. Among them, transfer students from community colleges count for the majority of new student enrollment. Engineering programs on campus have expanded quickly in the past 5 years; however, the Computer Engineering (CompE) program, the first engineering program established in the School of Engineering and Technology (SET), underwent a noticeable drop of enrollment in the past years – the number of female students is no exception. One thing we noticed during the recruiting process is that some female students (including some first-generation students) are confused by the term 'computer' which they took for granted the same as 'programming'. As one of the attempts of recruiting process, to help students get a deeper understanding of the Computer Engineering discipline and learn the difference between Computer and other engineering programs, a free half-day workshop is planned and organized. The workshop targets 30 female and minority students who are interested in STEM disciplines and currently attending community colleges in the area. During the event, attendees learn topics including (1) how to use a breadboard, (2) what is an RLC circuit, (3) how to describe the circuit behavior, and (4) how to use Arduino to implement feedback control of the capacitor's voltage. These topics are carefully chosen to align with our CompE curriculum and require only basic knowledge of physics and calculus. To assess the outcomes, attendees are asked to do an entry survey, and a follow-up exit survey, before and after the event, respectively. Data is collected and analyzed to see if the event could help attendees improve their understanding of Computer Engineering discipline and promote their interest in transferring to our CompE program for further study. Results are shared in this paper, with a summary including future plans.

Introduction

A diverse STEM workforce is essential to a nation's economic growth and global competitiveness, and it starts in the classroom [1]. As summarized in [1], common barriers to diversity in STEM education include stereotypes, lack of access to quality education, and self-perception, which we have observed and experienced in the past 16 years working at the University of Washington Tacoma (UWT). As an urban-serving university, the majority of new student enrollment on campus are transfer students from community colleges in the area. For example, whenever we reach out to recruit students and start introducing our Computer Engineering program, a ubiquitous question arises: What's the difference between Computer Engineering and other engineering disciplines? And further, does the word *computer* in *Computer Engineering* imply programming? Most of the time, these questions come from female students, first-generation students, or underrepresented students. Due to their diverse background, few of them would think of Computer Engineer as their future career. They have no confidence in getting into this field and have no idea about where and how to start. The article [1] calls for actions from educators and policymakers to create a diverse and inclusive classroom, pointing out that one approach is to engage students in STEM learning through hands-on lessons, which is one of the motivations behind the in-progress work reported in this paper. By hosting a free hands-on workshop to community college students, we are reaching out to the educationally underprivileged, providing them an opportunity to spike their interests and unveil their potential through a half-day diverse and inclusive learning experience—ultimately working toward our long-term goals of promoting women and underrepresented groups in engineering.

Another reason for hosting a hands-on free workshop is relevant to our program recruiting. Nationwide, by the Fall of 2021, a closer look at the data [2] showed that after a fairly significant increase in enrollments between 2010 and 2015, enrollment in engineering programs at USA had practically flattened between 2015 and 2020, which might have been affected by COVID-19. From the recent ASEE Engineering by the number reports [3], in particular, the table shown below (of Bachelor's degrees awarded by gender), the percentage of female students with Bachelor's degrees in Engineering is increasing, see Figure 1.

Gender	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Female	17.80%	18.10%	18.40%	18.90%	19.10%	19.90%	20.90%	21.30%	21.90%	22.40%	23.00%	24.00%	24.20%
Male	82.20%	81.90%	81.60%	81.10%	80.90%	80.10%	79.10%	78.70%	78.10%	77.60%	77.00%	76.00%	75.80%

Figure 1: Bachelor's Degrees Awarded by Gender (from [3])

It is worth noting that Computer Engineering, as well as Electrical Engineering, turn out to be the only two disciplines that have a percentage (of Bachelor's degrees awarded to women) less than 15%, see Figure 2; which is consistent with our observation of the ECE programs at UWT. Although the School of Engineering and Technology (SET) has expanded quickly in the past 5 years, the Computer Engineering program, being the first engineering program established in

SET, underwent a noticeable drop in enrollment throughout the past years, see Figure 3; and the number of female students is no exception.

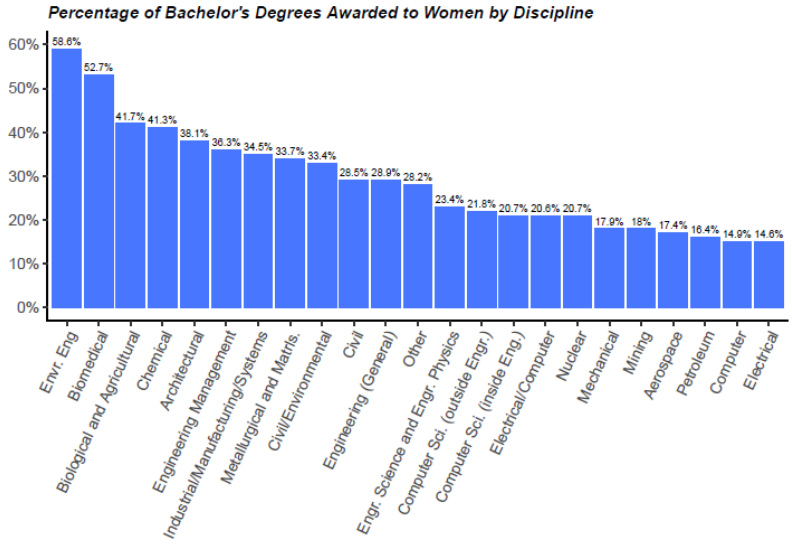

Figure 2: Percentage of Bachelor's Degrees Awarded to Women by Discipline [from [3]]

Year	16/17	17/18	18/19	19/20	20/21	21/22	22/23	23/24
Enrollment	56	56	64	51	36	34	25	23
Degrees Awarded	23	12	28	22	16	15	13	11

Figure 3: Enrollment and Graduation Data of the Computer Engineering program at SET, UWT

Faculty members of our ECE program have worked closely with recruiting staff to avoid this enrollment decrease, and in fact, we have got the enrollment number going up for this academic year 24/25 (not shown in Figure 3). Our efforts have been mainly oriented towards a series of activities reaching out to community colleges. These include collaborating with community college instructors in giving guest lectures, inviting community college students to the open house and lab tour, and organizing events during the annual National Engineers Week. Although we have organizations like SWE (Society of Women Engineers) for enrolled women students, we have never provided specific opportunities to women and minority community college students to explore our Computer Engineering program and encourage them to apply – this is another motivation behind the workshop to be presented in this paper.

The workshop idea was further encouraged by the IEEE Women-in-IES Ambassador Program [4]. In 2024, IEEE IES launched the Women-in-IES Ambassador Program which offers a gateway of the Women-in-IES community into the IES global community, offering mentorship, networking, and support to the local Women in Engineering community. A study in [5] showed that interest was a major driving force for women engineering students to choose engineering. Additionally, nearly half of the women engineering students mentioned that they had at least one family member working as an engineer. We thus believe introducing women to a professional

society like IEEE Women-in-IES can bring them a sense of belonging to the engineering family; we also believe being part of the professional society can spark their interests in engineering, and help this interest be sustained.

In short, the free workshop idea was supported by both the IEEE Industrial Electronics Society (IES) and the SET of UWT. It is designed with three goals: (1) to pipeline a diverse STEM workforce to the nation's future; (2) to promote the community college students transferring to engineering programs, in particular, the Electrical Engineering and Computer Engineering programs at the SET of UWT; (3) to promote the IEEE IES and Women-in-IES memberships. Details of the workshop will be given after a short survey of efforts—that other engineering educators have made—to promote the recruitment of female and minority students. Following the workshop learning objectives and activities, a set of entry and exit survey questions for assessment purposes will be presented together with the analysis results. Improvement ideas and future plans will be summarized at the end.

Background

Since women are significantly underrepresented in scientific and engineering fields, many efforts have been made in the past decades. For example, by comparing statistics of Women in Engineering in the United States to several other countries, advice was given in [6] to middle/high schools, universities, and industries respectively; so that each community could understand their roles and take action to improve the enrollment of women engineers overall. To increase enrollment of minority women in Engineering, especially in Civil and Mechanical Engineering, Alabama A&M University [7] has implemented a certain number of facilitating activities including scholarships, summer internships, awareness generation about the benefits of engineering education, increased levels of self-confidence development, desire to study technical education. To help with the enrollment of the undergraduate Electrical and Computer Engineering program, [8] presented an Electrical and Computer Engineering Leadership (ExCEL) Summer Program offered at the Prairie View A&M University. Results showed that the summer camp approach has contributed to the recruitment of minority and female students. In addition, education researchers studied the 'recruitment and retention' (of women STEM students) problem and proposed systematic approaches. One of them is the Extension Services for Undergraduate Programs (ES-UP) Systemic Change Model, proposed and practiced for women in Computing [9]. The model contains six components; among them—strategic recruiting that prioritizes recruitment activities which provide the greatest return with the least investment of resources, retention practices being mainstreamed into the experiences of all students rather than initiatives, and more details that can be found in the paper as well as the references therein.

Workshop Objectives and Organizing

The organizing faculty has taught in the SET of UWT for more than 16 years with expertise in Control Systems, and Embedded Devices. Thus, the workshop topic is determined by the faculty's teaching and research experience, meanwhile serving the three goals mentioned beforehand. Briefly, the workshop teaches circuit building on the breadboard and circuit control using Arduino. Specifically, hands-on experience allows attendees to learn (1) how to use a breadboard, (2) what is an RLC circuit, (3) how to describe the circuit behavior, and (4) how to use Arduino to implement feedback control of the capacitor's voltage. These topics are carefully chosen to align with the curriculum of our Computer Engineering program and require only basic knowledge of physics and calculus. For Arduino code, templates will be given and explained, so attendees can focus on the key concepts like A/D and D/A conversions, circuit modeling and performance, feedback control, as well as Proportional-Integral-Derivative (PID) controller.

The organizing faculty worked with the recruiting staff and started the preparation in late summer of 2024. ChatGPT found a name for the workshop as 'Circuit Breaker: Women in Engineering'; and Nov. 15 was chosen for this half-day hands-on free workshop from 12 to 4pm. We chose Nov. 15 since it was a Friday when community colleges in the area usually don't offer classes in the afternoon. Also, the Autumn quarter is a busy season and Nov. 15 avoided any time conflicts with other events including career fairs and cross-campus meetings. Meanwhile, the date was before the deadline for community college students making transfer decisions to universities.

For this half-day free workshop, we opened 30 seats for whoever had interests in STEM disciplines and were currently attending community colleges in the area, with priority given to women and minority students. To promote the event, we broadcast the registration link on both the university website as well as social media including Instagram and LinkedIn. One recruiting staff helped with the advertisement, sent invitation messages to community colleges, and printed workshop flyers/booklets. By the week of Nov. 8, 2024, we have got a registration number of 20, including several male students, as well as students who have transferred to our campus and considering applying to ECE programs.

On the day of the workshop, 7 students showed up on time, including 3 male students. All the attendees were from community colleges in the Tacoma area. The recruiting staff helped with the miscellaneous including collecting entry/exit survey data. Two MSECE graduate students and one lab technician provided hands-on help which greatly contributed to the success of the workshop.

The workshop went well, which is reflected in the entry/exit survey data. However, the four-hour duration turned out to be a bit longer for attendees; only 2 students finished all the hands-on

assignments. Based on the observation as well as the exit survey, a list of improvement ideas for future practice was generated and will be shared later.

Workshop Survey Questions and Results

We designed 12 questions for the entry survey and exit survey, respectively. Students' answers were collected for analysis, improvement, and future references. For these questions, we asked students to give a score in the range of 1 to 5 - 1 means 'not at all', and 5 is 'very positive'. For easy comparison and cross reference, we put similar questions into groups. Out of 7 attendees, 4 completed the entry survey, and 5 completed the exit survey (as well as additional questions).

The 1st group of questions serves the purpose of promoting IEEE/IES/Women-in-IES memberships. We made minor changes between two entry and exit questions for comparison purposes.

Entry/Exit survey Questions 1 & 2
Q1 (entry): How much do you know about IEEE?
Q1 (exit): How much do you know about IEEE and the IEEE Industrial Electronic Society?
Q2 (entry): How much do you know about IEEE Industrial Electronic Society?
Q2 (exit): How much interest do you have to be an IEEE IES student member?

Table 1: Answers to Survey Question Group 1
score in the range of 1 to 5 – 1 means 'not at all', and 5 is 'very much'

Entry Survey	1	2	3	4	5
Q1	100%				
Q2	75%	25%			

Exit Survey	1	2	3	4	5
Q1			40%	40%	20%
Q2		40%	40%		20%

Data analysis: We collected survey data, and the results are given in Table 1. Although the percentage is based on the different survey poll numbers and got a little bit hard to compare, the scales do increase. We can therefore tell the workshop did a good job in promoting IEEE and IEEE IES. One student indicated a strong interest to be an IEEE IES student member.

The 2nd group of questions is investigating the teaching effectiveness of this hands-on experience regarding knowledge on circuits, feedback control systems, and Arduino. Again, for comparison purposes, some changes have been made to Question 6 and Question 8 between the Entry and Exit Surveys.

Entry/Exit survey Questions 3 – 9:
Q3: How much do you know about resistors/resistance?
Q4: How much do you know about inductor/inductance?
Q5: How much do you know about capacitors/capacitance?
Q6 (entry): How much experience do you have in using breadboards?
Q6 (exit): How confident are you now in using breadboards?
Q7: How much do you know about Arduino?
Q8 (entry): How much interest do you have in learning a programming language?
Q8 (exit): How confident are you now in using a programming language?
Q9: How much do you know about feedback control systems?

Table 2: Answers to Survey Question Group 2
score in the range of 1 to 5 – 1 means 'not at all', and 5 is 'very much'

Entry Survey	1	2	3	4	5
Q3		25%	75%		
Q4	25%	75%			
Q5		75%	25%		
Q6	75%	25%			
Q7	100%				
Q8			100%		
Q9	60%	40%			

Exit Survey	1	2	3	4	5
Q3		20%	80%		
Q4		60%	40%		
Q5		40%	60%		
Q6		20%	60%		20%

Q7		60%	40%		
Q8	20%	60%			20%
Q9	40%	20%	20%		20%

Data analysis: From the survey results shown in Table 2, it seems all attendees are aware of the resistors/resistance so there was no big change after this workshop. For all the remaining engineering knowledge, the change is obvious. Scales moved from a majority in between 1 and 2 to a majority in between 2 and 3. One student showed a great deal of confidence (after attending this workshop) in using the breadboard, using a programming language, and knowing about the feedback control system – which is a big achievement considering the percentage is 20%! Thus, it is evident that the participants gained insights and knowledge in engineering subjects.

The 3rd group of questions serves the purpose of promoting the Computer Engineering program and other engineering programs at the SET of UWT.

Entry/Exit survey Questions 10 – 12:
Q10: How confident are you in differentiating Computer Engineering and Computing Science?
Q11: How confident are you in differentiating Computer Engineering and Electrical Engineering?
Q12: How much interest do you have in attending the Computer Engineering program at UWT?

Table 3: Answers to Survey Question Group 3
score in the range of 1 to 5 – 1 means 'not at all', and 5 is 'very much'

Entry Survey	1	2	3	4	5
Q10	20%	80%			
Q11	40%	40%	20%		
Q12	20%	40%	20%		20%

Exit Survey	1	2	3	4	5
Q10		60%	20%		20%
Q11		20%	60%		20%
Q12	40%	40%			20%

Data analysis: Clearly, data collected in Table 3 show that attendees have benefited from this workshop in telling the difference between Computer Engineering and Computer Science, as well as differentiating between Computer Engineering and Electrical Engineering. However, it seems the workshop didn't help convince them to transfer to our Computer Engineering program at UWT. Only 1 student showed interest in the entry survey and kept the same in the exit survey, i.e., confirming their decision to join the Computer Engineering program at UWT.

By the end of the workshop, in addition to the exit survey, students were required to comment on 7 additional questions; and their answers have been collected as shown below:

Which part of the workshop do you like the most?
'The build up was very fun and entertaining going from a simple circuit, then switch, then incorporating Arduino. I found it all very interesting and informative especially since I'm taking physics 222 which covers electric circuits.'
'Getting to learn how to build circuits'
'Working with the bread board'
'The hands on experience! This was really great'

How comfortable did you feel engaging in the workshop?
'Very comfortable'
'Pretty comfortable'
'Very'
'Not comfortable at all but everyone made it easy to engage and learn with no judgement'

How useful did you find the handouts?
'I liked them for referencing while working through. Also, it allowed me to move forward to work on the next setup'
'Very'
'Extremely'
'Amazing'

Would you recommend this workshop to someone else?
'Yes, as the treasurer for TCC engineering club I'm going to suggest others to make more of an eff ort to participate in these events'
'Yes'
'Yea'
'Yes!'

Rate your overall workshop satisfaction.
'10/10'

‘Highly satisfied’
‘10/10’
‘10/10’

What would you recommend for improving the workshop?
‘Skip the resistor for the initial test of led’
‘Nothing to improve’
‘Nothing’

Additional thoughts?
‘No’
‘N/a’
‘So much fun!’

Data analysis: Answers to the additional questions in the exit survey are overwhelmingly positive except one student who commented ‘Not comfortable at all but everyone made it easy to engage and learn with no judgement. Our observation and interpretation of this feedback is that one attendee felt uncomfortable with the workshop contents since they are new to them. Fortunately, we created a friendly and highly engaging environment, so the student learned things without pressure. This recognizes the effectiveness of the hands-on learning approach, which is diverse and inclusive, as we planned and expected.

Conclusion and Future Plans
This paper describes our in-progress work of practicing a workshop approach which targets 3 goals: (1) pipelining a diverse STEM workforce to the nation’s future; (2) promoting community college students to transfer into engineering programs, in particular, the Electrical Engineering and Computer Engineering programs at our unit; (3) promoting the IEEE IES and Women-in-IES memberships.

It is obvious that this hands-on workshop has worked successfully in terms of promoting our Computer Engineering program at the SET of UW Tacoma and IEEE/IES memberships. Based on the comparisons between the entry and exit surveys, the participants clearly gained more confidence in dealing with engineering skills and concepts. However, after this first practice, we noticed and realized many aspects which can be improved. For example, due to the low attendance rate, the poll results can only be used as a reference to assess the achievement of our goals. Compared to students at four-year universities, community college students have a very diverse population in terms of race, ethnicity, age, socioeconomic status, and educational background. Thus, events like this free, no-requirement workshop offer a chance for underprivileged or underrepresented students interested in engineering to explore their interests further and encourage them to join engineering programs. However, such events need to be

planned earlier before they mark their calendars with other big commitments like part-time jobs, exams, or job fairs. Additionally, it seems the 4-hour workshop was too intensive regarding the topics covered and the survey assigned. More break time must be added, and the survey assessment would be better separated into stages. This motivates us to come up with the following ideas for a more practical and long-term plan:

1. Separate the workshop to be a series of short sessions instead of a single intensive one.
2. Coordinate with the community colleges for the workshop series so students can fulfill their time commitments well.
3. Connect with more community colleges and broadcast the free workshop so that a high attendance rate can be secured. To promote women in engineering, we'd like to see more women attendees, which is challenging. In fact, we should collaborate with middle/high schools, communities, and industry too, to help promote recruitment from community colleges together.
4. Work with community college instructors so that 1-2 guest lectures can be combined with hands-on workshop lessons.
5. In addition to the hands-on workshop, offering a university summer camp or summer programs to the educationally underprivileged would give them an opportunity to spike their interests and unveil their potential through a half-day diverse and inclusive learning experience.

What is presented in this paper is just one effort we tried with the support of the IEEE Women-in-IES Ambassador program. It turned out to be a feasible and effective way to promote our Computer Engineering program and recruitment for women in engineering. If incorporated more widely, this workshop holds the potential to improve accessibility for underprivileged students to university-level resources, as well as bridging the gap between underrepresented individuals and engineering education in the future. However, more time and budgeting needs to be invested for integration with our school/program routine so that more solid quantitative results can be shared in the future.

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