Improving the Student Experience to Broaden Participation in Electrical, Computer and Software Engineering

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Abstract— **This Innovative Practice Full Paper presents a student experience model being implemented in the Electrical and Computer Engineering (ECE) Department at Iowa State University. The department has been implementing, adapting and enhancing a student experience model as part of a scholarship program designed to support and increase the success of students from underrepresented groups in the fields of electrical, computer, software, and cyber security engineering, including community college transfer students. The student experience model uses evidence-based practices focused on professional and leadership development. Interventions include a weekly seminar; group activities such as outreach projects and volunteering; conference participation; faculty and peer mentoring; academic and social support; and collaborative activities with diversity programs, learning communities, student organizations, and companies. Feedback from students and input from peer mentors have been used to improve programming with an emphasis on sense of belonging, professional development, supportive community, leadership, and holistic well-being. In addition, due in part to various entry points into the model, the wide variety of student backgrounds, needs and experiences has been illuminated. This has helped the department and faculty become more aware of issues and consider new models and structures. This paper provides an overview of the student experience model and outcomes, including a summary of research results.**

Keywords—student experience, broadening participation, inclusion, student professional development, engineering identity

I. INTRODUCTION AND BACKGROUND

The Electrical and Computer Engineering Department (ECE department) at Iowa State University has been implementing, adapting and enhancing a student experience model designed to increase the success of students from underrepresented groups in electrical, computer, software, and cyber security engineering fields, including community college transfer students. The ECE department partnered with the university's Women in Science and Engineering Program (WISE) starting in 2014 to improve the student experience following an external assessment of diversity and inclusion in its undergraduate programs [1]. This led to an NSF S-STEM proposal and grant funded in 2016 for the ECE scholarship program, which is a multi-institutional collaborative effort among the department and two community colleges that provides scholarships for students majoring (or preparing to transfer) in electrical engineering, computer engineering, software engineering, and cyber security engineering. WISE programming and practices serve as models of inclusion and equity not only for womxn students but also other underrepresented groups. The ECE scholarship program leverages key program elements from WISE as well as the department, college and institutions.

The ECE scholarship program is partially guided by the tenets of engineering identity research which focuses on the importance of "becoming" an engineer and the sense of confidence one has with assuming that role. Within this knowledge base, it is particularly important for students, especially women or students of color, to feel recognized as engineers (both by themselves and others), to establish understanding or competence of the relevant engineering concepts, and to perform their identities as engineers [2]-[8]. The ECE scholarship program uses high impact practices to provide opportunities to positively impact student retention, such as learning communities, service-learning experiences, and leadership development. The program provides a supportive

space for marginalized students to find community and explore engineering identity and leadership, while navigating their coursework and career in these fields [9]-[16]. Leadership development programs can help marginalized students understand underlying structural and cultural inequities in organizations, rather than seeing themselves as somehow deficient or having to conform to traditional models of leadership.

II. STUDENT EXPERIENCE MODEL

Strategic partnerships across both student and academic affairs have been leveraged to support recruitment and retention in the ECE scholarship program. The recruitment and scholarship application processes have been a collaborative effort among project team members, the ECE department, College of Engineering, WISE, related university offices, and community college partners. Essay questions in the application emphasize interest to the broader student population. There is a focus on leadership and community in the application and in the program. In addition, WISE has promoted the program through its outreach and recruiting events. The department is working with WISE to offer outreach sessions that better represent electrical, computer, software, and cyber security engineering fields for their audiences. The department, WISE, the college, and our community college partners are also providing support for community college students and transfer students through several programs and activities, including the Engineering Admissions Partnership Program, the WISE Transfer Experience, and a transfer orientation course in the department.

The student experience uses evidence-based practices to support scholars through graduation using a variety of academic and extracurricular activities focused on professional and leadership development. WISE staff are directly involved with planning and activities, and WISE activities are part of the student experience. Interventions implemented in the program include:

- weekly seminar,
- leadership studies course for incoming first-year scholars,
- cohort and group activities such as discipline-based outreach or service volunteering,
- conference participation,
- faculty and peer mentoring,
- involvement in discipline-based learning communities and student organizations,
- career fair and company event participation, and
- collaborative activities with diversity programs on campus.

A distinctive feature of the program is funding for student travel to professional conferences to support their career exploration, professional formation, and identity development in ECE fields. Conferences attended include the Grace Hopper Celebration of Women in Computing, Women in Cybersecurity Conference, Richard Tapia Celebration of Diversity in Computing, SWE Annual Conference, SHPE National Convention, AfroTech, and SACNAS National Diversity in STEM Conference. These opportunities are promoted when recruiting students and shared via social media and news stories.

In addition to conference travel, another unique feature of the program is participation in a first-semester leadership course and weekly seminar. The weekly seminar has evolved since the beginning of the program to be more student-driven. The focus of the seminar is on professional and identity development as an engineer through three basic processes [3] [5]:

1. Engaging with professional activities (courses, internships, projects, etc.), discovering competencies that they enjoy or excel at, demonstrating knowledge and skills (what they know);

2. Developing social networks involving the ECE profession (e.g., student organizations, conferences, internships, mentors, etc.) (who they know); and

3. Sense-making to understand personal and professional interests and goals, including professional roles, responsibilities, and opportunities (who they are and want to be).

Key activities during the seminar include career fair and interview preparation, career and networking advice, communication skill building, conference preparation, project-based service learning and volunteering, mentoring guidance, discussions with ECE faculty mentors, tech talks by ECE professors and graduate students, academic and social support, and written reflections. Mentoring resources used by faculty and students include principles, practices, worksheets and guides developed by Packard, Montgomery, Engage Engineering, and LSAMP Indiana [17]-[22]. Other programming and events include a welcome open house, social events organized by peer mentors, lunch with faculty, annual department scholarships and awards banquet, and career workshops. The ECE scholarship program also has dedicated lab-like space for students for studying, meeting with peer mentors, and interacting with other scholars. Communication with and among scholars is supported through email, Canvas, and a Slack workspace. Scholars also receive a weekly email newsletter edited by a peer mentor.

The implementation of activities through four years of the project has used a continuous improvement approach involving stakeholders and incorporating feedback, evaluation and research. Expanded partnering between the program and WISE resulted in the creation of a Student Experience Coordinator position. The Student Experience Coordinator has arranged and adapted programming specifically designed to support current students. Using feedback collected during spring 2018 and input from peer mentors, programming in the past year was organized with an emphasis on sense of belonging, professional development, supportive community, leadership, and holistic well-being. The Student Experience Coordinator facilitates weekly seminars and serves as a liaison among peer mentors, scholars, project team members and WISE staff to promote scholar success. The Student Experience Coordinator also oversees the peer mentoring program, which uses the WISE model for training, supervision, and responsibilities. The peer mentoring program demonstrates how a mentor/mentee

relationship is to be cultivated so as to foster meaningful relationships among peers. Student-faculty interaction is both formal and informal. Project team members interact with scholars in program activities and in courses. In addition to serving as mentors, faculty members are involved in several student-faculty networking events.

III. RESULTS

Since 2017, 90 students in the ECE department have been awarded NSF S-STEM scholarships: 35 in computer engineering, 26 in electrical engineering, 28 in software engineering and one in cyber security engineering. 67% identify as female, and 33% are from racial/ethnic minority groups. One of the proposed outcomes for the ECE scholarship program was to double the number of women enrolled in these majors. At the time of the proposal, there were 1,492 undergraduate students enrolled in these majors, including 120 women and 178 minorities (fall 2014). Thus doubling the number of women would be 240. As of fall 2019, the total undergraduate enrollment in these majors was 2,136, including 244 women and 406 minorities. Thus the number of women has doubled, and the number of minority students has more than doubled.

A more difficult goal has been to increase the percentage of female students. However, some percentages are tracking positively. Through three years of scholarship program (fall 2016 to fall 2019), the number of undergraduate women in electrical, computer, cyber security and software engineering increased by 28%, and the number of racial/ethnic minority students increased by 33%. These increases are greater compared to an overall increase of 7% for all students enrolled in these degree programs. These percentage increases are highlighted in Table 1 below.

Aspects of the ECE scholarship program perceived as successful include:

(1) recruitment of scholars,

(2) creation of a strong community of scholars allowing students to network and make connections with each other in and out of class,

(3) financial support allowing students to focus on learning,

(4) mentoring and support of students,

(5) access to resources and support beyond the classroom,

(6) helping scholars develop their leadership skills,

(7) opportunities for scholars to attend conferences, reinforcing sense of community, and

(8) providing professional development opportunities.

A. Research Studies and Highlights

Two complementary research studies are being conducted as part of the program. These studies are exploring how diverse students in ECE majors develop and sustain their engineering identities (identity study), and how the learning environment can support these students to persist in completing ECE degrees (motivation study). These studies are informing and improving project activities, and are relevant to departmental and wider efforts in support of marginalized students.

TABLE I. UNDERGRADUATE ENROLLMENT IN ECE MAJORS AS OF FALL 2019 (AFTER YEAR 3 OF GRANT)

Academic Year	17-18	18-19	19-20	17-18*	18-19*	19-20*	Change F16-F19**	
Total ECE Students	2065	2144	2136				133	6.6%
Total ECE Women	204	236	244	9.9%	11.0%	11.4%	54	28.4%
Total ECE Minority	340	382	406	16.5%	17.8%	19.0%	101	33.1%
Computer Engineering	836	802	696				-110	-13.6%
Women	66	74	65	7.9%	9.2%	9.3%	3	4.8%
Minority	151	144	137	18.1%	18.0%	19.7%	7	5.4%
Electrical Engineering	546	557	539				-90	-14.3%
Women	57	63	64	10.4%	11.3%	11.9%	1	1.6%
Minority	72	91	95	13.2%	16.3%	17.6%	19	25%
Software Engineering	682	785	825				259	45.8%
Women	81	99	104	11.9%	12.6%	12.6%	39	60.0%
Minority	117	147	159	17.2%	18.7%	19.3%	60	60.6%
Cybersecurity Engineering (new)	0	0	76				11	2.0%
Women	0	0	11	//////	//////	14.5%	//////	//////
Minority	0	0	15	//////	//////	19.7%	//////	//////

* Percentage of diverse students (women or minority) among total students for indicated year (e.g., women were 11% of all ECE students in fall 2018)

** Percentage change in enrollment of specified student population over multi-year period (e.g., the number of EE minority students increased by 25% percent from fall 2016 to fall 2019)

In [23], findings from the identity and motivation studies were combined, resulting in the following analysis. The sample includes 28 ECE scholarship students (8 of whom transferred from another institution) who participated in qualitative interviews and 34 ECE scholarship students who completed surveys. The researchers were interested in the role of autonomy, competence and relatedness in student experiences, given that self-determination theory posits these positively relate to career well-being. The analysis of students' 90-minute interviews and reflective journaling illuminated three themes relevant to the present study. The first pertained to relatedness: students described feeling connected to faculty and peers as a result of the program's engagement activities, systematic meetings, and dedication of physical space. The other two themes related to career barriers. Students described (1) relationships with male classmates as strained and inhospitable, and (2) isolating or condescending responses to scholars' intersecting identities (e.g., being a transfer student, a mother, older, a student of color). The initial quantitative analyses emphasize the role of autonomy as a potential mechanism for promoting engagement of underrepresented ECE students, as well as the importance of reducing career barriers in order for them to thrive. Taken together, the presented qualitative and quantitative analyses suggest self-determination theory may represent an effective framework for conceptualizing the relationship between ECE environments and the career satisfaction of underrepresented students. As such, constructing learning environments that promote relatedness and autonomy among underrepresented ECE students may comprise an effective means for diversifying these fields.

More specifically, the motivation survey results reveal that as scholars experience more volitional autonomy in their major (i.e., more ability to pursue one's own interests, control one's own learning, and make choices that align with one's interests), students also experience more academic major satisfaction (i.e., greater contentment with one's choice to pursue their current major) despite the presence of any environmental barriers. Such findings suggest that allowing students more freedom to shape their educational experiences within their major may result in greater satisfaction with their decision to pursue the major. Results also suggest that as scholars experience more volitional autonomy in their major, students also experience less subjective career distress (i.e., negative feelings about the pressures or obstacles associated with pursuing a career in ECE) even when environmental barriers are present. Taken together, these data suggest that increasing student autonomy may enhance their willingness to remain in ECE majors and decrease their distress regarding the pursuit of a career in these fields.

The identity study has focused on different groups of students, and selected initial findings are summarized [6] [24]-[28].

For women:

1. The scholarship program helps make connections and enhance identity development.

The program helped students make connections to faculty members and other female peers. Activities, meetings, and space enabled students to frequently see each other and feel as though the community of women in ECE was connected both in and outside of the classroom. Students believed that the program has helped them to feel more like an engineer by enabling them to work on and build an interest in real-life engineering issues, be recognized by their faculty and female peers, and feel a sense of competence and belonging within their department and college.

2. ECE women struggle to gain identity recognition from male peers.

Despite their involvement within the program, women continued to acknowledge that their relationships with male peers remained strained. Male peers often failed to recognize the abilities of the participants and attempted to marginalize them both inside and outside of the classroom. Although they connected with more women in their department, the participants in this study were forced to return to normal department conditions once they left the program activities, relationships, and spaces. This return marked a challenge in developing and refining an engineering identity. Students appreciated the opportunities given to expand their relationships with other women in ECE, but were left wondering how the department might shift to be more inclusive as a whole, rather than just within this diversity effort.

3. Intersecting identities influence how women interact and develop engineering identities.

ECE women expressed the ways in which their varying identities influenced their engineering interactions and subsequent engineering identity development. Students related that identities such as gender, age, race/ethnicity, motherhood, creative nature, and transfer background influenced the way in which their peers, faculty, and others interacted with them regularly.

For community college students:

1. STEM identity is shaped by intersecting identities and pre-college experiences.

Findings revealed that various identities (e.g., homeschool, rural, veteran, socio-economic status, transfer) shaped STEM identities. Homeschool students delved deeply into their math and science curriculum in order to follow their interests and were often positively reinforced by family members. Rural students developed and maintained STEM interests as a result of making connections between their environments and the content that they were learning (e.g. farming). STEM identity was also shaped by the pre-CC experiences that students had, particularly those associated with their familial relationships. Students with greater high school STEM preparation (e.g. math/science college courses, programming classes) felt a greater sense of STEM identity.

2. STEM identity is connected to performing math and science competence and innovation.

The study found that STEM identities were connected to performance of that identity in front of others. Performing STEM tasks enhanced identity and allowed students to see themselves in these types of roles. Undergraduate research and other hands-on experiences allowed CC students to connect to the field and see their STEM interests reflected. These experiences also became a space for others to recognize students in these roles. STEM identity was also connected to being

innovative. Rather than merely feeling confident in their abilities, students discussed the need to appear confident and innovative to others within the often competitive STEM environment.

3. Recognition of STEM identity is complicated by community college stigma and gendered experiences.

Lastly, recognition of a student's STEM identity was complicated by the persistent stigma associated with CC transfer. In terms of gender, this study found that men and women possessed different STEM identity recognition experiences. Men often gained a sense of self- and outside recognition of their STEM identities for their roles as "fixers" in their families and communities. Women struggled to be recognized and, as a result, sought to redefine what it meant to be in a STEM role (e.g., connecting STEM to their multiple interests rather than having it be something apart from rest of their life). Redefinition allowed women to see themselves more clearly in STEM roles and feel a greater sense of STEM identity.

This study highlights the importance of community college settings and other important identities (e.g. homeschool, veteran, rural). The study also shows that STEM identity is highly connected with math, science, and innovation experiences, adding to the body of literature concerning the nature of the need to innovate in order to see oneself in a STEM role which could have implications for understanding STEM identity performance, in particular. Finally, this study highlights how identity recognition is influenced by stereotypes of CC attendance and gender. This finding may have implications for structuring STEM identity-building experiences at CCs and educating stakeholders about CC stereotypes and pathways. In terms of gender stereotypes, this study highlights the subtle ways in which women resist those stereotypes by redefining the purpose and nature of STEM.

B. Departmental Impact

The results of the project are being used by team members and department leaders to further improve the student experience and learning environment in the department. For example, the department's 2018-23 strategic plan has several actions that reflect the influence of and commitment to project goals:

Diversity and Inclusion Key Actions—

- We will promote inclusive practices and multicultural competencies in our education, research, and engagement programs.

- We will create welcoming educational and work environments and spaces in which differences in backgrounds and perspectives are valued and respected and every individual feels a sense of belonging.

- We will cultivate diversity, equity, and inclusion awareness, skills and experience through training and educational opportunities, and resources that focus on departmental needs.

- We will partner with internal and external stakeholders and draw on guidance from professional organizations

and the engineering education community to enhance our efforts.

Undergraduate Education Key Actions—

- We will promote recognition and incentives for faculty who apply evidence-based scholarly practices in the curriculum and who engage in the scholarship of teaching and learning.

Research Key Actions—

- We will expand research on engineering education by leveraging federal, state, and industry initiatives.

In addition, coincident with the program, department communications, such as brochures, news articles, and social media, have more prominently featured stories that bring attention to diverse people and inclusive practices, e.g., news articles [29]-[37]. Several communications examples are shown in Fig. 1.

Fig. 1. Department communications examples that bring attention to diverse people and inclusive practices

IV. Discussion

Several scholars serve as peer mentors in the program. In addition, outside of the program, several take appointments as undergraduate teaching assistants, often as lab instructors. Several have taken leadership roles in student organizations. To some extent, the scholars feel empowered to take on these roles, and help other students, faculty, courses/labs and the department. So they are not only active in the scholarship program and being impacted by it, but they are impacting the department and their learning environments. They are leveraging their new relationships with faculty to foster meaningful engagement among students, faculty and staff.

Because of the flexible approach we used, by design, to bring scholars into the program at various entry points (as current students at varying levels, as new freshmen from high school, as new transfer students), we have become acutely aware of the wide variety of student backgrounds, needs and experiences. This has been challenging for the project in terms of programming, especially as the number of scholars increased, but also illuminating for faculty members on the team. We are now more aware of problems encountered by students, and are motivated to improve and consider new models and structures.

The partnership with community colleges is helping us understand and improve the transfer process and student experience for students from partner and similar institutions. Some of this is accomplished through new interactions between faculty. As partners, we can more closely follow and guide the journeys of students and mutually share in their educational and professional development. Also, researchers have the opportunity to engage with community colleges for the project's research studies.

The program activities and research studies are also impacting faculty development. A faculty team member has already reflected that working with scholars has increased their awareness of diversity and inclusion issues as they relate to the classroom environment. Research study findings are helping faculty understand how ECE and community college students develop their engineering identities, overcome barriers, make choices, and persist along their educational and career paths.

The NSF S-STEM funding enables the scholarship program in its current form. Sustaining the program and the student experience it affords may require institutional or structural changes that ensure continued success. Some aspects that are sustainable beyond S-STEM funding include: recruitment of diverse students and students transferring from community college; partnerships with WISE and other diversity programs; activities that provide enriching and supportive student experiences and foster identity development; connections between faculty and students; implementation of strategic actions in the department; and continued engagement and development of cross-institutional partnerships.

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