

Evidence-Based Planning to Broaden the Participation of Women in Electrical and Computer Engineering

Diane Rover, Joseph Zambreno, Mani Mina, Phillip Jones, and Lora Leigh Chrystal

Iowa State University, Ames, Iowa, USA

drover@iastate.edu, zambreno@iastate.edu, mmmina@iastate.edu, phjones@iastate.edu, lchrysta@iastate.edu

Abstract— The percentages of women in undergraduate electrical and computer engineering programs at Iowa State University averages below the national average. An external assessment of diversity and inclusion provided an impetus for faculty, staff and administrators to discuss issues, focus on specific areas, and collaborate on planning. In particular, the department has teamed up with the university's Program for Women in Science and Engineering to better integrate their programs with departmental activities. This has resulted in an enhanced student experience model being designed for undergraduate ECE women. The model leverages effective practices including learning communities, leadership and professional development, academic support and advising for the ISU Engineering Basic Program, academic preparation for the ECE field, and state and national resources for inclusive ECE career awareness, recruiting and teaching. The WI-ECSEL Initiative has been designed to improve diversity and inclusion in Iowa State's electrical, computer, and software engineering programs; improve educational pathways including transfer transitions from community colleges; provide a supportive and integrated student experience; establish a community of practice for faculty; and use research to inform practice.

Keywords— diversity and inclusion; learning community; student professional development; women in science and engineering program

I. INTRODUCTION

At Iowa State University, undergraduate female enrollment and degrees awarded in electrical and computer engineering (ECE) have averaged three to four percent below the national average. Nationally, females accounted for 19.9 percent of all bachelor's degrees awarded by an engineering program in 2015 and comprised 21.4 percent of undergraduates enrolled in engineering [1]. The percentage of bachelor's degrees awarded to women in electrical engineering was 12.5 percent and in computer engineering, 10.9 percent, the two lowest percentages among all engineering disciplines. Women comprise about 8 percent of undergraduates enrolled in Iowa State's ECE programs, compared to 12 percent nationally. Across all engineering programs at Iowa State, about 16 percent of undergraduates are women.

The department ranks in the top five nationally in computer engineering degrees and the top 15 in electrical engineering degrees awarded annually. With increasing enrollments, the number of undergraduate women has increased but the

percentage has remained mostly constant. Over the past two years, with an emphasis on diversity from the dean of engineering and department chair, the department has undertaken educational and climate projects such as the Transformative Learning Area for students; industry and department support for women students to attend the Grace Hopper Conference; a study conducted by external consultants, Partners for Educational Development (PfED) [2], on the experiences of undergraduate women in electrical and computer engineering (ECE); and collaborating with education and social science faculty on proposals to National Science Foundation programs supporting advancements in engineering education (including the Scholarships in STEM program; and the Revolutionizing Engineering and Computer Science Departments (RED) program, part of Improving Undergraduate STEM Education/Professional Formation of Engineers, which was recently awarded to the department [3]).

The study and its results have provided an impetus for faculty, staff and administrators to discuss issues, focus on specific areas, collaborate on planning, and move away from traditional 'deficit thinking' efforts by using the Center for Gender in Organizations (CGO) framework for promoting gender equity in organizations [4-5]. The four frames of gender equity include: 1) equip the women (prepare women for success); 2) create equal opportunity (level the playing field); 3) value difference (value diversity); and finally, 4) re-vision work culture. The first three frames are traditional gender equity approaches that focus on the "symptom of the problem" and are only part of the solution. CGO asserts this fourth frame offers "a new category of organizational intervention" focused on the "underlying systemic factors in organizations" by considering gender as a social construct. In particular, the department has teamed up with the university's Program for Women in Science and Engineering (WiSE) to better leverage their programs and knowledge resulting in an enhanced student experience model and contributing to departmental change. WiSE was founded in 1986 and offers programs and services that engage people at Iowa State, across Iowa and beyond to enhance the science, technology, engineering and math educational experience for women [6-8]. The student experience involves learning communities, leadership development, professional development, academic support such as tutoring, academic advising, academic preparation for the field, and state and national resources for inclusive ECE career awareness, recruiting and teaching. While most of these components have

been available, there was not a coordinated effort to use them on a larger scale to effect change. In addition, new research studies will be conducted to build on the PfED study's findings and inform student experience model implementation by exploring how undergraduate women in ECE develop and sustain their engineering identities, and what drives these women to thrive and persist in ECE degree programs.

This paper describes the collaborative planning process that the department has used to leverage, re-envision and integrate program elements. The student experience is based on new and existing evidence-based programming to support an improved climate for undergraduate women. In addition, this paper introduces the newly funded NSF RED project that will address organizational level change and thus a more complete solution to gender equity.

II. PLANNING PROCESS

An in-depth look at diversity and inclusion was prompted in part by a charge from the dean of engineering to each department. The ECE department chair formed an ad-hoc committee to begin a review process. As part of this effort, the PfED consultants were enlisted to conduct a needs analysis and advise the department on potential strategies for improvement.

An external assessment of diversity and inclusion focused on undergraduate education in the ECE department was conducted in 2014 by Partners for Educational Development. In fall 2014, the PfED consultants interviewed undergraduate women students in ECE and delivered a report in 2015 [9]. A working group of student affairs staff with relevant expertise from the department, college and WiSE was assembled to assist with aspects of the study and provide guidance and feedback.

The qualitative climate study was formulated around factors drawn from evidence-based research including pre-college programs, financial resources, learning environment and interactions, undergraduate research training, mentors and role models, systemic support structures and interventions, and career/professional development. The study examined personal experiences, academic experiences, confidence, resources used/needed, and relationships with faculty and peers. The report found that department retention patterns align with the literature on individual and institutional factors affecting the first and second year experiences as critical points in the academic pathway [10-16]. Findings suggested that institutional factors are significant in impacting retention of female undergraduate students in ECE and affect students' individual perceptions and behaviors. From themes that emerged from the study, both strengths and barriers were identified. The study provides the local context to address the under-representation of women in undergraduate ECE programs at Iowa State.

The report was reviewed by the working group, which then drafted a white paper for departmental action. A departmental team was formed to develop a comprehensive plan as the basis for an NSF Scholarships in STEM (S-STEM) proposal. This team was expanded into an interdisciplinary group including education and social scientists. Input was also sought and obtained from key stakeholders such as industry and community college partners. This process resulted in a new departmental and collaborative initiative called WI-ECSEL,

Women in Electrical, Computer and Software Engineering as Leaders.

The external assessment was coincident with an effort by the department to review and promote positive learning environments for all students in the department. In early 2014, an effort to reform the curriculum stalled due to faculty concerns, revealing that deeper departmental transformation was needed. Shortly thereafter, the National Science Foundation announced the RED program aimed at helping universities transform department structures, policies, practices and curricula to enable groundbreaking changes in undergraduate engineering education. The vision for the RED program resonated with the department chair and those involved in the curricular reform effort. Thus an interdisciplinary team was formed to pursue the RED opportunity. The department's proposal was not funded in the first round, however substantial improvements led to a successful proposal as part of the second cohort of RED awards.

Through the project, Reinventing the Instructional and Departmental Enterprise (RIDE) to Advance the Professional Formation of Electrical and Computer Engineers, the department has plans to involve students, faculty, practicing engineers and others in collaborative, inquiry-driven processes to collectively and systematically transform the department and its graduates. Students are not only learning about fundamental ECE technologies in core courses during their sophomore and junior years (the middle years are the focus of RED), but also the socio-technical context to go beyond the hardware and software toward responsible development. To accomplish this, faculty will be reshaping core curricula using evidence-based pedagogical strategies and working together to enhance their understanding and integration of these strategies in courses.

The RIDE project has created a novel cross-functional, collaborative instructional model for course design and professional formation, called X-teams. The pedagogical approaches (a) promote design thinking, systems thinking, professional skills such as leadership, and inclusion; (b) contextualize course concepts; and (c) stimulate creative, socio-technical-minded development of ECE technologies for future smart systems. X-teams are also serving as change agents for the rest of the department through communities of practice referred to as Y-circles. Y-circles, comprised of X-team members, faculty, staff, and undergraduate and graduate students in the department, will engage in a process of discovery and inquiry to bridge the engineering education research-to-practice gap and contribute to an organizational culture that fosters and sustains innovations through an agile framework. A key goal for the RIDE project is to broaden the participation of underrepresented students, especially undergraduate women, in ECE. Project activities will emphasize inclusive teaching practices and learning experiences. Taken together, WI-ECSEL and RIDE encompass all four frames of the CGO framework.

III. DESIRED OUTCOMES

The WI-ECSEL initiative has been designed to improve diversity and inclusion in Iowa State's electrical, computer, and

software engineering (ECSE) programs; improve educational pathways including transfer transitions from community colleges; provide a supportive and integrated student experience; establish a community of practice for faculty; and use research to inform practice. A specific outcome is increasing the percentage of undergraduate women enrolled in ECSE degree programs at Iowa State from 8% currently to 12% (national average), and longer term to 16% (college average). In terms of baseline data, this means doubling the number of women enrolled from 120 to 240. We will also be tracking retention and graduation rates. Current rates in engineering for selected groups at Iowa State are shown in Table I. The current

1-year retention rate for female students in ECSE majors is 80%; we will target 85%. The 2-year retention rate is 63%; we will target 75%. The desired increase in the 6-yr graduation rate for female students in ECSE majors is from 34% to 60%.

The target rates (taken from the first row in Table I below) represent the positive effect of the WiSE learning community and other WiSE program activities on overall female STEM/engineering retention and graduation rates. Ideally, rates for ECSE women participating in the WI-ECSEL initiative will approach the first row of the table. However, these rates reflect persistence across all engineering majors, which allows for greater flexibility than in ECSE majors alone.

Table I. AVERAGE RETENTION AND GRADUATION RATES IN ENGINEERING BY GENDER FOR STUDENTS WHO START IN ENGINEERING (2000-2012)

	1-Year Retention	2-Year Retention	3-Year Retention	4-Year Grad.	5-Year Grad.	6-Year Grad.
Female in WiSE LC	85%	75%	74%	24%	58%	62%
F - Other STEM LC	81%	70%	67%	20%	51%	54%
Other STEM Female	75%	63%	61%	17%	36%	40%
Total STEM Female	82%	71%	70%	22%	52%	56%
STEM Male	85%	76%	74%	17%	48%	52%
Total	84%	76%	73%	18%	49%	53%

IV. INCLUSIVE STUDENT EXPERIENCE MODEL

The student experience model for the WI-ECSEL Initiative is illustrated in Fig. 1. It leverages effective practices by re-framing programmatic elements to include the four frames of gender equity in organizations and includes learning communities, leadership and professional development, academic support and advising for the ISU Engineering Basic Program, academic preparation for the ECSE field, and state and national resources for inclusive ECSE career awareness, recruiting and teaching. It includes academic, co-curricular and extracurricular activities linked through the learning community model. Activities address needs identified by WiSE, through the PfED study, and in related literature. Different entry points into the student experience are accommodated to allow flexible pathways for students, including incoming first-year students, undeclared second-year students and community college transfer students. There is a focus on professional and leadership development and engagement throughout the student experience.

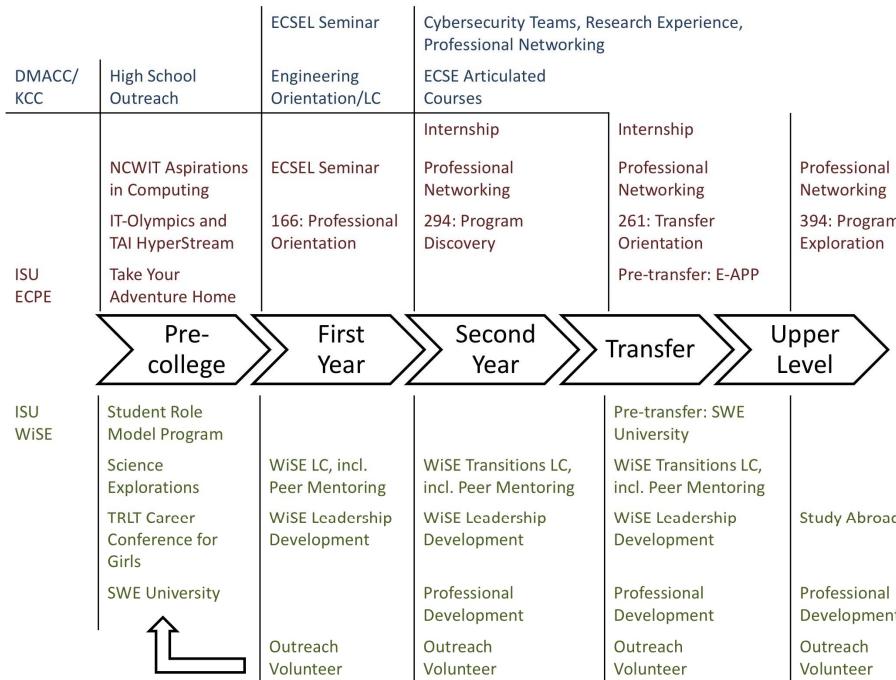
WiSE programming is based on established research and forms the foundation for the ECSEL student experience model. Most female and underrepresented minority students indicate that it was the encouragement they received from a role model or teacher that proved to be significant in their decision to enroll and remain in STEM programs. The lack of female role models overall and the opportunity to connect with them reinforces questions female students have about pursuing a STEM degree and whether they will be successful in that pursuit [10, 17, 18]. All WiSE programs have been built upon the philosophy that to increase the participation of women in STEM it is critical for girls and women to connect with other women who are involved with STEM; this role modeling allows women to visualize their ability to pursue and succeed in STEM. WiSE

mentoring provides the opportunity for women to see themselves as STEM professionals by connecting with other women in STEM.

Extracurricular activities, like the Student Role Model Program and Taking the Road Less Traveled, are essential components of gender equity. These out of school activities provide pre-college girls with experiential learning and investigative opportunities in academic areas that are not part of the regular school day. Involving ECSE students as Student Role Models, highlighting the success of faculty and students, and using hands-on activities focused on computing that show how these fields can make a difference in the world help shape interest and confidence in STEM courses and careers [19] [20].

At the undergraduate level, quantitative evidence supports Tinto [21] and Seymour and Hewitt's [10] qualitative results that there are gender differences in the reasons students leave their majors. Women are more likely to leave voluntarily due to social forces, and males, due to poor academic performance. The WiSE learning communities work to reduce these social forces through various academic, social and leadership programs within the community [11, 22, 23]. For example, leadership development programs focus on having women understand the underlying systemic effects of gender in organizations and not that women are somehow deficient. Programs center on how to handle gendered situations that may inhibit their ability to be successful and not on how to conform to traditional models of leadership. Further, participation in service-learning courses also increases retention rates for first-year students, providing an option for students who cannot participate in a residential program [24]. Beyond the first year, females show a higher risk of leaving engineering in semesters 3 to 5 than males, while the risks are similar during other semesters [25]. Therefore programming during the first three semesters is critical for retention of female STEM students.

Fig 1. ECSEL inclusive student experience model.



Abbreviations— DMACC: Des Moines Area Community College, KCC: Kirkwood Community College, ECSEL: Electrical, Computer and Software Engineers as Leaders, LC: learning community, ECSE: Electrical, Computer and Software Engineering, ISU: Iowa State University, ECPE: Electrical and Computer Engineering Department, WiSE: Program for Women in Science and Engineering, NCWIT: National Center for Women and Information Technology, TAI: Technology Association of Iowa, E-APP: Engineering Admissions Partnership Program, TRLT: Taking the Road Less Traveled, SWE: Society of Women Engineers

Findings from an ISU/DMACC NSF STEP project showed that participating in multiple learning communities was especially effective for women students in engineering (e.g., both WiSE and major-specific learning communities). This effect was determined using Kaplan-Meier survival estimates of the survival function, which compares the probability of different sets of students being retained in successive academic terms. The data show that women participating in more than one learning community are significantly more likely to be retained than are women participating in one or no learning communities [26].

While there is extensive literature on “transfer shock” or the decrease in students overall GPA when transferring institutions, there is less research on the effective practices to reduce transfer shock, the needs of transfer students, or the underlying characteristics of successful inter-institutional partnerships. Assessment from the ISU/DMACC NSF STEP project showed that participants in the Engineering Admissions Partnership Program (E-APP) have significantly increased first-year retention rates over non participants [26-30]. E-APP is a key program element that integrates community college and transfer students into the ECSEL student experience. It is designed to give Iowa community college transfer students multiple contact points and resources to enhance the transition to ISU. Iowa community college students who are taking courses that lead to transfer can enroll in ISU’s APP, and those interested in engineering are automatically in E-APP. Students are paired up

with an ISU adviser to help with transfer processes. E-APP promotes networking with students and staff via social media and campus events, including the engineering career fair. Building on the success of E-APP, transfer women participating in a visit day while still enrolled at the community college provides those students with a network of support at both their community college and at ISU through mentoring and the development of professional skills.

The ECSEL student experience model also provides opportunities for interactions with faculty mentors through departmental programming. As shown in Fig. 1, the ISU ECPE curricula include required courses such as ENGR 101 (orientation), CPRE 294 and CPRE 394, which include meetings with faculty mentors who provide professional and career guidance to students. In ENGR 101, small groups of students take an assigned professor to lunch (paid for by the department). This “take a professor to lunch” program has proven to be very useful in connecting students with at least one faculty member early on. The focus of CPRE 294 is on engineering practice, contemporary issues, and research opportunities in the department. The focus of CPRE 394 is on career guidance, professionalism and ethics, and portfolio development.

ECSEL program elements shown in Fig. 1 are described below.

A. ISU Program for Women in Science and Engineering (WiSE)

1) Pre-College Programming

Student Role Model (SRM) Program: The SRM program excites pre-college students about science and engineering through hands-on activities facilitated by ISU undergraduate women in STEM majors. Teachers from across the state access the SRM program through the WiSE website and select from over 100 STEM activities that align with the educational goals of the Iowa Core Curriculum.

Science Explorations: Through Science Explorations, students studying in STEM gain leadership experience by planning, organizing and facilitating a 4-week after school camp for girls each semester to stimulate interest and excitement for STEM fields.

Taking the Road Less Traveled (TRLT) Career Conference: One-day conferences provide 2400 attendees in grades 6-12 each year the opportunity to explore STEM careers, interact with females employed in STEM careers, participate in hands-on activities, and experience a college campus.

SWE University: SWE U. is a collaborative outreach event with the SWE student organization, College of Engineering, and WiSE. During the two-day experience, SWE U. participants explore campus, learn about engineering disciplines, connect with current students, network with other SWE U. participants, and stay overnight in an Iowa State residence hall. The event concludes with a dinner in which SWE U. participants and their parents visit with engineering faculty and staff.

2) Undergraduate Programming

WiSE Learning Communities: WiSE LCs offer living and learning opportunities for women majoring in STEM (375 first-year students in FY15). Each WiSE floor is comprised of 22-25 women in STEM majors and is led by a peer mentor. Peer mentors are upper-division STEM students who help first-year students transition to college. Peer mentors play a vital role in the planning and implementation of activities for their mentees and also refer them to applicable campus resources

WiSE Transitions Learning Communities: Students participating in “transition” learning communities focus on personal, professional, and leadership development while continuing to create community with other women in STEM. WiSE offers a one-credit success seminar each fall that helps students develop the skills necessary to be prepared for leadership roles on campus as well as internships. Additionally, students participate in a variety of career programs throughout the year including job shadows, mock interviews, career fair prep, resume workshops, and other networking events. Peer mentors meet with their mentees both individually and during larger group programs and events.

Academic Support: Together with the College of Engineering, WiSE has offered free tutoring. In addition, WiSE study groups facilitated by Academic Success Center tutors are available in the residence halls.

WiSE Leadership Development: Leadership development is an important component of the WiSE learning community experience through a variety of workshops and seminars focused on professional, academic, and leadership development. The WiSE program uses Gallup's StrengthsQuest™ which can help students understand how to apply their talents to the choices they make in their academic, career and personal lives. WiSE hosts fall retreats for first-year students; second-year and transfer students continue their strengths journey through their individual learning communities. The signature leadership program is an annual one-day spring leadership conference. Students engage in sessions that build awareness of assumptions that drive behavior and how to identify gendered differences and situational strategies to use when encountered. Topics include: unconscious bias, stereotype threat, micro-aggressions/micro-inequities, the impostor syndrome, and becoming confident leaders. Additionally, students participate in panels and networking activities with industry professionals and ISU faculty.

CLPS 270, Community Leadership and Public Service, is an introductory leadership course that provides students with an understanding of effective leadership practices and information about campus opportunities. Students are expected to connect course content to their own lives and to become engaged in campus activities where they can apply what they learn.

Professional Development: WiSE hosts graduate school panels, networking events, and a variety of workshops to enhance resumes, networking, interviewing skills, and career fair preparation

Outreach Volunteering: WiSE Ambassadors are a small group of students who volunteer to assist WiSE by connecting with high school students during the recruitment process.

Study Abroad: WiSE provides women studying in STEM fields the opportunity to travel abroad during spring break and participate in a 3-credit course where they analyze issues facing women in STEM internationally. While abroad, participants tour science and engineering facilities, meet students and professionals, and engage in the culture of the destination.

B. Department of Electrical and Computer Engineering (ECPE)

1) Pre-College Programming

ECPE Take Your Adventures Home [31]: TYAH is an outreach program that pays transportation costs for ECSE students to go back to their hometown high school to share their ISU ECSE “adventure” with students, teachers, and counselors.

IT-Olympics and TAI HyperStream [32] [33]: IT-Adventures is an innovative program that is dedicated to increasing interest in and awareness of technology among high school students through inquiry-based learning focused on four content areas: Cyber Defense, Game Design Programming, Robotics, and Multimedia. The basis of the program is the formation of HyperStream Clubs in high schools across Iowa. HyperStream is a technology career awareness program of the Technology Association of Iowa (TAI). The capstone event for

students who participate in IT-Adventures is a two-day competition called IT-Olympics on the ISU campus.

NCWIT Aspirations in Computing [34]: ISU is a member of the NCWIT Academic Alliance and administers the state-level NCWIT Aspirations in Computing Award program for high school women who are active and interested in computing and technology. Affiliate award winners receive recognition at an award ceremony held alongside IT-Olympics.

2) Undergraduate Programming

ECPE Learning Communities: ECSE students can participate in the Cpre LC or EE LC (as well as the WiSE LC), which provide various academic, social and professional support.

Professional/Engineering Orientation (CPRE/EE 166): This 1-credit required seminar introduces students to ECSE professions and career options, departmental rules, advising center, degree requirements, program of study planning, student organizations, and portfolios.

Career Awareness and Guidance (CPRE/EE 294/394): These required courses include meetings with faculty mentors.

Professional Networking: Women students in ECSE have an opportunity to travel to professional meetings, such as the Grace Hopper Conference, SWE Conference, Women in Cybersecurity Conference, etc.

Digital Women Student Organization: Digital Women [35] is a community of women dedicated to encouraging, supporting and retaining women in Computer Science, Software Engineering, Electrical Engineering, and Computer Engineering at Iowa State.

ECSE Articulated Courses at CCs: ISU defines a set of courses common to all engineering curricula, called the Engineering Basic Program. Studies via the ISU/DMACC NSF STEP project have shown increased transfer student success related to Engineering Basic Program performance [36-38].

Engineering Admissions Partnership Program (E-APP): Studies of E-APP have shown increased transfer student success [39].

Transfer Orientation (CPRE/EE 261): This 1-credit required seminar introduces transfer students to the College of Engineering and ECSE professions. It provides information about university, college and department policies, procedures, and resources.

V. SUMMARY

The WI-ECSEL Initiative is in the early stages of implementation. An NSF S-STEM proposal was submitted and is pending, which would support scholarships for low-income, academically talented, diverse students participating in the ECSEL student experience. It would also support two complementary research studies to explore how young women in ECSE develop and sustain their engineering identities, and what drives these women to thrive and persist in ECSE degree programs.

Implementation of the ECSEL student experience is proceeding using program elements from the department and WiSE. Implementation is focused on:

- Providing a positive and coordinated student experience;
- Emphasizing evidence-based practices to support diverse students;
- Increasing student-faculty interaction;
- Promoting collaborative structures across units to effectively and efficiently support students;
- Enhancing student professional identity as an ECS engineer;
- Increasing student motivation, satisfaction and retention; and
- Improving messaging and marketing to prospective students.

Additional longer-term benefits of the initiative are partnerships with community colleges, industry, diversity programs, and researchers to broaden participation of women in ECS engineering majors; education pathways through the community college into four-year ECS engineering programs; diverse workforce development in ECS engineering fields; and understanding of and engagement with ECS engineering by prospective students, parents, and teachers.

We envision that the student experience model in ECSEL will be adaptable by other departments and provide a template for collaboration and integration of program elements. The ECSEL initiative will be evaluated as it moves forward and results will be shared. The initiative resulted from a focused, collaborative planning process that matured over time and has leveraged various opportunities.

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