ECSEL: ELECTRICAL, COMPUTER, AND SOFTWARE ENGINEERS AS LEADERS

PROJECT SUMMARY

The proposed S-STEM project, ECSEL: Electrical, Computer, and Software Engineers as Leaders, is a multi-institutional collaborative effort among Iowa State University (ISU), Des Moines Area Community College (DMACC), and Kirkwood Community College (KCC) that will fund scholarships for students majoring (or preparing to transfer) in electrical engineering, computer engineering, and software engineering. The total number of scholarships to be awarded across all three institutions over five years is 582. The project will implement and test a student experience model that leverages existing program elements from ISU's Department of Electrical and Computer Engineering, College of Engineering, Program for Women in Science and Engineering, DMACC, and KCC. The ECSEL student experience consists of common practices and supports that span institutions including: learning communities, leadership development, professional development, academic support such as tutoring, academic advising for the ISU Engineering Basic Program, academic preparation for the ECSE field (including cyber security), and state and national resources for inclusive ECSE career awareness, recruiting and teaching. Research studies will explore how diverse students in ECSE develop and sustain their engineering identities, and what drives these students to thrive and persist in ECSE degree programs.

The objectives of the project are to: 1) Pursue S-STEM goals; 2) Implement a scholarship program and student experience; 3) Coordinate key activities across institutions; 4) Investigate research questions; 5) Establish a community of practice for ECSE faculty; 6) Improve diversity and inclusion in ECSE programs; 7) Strategically manage the project within and across institutions; 8) Evaluate project effectiveness, outcomes and impacts; 9) Improve educational pathways and contribute to a diverse workforce.

Expected outcomes for the project include these targets for enrollment, retention and graduation:

- Increase the percentage of undergraduate women enrolled in ECSE degree programs to 16%, thus doubling the number of women enrolled from 120 to 240.
- Attain 1-year and 2-year retention rates of 86% and 80%, respectively, for female students in ECSE majors and ECSEL scholars.
- Attain a 6-year graduation rate of 55% for female students in ECSE majors and ECSEL scholars.

Intellectual Merit
The proposed ECSEL student experience uses many existing high-quality, evidence-based program elements, drawing on results from past NSF projects, experts at ISU, and leading researchers. Two complementary research studies will contribute to the knowledge base. One proposed research study will explore how diverse students in ECSE develop and sustain their engineering identities. The study will examine engineering identity development through the use of Social Cognitive Career Theory (SCCT). This research study will utilize a phenomenological approach to examine the lived experiences and engineering identity development of ECSEL students using SCCT. The other study will use Self-Determination Theory (SDT) of motivation to understand how the environment can support diverse students to seek out ECSE programs and to persist in completing ECSE degrees. Most environmental supports have not been related to SDT. The study will examine whether environmental supports positively affect students' perceptions of competence, autonomy, and belongingness and directly and indirectly affect their satisfaction with ECSE majors and intentions to stay in an ECSE program.

Broader Impacts
The broader impacts outcomes of the project include: opportunities for low-income academically talented students with financial need; partnerships with community colleges, industry, diversity programs, and researchers to broaden participation of women in ECS engineering majors; development of diverse workforce in ECS engineering fields; improved education pathway through the community college into ECS engineering degree programs; engagement with ECS engineering by prospective students, parents, teachers; and capacity-building in cyber security to support national security.

A. RESULTS FROM PRIOR NSF SUPPORT

A.1. S-STEM and STEP Prior Support

ISU co-PIs Rover and Shelley were PI/co-PI for NSF S-STEM grant 0807051, "**E2020 Scholars: Advancing the NAE Vision**," 7/15/2008-6/30/2014, $600,000.
Intellectual Merit: The E2020 Scholars Program provided scholarships for cohorts of undergraduate engineering students and student development and learning in professional skills: leadership, global awareness and understanding, systems thinking, and innovation and entrepreneurship.
Broader Impacts: The E2020 Program created a student-centered, inclusive learning environment attractive to diverse students. (www.engineering.iastate.edu/e2020)
Publications: [1] [2] [3] [4] [5]
Amount of the scholarship: $2500/year
Number of scholarship recipients: Three cohorts of scholars were selected, entering fall 2009, fall 2010, and fall 2011. A total of 73 E2020 scholars were named in these cohorts, including 31 transfer students, 27 women, and 12 underrepresented minority students. One scholar died in a car accident.
Number of recipients transferring from 2-year institutions to 4-year programs: 31
Number and percentage of recipients graduating: Through fall 2014, 40 (56%) graduated, and 25 (35%) remained in the program making progress toward an engineering degree.
Number of recipients leaving the program: Through fall 2014, a total of 7 (9.7%) had left the program.

Influence on Proposed Project: Effective recruitment, scholarship and retention practices from the E2020 project serve as a model for the proposed project, including grand-challenge themes that motivated students, leadership development, inclusive teaching, faculty mentors, and support for transfer students.

ISU and DMACC co-PI's Rover, Shelley and Hensen were PI/co-PI for NSF STEP grant 0653236, "**Collaborative Research: SEEC: STEM Student Enrollment and Engagement through Connections**," 7/15/2007-6/30/2014, $1,999,945. **Intellectual Merit:** The goal was to increase the number of engineering graduates at ISU and the number of pre-engineering students at DMACC through strategies focused on learning communities, academic advising, student engagement and success, and career awareness. Over the grant period, engineering enrollments and graduates increased significantly at both institutions. The project created the Engineering Admissions Partnership Program (E-APP), leveraging ISU's APP program, to support transfer students prior to entering ISU. DMACC created an engineering orientation course, now offered at multiple DMACC campuses as part of its pre-engineering program. The project also developed new messaging for academic advisers, faculty and students based upon community college student success data. New recruiting materials and activities were developed and have been sustained at both institutions.

The project developed a model for the progression of a community college student toward a degree in engineering and the relevant SEEC intervention strategies. This model reflects the many variables that may impact the engineering transfer student. The introduction of SEEC strategies correlated with increased success rates for in-state community college transfer students. Before SEEC, community college transfer students left ISU at higher rates than they did following initiation of the SEEC project. Statistical analysis of retention data showed that transfer students who participate in a learning community will be retained at a level near direct-from-high-school students in learning communities and will surpass all those who do not participate. Also, community college transfer students enrolled in E-APP had statistically significantly higher one-year retention rates than non E-APP students. Statistical analysis also showed that students are able to increase their success by increasing their grades in core coursework, either at the transfer institution or at ISU, and by increasing their overall transfer GPA. The SEEC transfer student success study changed pre-engineering advising by community college and Iowa State academic advisers and the guidance given to prospective transfer students.

Broader Impacts: The project contributed to a transfer-friendly and student-success-focused environment in engineering at both institutions. Data sharing between the institutions was improved through the SEEC study. Collaboration across institutions demonstrated the value of research and evidence to inform educational innovation. Positive outcomes from SEEC provide lessons learned that will benefit other efforts to enhance community college student success through similar navigational programs.
Publications: [6] [7] [8] [9] [1] [10] [11] [12] [13] [14] [15] [16]

Number of students who participated in project activities: 8140 (reported in annual STEP survey)
Expected and actual increase in the number of students graduating with degrees in targeted STEM programs: The goal was to increase engineering graduates at ISU by 100 per year during the project, to 900 graduates annually by 2012. The number of engineering graduates surpassed the goal in 2012-13 at 1013 graduates, an increase of over 200 more engineering graduates per year.
Retention and graduation rates in STEM programs participating in the STEP project at baseline: see the following table; additional results are included as a supplemental document.

	Full-Time Cohort	Retention Rate to CoE				Grad Rates from CoE		
		1-Year	2-Year	3-Year	4-Year	4-Year	5-Year	6-Year
2007	1186	71.70%	58.00%	53.60%	36.00%	17.60%	47.00%	51.10%

Influence on Proposed Project: The SEEC project developed, used and adapted evidence-based practices that will continue to be leveraged and enhanced in the proposed project to achieve student outcomes for the WI-ECSEL S-STEM cohorts.

Kirkwood Community College (KCC) has four previous NSF awards relevant to this application: three were scholarship grants (CSEMS and S-STEM), and the fourth was a STEP grant. These significant awards—combined with additional funding streams—have allowed continual systemic improvement in the way KCC recruits, supports, and connects students to STEM career opportunities. These three grants represent fourteen years of an evolving STEM scholarship program at Kirkwood: 1) NSF CSEMS grant 0123128, "**The NSF Technology Scholars Program**," 07/02 – 06/06, $400,000; 2) NSF S-STEM grant 0631120, "**STEM Scholars Program**," 01/07 – 12/11, $500,000; 3) NSF S-STEM grant 1150634, "**STEM Scholars Program**," 1/12 – 12/16, $600,000. Ninety five (95) students were supported in the CSEMS grant, and a total of 250 students received support from the first S-STEM grant. In the first three years of the current *STEM Scholars* Program, KCC has made awards to more than 80 students.

Previous award winners have been a diverse group. Over 80 percent of the STEM Scholars have been first-generation college students; 28 percent were female; and nine percent non-white. The percentage of underrepresented populations steadily increased each year. Over 42 percent of the students were enrolled in programs of study that led to an Associate of Applied Science degree, while the remaining 58 percent sought a four-year STEM degree. A significant retention innovation was the creation of a required *NSF Technology Seminar*. Scholars who participated in the required *NSF Technology Seminar* created a *Personal Growth Plan,* which specified their learning goals, and developed their *Personal Growth Portfolio* to document their progress. Scholars engaged in project-based learning and research that promoted awareness of future STEM careers, and were enrolled in academic programs that led to those careers.

KCC and partners completed a six-year project initiated in 2004 that resulted in a large increase in STEM majors, STEM graduates, and STEM transfers: NSF STEP grant 0431603, "**STEPs to Bridge the Way**," 10/04 – 09/10, $500,000. Project partners included four large metro high schools and three state universities. With additional revenue from a variety of sources, the project expanded to include 33 area high schools and nine colleges and universities. One of the most important innovations was the introduction of Project Lead the Way (PLTW) - an engineering curriculum - into Iowa schools. KCC now has 30 area high schools that supported 1,345 PLTW students this past year.

A.2. Other Prior Support

PI Zambreno is PI for NSF CCF-1149539 "CAREER: Architectural Support for CPU / GPU Hybridization", 4/1/2012–3/31/2017, $466,312. **Intellectual Merit:** this project investigates techniques that minimize limitations of the traditional coprocessing model for GPUs, including performance bottlenecks, vulnerable shared memory spaces, and inflexible resource management. **Broader Impacts:** this project has supported two full-time PhD students and has resulted in multiple publications [17] [18] [19]. As part of this work, he is creating video game scripting engines [20] in order to introduce programming concepts to high school students. This work was recently featured in the NSF's Perspectives on Broader Impacts publication [21]

Co-PI Jacobson was PI for NSF grant 1027476 "Iowa Community College Information Assurance and Computer Security Training" 9/1/2010-8/30/2015, $245,303. **Intellectual Merit:** the ICCIACST program uses a "train-the-trainer" approach to build and strengthen the skills of the community college IT instructor and then allow them to transfer that information assurance and computer security knowledge to their own students in the classroom and local business community through outreach projects [22] [23]. **Broader Impacts:** the program worked with 10 community colleges in the state of Iowa and also held a workshop for about 20 colleges across the country to help them introduce cyber defense competitions into their schools.

B. PROJECT OBJECTIVES AND PLANS

The proposed WI-ECSEL project comprehensively addresses NSF S-STEM goals: (SS1) To increase the recruitment, retention, transfer, student success, and graduation of low-income academically talented students with demonstrated financial need who pursue baccalaureate degrees in STEM and enter the STEM workforce or graduate study; (SS2) To implement and sustain effective, supportive curricular and co-curricular activities, practices, and strategies for students in (SS1); and (SS3) To study models and activities in (SS2) and contribute to understanding the factors that affect academic/career pathways of students in (SS1). The S-STEM goals will be pursued through the following nine WI-ECSEL project objectives:

1. Pursue S-STEM goals (SS1-SS3) to recruit and retain diverse students in electrical, computer and software engineering (ECSE) disciplines.
2. Implement a scholarship program and student experience that support various ECSE pathways, emphasizing leadership development and professional preparation.
3. Coordinate key activities (practices, supports, curriculum, prior results, models and studies) across institutions to enhance transfer student success.
4. Investigate research questions to study the effect of project activities and better understand and influence student success and department culture.
5. Establish a community of practice for ECSE faculty to support their mentoring of students, inclusive teaching, and understanding of student success based on research findings.
6. Improve diversity and inclusion in ECSE programs, leveraging and enhancing support for women students.
7. Strategically manage the organizational, financial, data, and communication aspects of the project within and across institutions.
8. Evaluate project effectiveness, outcomes and impacts.
9. As broader impacts, improve educational pathways and contribute to a diverse workforce prepared to address societal needs including the nation's information infrastructure and security.

These project objectives are informed in part through an external assessment of diversity and inclusion in Iowa State University's ECE Department in 2014 conducted by Partners for Educational Development. [24]. This study, described in Section C, provides the local context to address the under-representation of women in undergraduate ECE programs at ISU. ISU's undergraduate female enrollment in ECE averages 3% below the national average in electrical engineering and 4% below national levels in computer engineering. One of several preliminary recommendations of the study was to increase scholarships.

A logic model approach will be used for project management and evaluation. The complete logic model is given as a supplemental document summarizing project resources, activities, outputs, outcomes and impacts, including measurable student, program, and process outcomes. The outcomes will be achieved through the ECSEL Student Experience illustrated in Figure 1 and described in Sections D and G. The student experience leverages existing elements from the department, the Program for Women in Science and Engineering (PWSE), and the colleges. ECSEL scholarship recipients will be organized in separate cohorts at ISU, DMACC and Kirkwood. As described in Section F, incoming first-year students will be selected for a cohort, and undeclared second-year students and community college transfer students will be selected and added to a cohort that progresses through a shared student experience.

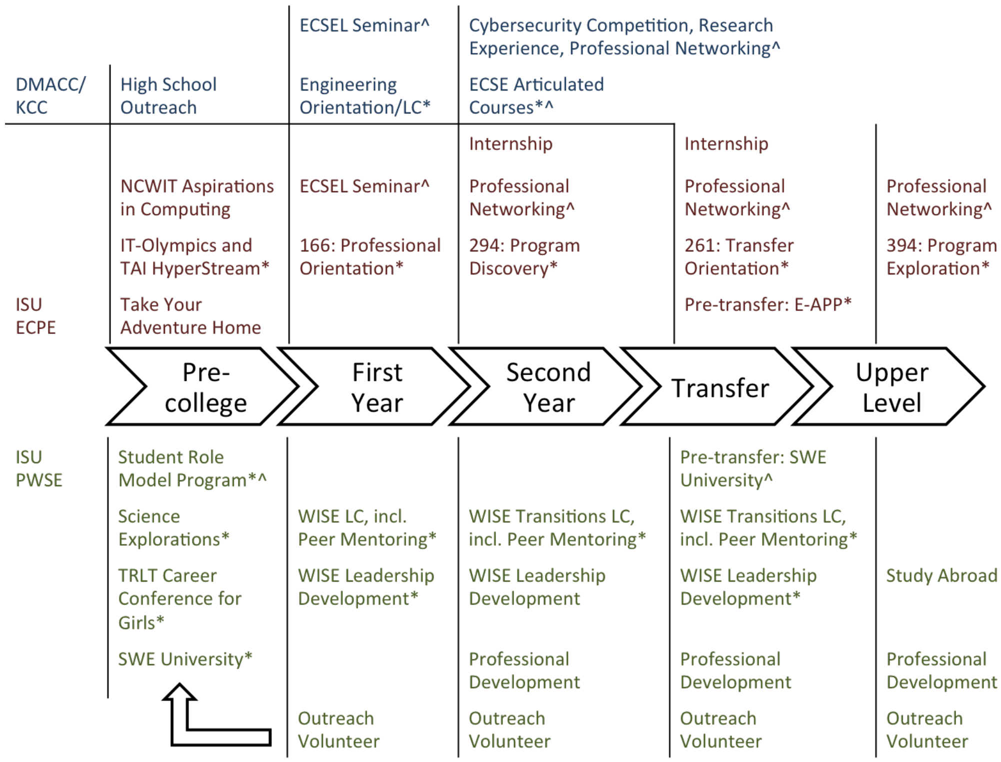

Figure 1. ECSEL Student Experience (*: existing program; ^: new element for ECSEL; see sections D and G for more details; see the logic model in the Supplemental section for acronym definitions)

The ECSEL student experience is comprised of common practices and supports that span institutions including: learning communities, leadership development, professional development, academic support such as supplemental instruction, academic advising for the ISU Engineering Basic Program, academic preparation for the ECSE field (including cyber security), state and national resources for inclusive career ECSE career awareness, recruiting and teaching. The project will incorporate results from prior NSF STEP and S-STEM projects (see Section A) as well as coordinate with current projects such as the IINSPIRE LSAMP Alliance, which all three institutions belong to [25]. Two complementary research studies will be conducted with project activities to examine their effects and contribute to the knowledge base (see Section G). The studies will 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.

C. SIGNIFICANCE OF PROJECT AND RATIONALE

The NSF S-STEM goals (SS1-SS3) and WI-ECSEL project objectives (1-9) were listed in Section A. The logic model will guide the implementation of activities to meet these goals and objectives. The project outcomes will be achieved through the ECSEL Student Experience (Figure 1 and Sections D and G).

Through the WI-ECSEL project, scholarships will have a significant influence on one of the largest producers of engineering degrees in the nation. ISU ranks 12th in the nation in engineering bachelor's degrees awarded (1,121 degrees, 2014), 19th in bachelor's degrees awarded to women (204, 2014), and 8th in undergraduate enrollment (7,688, 2014). The department **ranks 2nd nationally in computer engineering degrees** (116, 2014) and 21st in electrical engineering degrees (105, 2014) [26]. Undergraduate student enrollments and demographics are given in Table 1.

Table 1. Undergraduate Student Enrollment at Iowa State University (2014) [27]

	Total	Freshmen	Sophomores	Juniors	Seniors	Women	URM
University	28893	6993	6169	6717	8457	12544	3562
College of Engineering	7523	2110	1608	1568	2171	1149	916
ECE Department (ECSE majors)	1492	409	295	345	443	120	178

Table 2 -2013presents retention and graduation rates for the department disaggregated by gender. Additional retention and graduation data are available as a supplemental document. Note that these data are for students retained in ECSE majors who start in ECSE majors as freshmen. The data do not include students who start in other majors at ISU and transfer into ECSE majors. A number of undeclared and non-ECSE engineering students transfer into ECSE majors near the sophomore year.

Table 2. Average Retention and Graduation Rates in ECE by Gender (2000-2012)

	1-Year Retention	2-Year Retention	3-Year Retention	4-Year Graduation	5-Year Graduation	6-Year Graduation
Female	80%	63%	61%	20%	34%	34%
Male	80%	69%	64%	16%	37%	37%
Total	80%	69%	64%	16%	37%	36%

Expected outcomes for the project include these targets for enrollment, retention and graduation:

- Increase the percentage of undergraduate women enrolled in ECSE degree programs; from current 8% 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.
- Increase the 1-year and 2-year retention rates for female students in ECSE majors; 1-year: 80% to 86%, 2-year: 63% to 80%.
- Increase the 6-year graduation rate for female students in ECSE majors; from current 6-year average of 34% to 55%.

The target rates (taken from shaded cells in Table 3 below) represent the positive effect of the WISE learning community and other extant PWSE program activities, which are included in the WI-ECSEL student experience (Figure 1).

Table 3. Average Retention and Graduation Rates in STEM by Gender for Students who Start in STEM (2000-2012)

	1-Year Retention	2-Year Retention	3-Year Retention	4-Year Grad.	5-Year Grad.	6-Year Grad.
Female in WISE LC	90%	85%	84%	36%	62%	64%
F - Other STEM LC	87%	82%	79%	40%	56%	57%
Other STEM Female	77%	69%	66%	25%	38%	40%
Total STEM Female	86%	80%	78%	35%	53%	55%
STEM Male	89%	84%	82%	23%	51%	55%
Total	88%	83%	81%	27%	52%	55%

Along with the prescribed S-STEM student outcomes, other student, program and process outcomes are specified in the logic model. The student experience and outcomes were influenced by findings from the departmental assessment done by Partners for Educational Development [28]. For example, the PfED 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 [29] [30] [31] [32] [33] [34] [35]. 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. 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 and are reflected in proposed project activities, including research.

At ISU, WI-ECSEL scholars will receive $8000 per year for up to four years. An analysis from the Financial Aid Office for current ECSE students indicates an average unmet financial need of over $15,000. The $8,000 amount is equivalent to the largest merit scholarship provided by the College of Engineering, and has proven to be a competitive base amount for a student's financial aid package. Of the total ISU budget, we are requesting $2,352,000 for scholarships in order to support 294 scholarships. The distribution of WI-ECSEL scholarship awards into a total of six cohorts at ISU is shown in Table 4. As shown in the table, we have devised a schedule for awarding scholarships to 100 students, with entry points for a given cohort split among incoming freshmen students, undeclared engineering sophomore students, and transfer students. We assume a retention rate of 90% for the students in each cohort.

Table 4. Distribution of WI-ECSEL Scholarships to Six Student Cohorts at ISU

Cohort	**Grad Date**	**Recruited Size**	Year 1 16-17	Year 2 17-18	Year 3 18-19	Year4 19-20	Year 5 20-21	**Budgeted Scholarships**
1	2018	5	5					$72,000
2	2019	15	5	10				$336,000
3	2020	20		10	10			$448,000
4	2021	30		10	10	10		$856,000
5	2022	20			10	10		$488,000
6	2023	10				10		$152,000
Total Recruits		100	10	30	30	30		$2,352,000

Basic enrollment and student persistence numbers at DMACC and KCC are provided as a supplemental document, for the programs most likely to feed into the ECSE disciplines at ISU. In prior S-STEM grants, KCC has demonstrated success in enticing undeclared students to join STEM disciplines through the awarding of smaller grants, with the larger grants reserved for students who have declared in STEM disciplines.

This model will be continued at both DMACC and KCC for students in the ECSE feeding disciplines listed below. The WI-ECSEL *Explorer* scholarship will be provided as $1,000 for up to two terms to recruit academically well prepared, but undeclared majors, to the listed programs. The full WI-ECSEL scholar awards will be up to $5,000 per term based on demonstrated need. A summary of WI-ECSEL scholarship distributions per year are provided in Table 5.

Table 5. Distribution of WI-ECSEL Scholarships at DMACC and KCC

Year	**DMACC Scholarships**			**KCC Scholarships**		
	Full Awards	**Explorer Awards**	**Budget**	**Full Awards**	**Explorer Awards**	**Budget**
Year 1	0	10	$10,000	8	5	$33,000
Year 2	8	10	$50,000	16	12	$76,000
Year 3	12	15	$75,000	14	12	$74,000
Year 4	15	15	$90,000	12	12	$72,000
Year 5	17	15	$100,000	10	12	$70,000
Totals	52	65	$325,000	60	53	$325,000

D. ACTIVITIES ON WHICH THE CURRENT PROJECT BUILDS

Existing program elements to be used in the proposed WI-ECSEL student experience (Figure 1) are defined below[1]. The new program elements to be added are defined in Section G.

ISU Program for Women in Science and Engineering (PWSE or WiSE)
Pre-College Programming:
Student Role Model (SRM) Program: Proposed ECSEL enhancement: Involve more ECSE students as Student Role Models. Distribute information about the WI-ECSEL program.
Science Explorations: Proposed ECSEL enhancement: Engage ECSE scholars and the Digital Women student organization in presenting each semester.
Taking the Road Less Traveled (TRLT) Career Conference: Proposed ECSEL enhancement: Invite an upper-division ECSEL scholar to deliver a keynote talk. Involve ECSE students and faculty as facilitators of small group discussions and hands-on sessions with participants. Distribute information about the WI-ECSEL program.
SWE University: Proposed ECSEL enhancement: Involve ECSE students and faculty. Market the WI-ECSEL program with applicants and participants.

Undergraduate Programming:
WiSE Learning Communities: Proposed ECSEL enhancement: Set up a residential floor for first-year ECSEL scholars. Peer mentor(s) will coordinate with ECSE staff and faculty mentors.
WiSE Transitions Learning Communities: Proposed ECSEL enhancement: Sophomore and transfer ECSEL scholars will have the option to participate individually or as a cohort.
Academic Support: Tutoring continues to be a significant way of providing academic support for WiSE students.
WiSE Leadership Development: Proposed ECSEL enhancement: Set up a section of CLPS 270: Community Leadership and Public Service for an ECSEL cohort. Involve ECSEL scholars in leadership activities.
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: Proposed ECSEL enhancement: Involve ECSEL scholars as WiSE Ambassadors and in other volunteer roles.
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.

Department of Electrical and Computer Engineering (ECPE) and Community Colleges
Pre-College Programming:
ECPE Take Your Adventures Home [36]: Proposed ECSEL enhancement: Involve ECSEL scholars as Ambassadors and adapt messaging from WiSE outreach.
IT-Olympics and TAI HyperStream [37] [38]: Proposed ECSEL enhancement: Adapt messaging from WiSE outreach. Distribute information about the WI-ECSEL program. Involve ECSEL scholars as volunteers.
NCWIT Aspirations in Computing [39]: Proposed ECSEL enhancement: Distribute information about the WI-ECSEL program.
CC High School Outreach [40]: Proposed ECSEL enhancement: Adapt messaging from WiSE outreach. Distribute information about the WI-ECSEL program. Involve ECSEL scholars as volunteers.

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[1] Details regarding the existing PWSE and ECpE programs upon which this project will build are described in the "Facilities, Equipment, and Other Resources" document.

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): Proposed ECSEL enhancement: Schedule ECSEL scholars together. Use/expand inclusive teaching practices.

Career Awareness and Guidance (CPRE/EE 294/394): The ECpE curricula include required courses such as ENGR 101, CPRE 294 and CPRE 394, which include meetings with faculty mentors. Proposed ECSEL enhancement: Schedule ECSEL scholars together in courses. Use/expand inclusive teaching practices. Connect students with ECSEL faculty mentors.

Internship or Research Experience: Proposed ECSEL enhancement: Provide internship or research opportunities for ECSEL scholars as rising sophomores[2].

Cybersecurity Competition: The Information Assurance Center at ISU hosts a number of Cyber Defense Competitions every year, providing an environment for high school, community college, and university students to participate in inquiry-based learning CDCs.

ECSE Articulated Courses at CCs: ISU defines a set of courses common to all engineering curricula, called the Engineering Basic Program. Studies via the STEP SEEC project have shown increased transfer student success related to Engineering Basic Program performance [14] [10] [11]. Proposed ECSEL enhancement: Adapt SEEC academic advising guidelines for ECSEL community college students. Use/expand inclusive teaching practices.

Engineering Admissions Partnership Program (E-APP): E-APP was implemented through the STEP SEEC project. Studies of E-APP have shown increased transfer student success [6]. Proposed ECSEL enhancement: DMACC and Kirkwood ECSEL scholars will be expected to enroll in E-APP and participate as a cohort.

Transfer Orientation (CPRE/EE 261): Proposed ECSEL enhancement: Schedule ECSEL transfer scholars together. Use/expand inclusive teaching practices.

Overview of Evidence-Based Practices Used in the ECSEL Student Experience

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 [41] [29] [42]. 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. By recruiting ECSE students as Student Role Models, highlighting the success of faculty and students, and creating new kits focused on computing that show how these fields can make a difference in the world will help shape interest and confidence in STEM courses and careers [43] [44].

At the undergraduate level, quantitative evidence supports Tinto [45] and Seymour and Hewitt's [29] qualitative results that there are gender differences in the reasons students leave their majors. Women are

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[2] The ISU ECpE External Advisory Board (EAB) as well as the Technology Association of Iowa (TAI) have agreed to assist in finding internship opportunities at their constituent companies for ECSEL scholars, specifically between freshman and sophomore years.

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 [46] [47] [30]. Further, participation in service-learning courses (e.g. CLPS 270, Community Leadership and Public Service) also increases retention rates for first-year students, providing an option for students who cannot participate in a residential program [48]. 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 [49]. Therefore programming during the first three semesters is critical for retention of female STEM students.

Findings from the STEP SEEC 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 [50].

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 prior NSF STEP SEEC grant showed that participants in E-APP have significantly increased first-year retention rates over non participants [51] [52] [53] [54] [50]. Building on the success of E-APP, transfer women participating in a visit day while still enrolled at the community college will provide those students with a network of support at both their community college and at ISU through mentoring and the development of professional skills.

E. S-STEM PROJECT MANAGEMENT PLAN

The ECSEL project will be led by the PIs at each institution, who will administer the project and interact with the NSF. The required leadership roles are assigned as follows:

	ISU	**DMACC**	**KCC**
Faculty Member	Joe Zambreno, PI Assoc. Prof., ECE	Uriah Tobey, PI Instructor, Math and Engineering	Cate Sheller, PI Prof., Computer Science
STEM Administrator	Sarah Rajala, co-PI Dean, Engineering	Kari Hensen, co-PI Associate Dean, Arts & Sciences	Marvin Bausman, co-PI Dean, Math & Science
Researcher	Mack Shelley, co-PI Prof., Political Science & Stat.	Janet Emmerson, co-PI Director, Institutional Research	Heather Conley, co-PI Director, Grants Dev.
Senior Personnel **Researchers**, ISU: Lisa Larson, Prof., Psychology; Sarah Rodriguez, Asst. Prof., Educ.			

Other co-PIs at ISU include ECE professors Doug Jacobson and Diane Rover. Other senior personnel at ISU include ECSE faculty mentors: Katie Stolee, Julie Dickerson, Mani Mina, Suresh Kothari, Johnny Wong, Gary Tuttle, Phillip Jones, Namrata Vaswani, Julie Rursch, Tien Nyugen. Other key collaborators include Vicky Thorland-Oster (Manager, ECPE Student Services), Lora Leigh Chrystal (Director, PWSE), and Joel Johnson (Director, Engineering Student Services). Among these, Jones, Mina, Thorland-Oster, and Chrystal are part of the leadership team, along with the co-PIs and researchers. The RISE external evaluator is Mari Kemis. Team members are exceptionally qualified to work on this project, as shown in their biographical sketches. Team members bring a diversity of expertise, backgrounds and perspectives to the project. Team member roles and responsibilities are described in the Budget Justification. Commitment letters are provided for unfunded collaborators.

The project is structured into teams with leaders* as follows. Each team is responsible for activities contributing to the WI-ECSEL project objectives in italics (see section B for list of objectives).

- **Project Leadership Team**: Zambreno*, Tobey (DMACC), Sheller (KCC), Rajala, Shelley, Jacobson, Rover, Larson, Rodriguez, Jones, Mina, Thorland-Oster, Chrystal *(Objectives 1,3,7,8,9)*
- **Scholarship Team (ISU)**: Thorland-Oster*, Chrystal, Johnson, selection committee *(Objective 2)*
- **Cohort Experience Team**: Rover*, Thorland-Oster, Chrystal, Mina, Jones, graduate assistants, faculty mentors, peer mentors, DMACC member, KCC member *(Objectives 2,3,6,9)*
- **Mentoring Team**: Mina*, Rajala, Hensen (DMACC), Bausman (KCC), faculty mentors *(Objectives 2,5,6)*
- **Research Team**: Larson*, Rodriguez*, Shelley, Emmerson (DMACC), Conley (KCC), Mina, Rover, graduate assistants *(Objectives 1,4,6)*
- **Community College Partnership Team**: Jacobson*, Tobey (DMACC), Sheller (KCC) *(Objectives 3,7,8,9)*
- **Internship Team**: Jones*, Jacobson, Mina *(Objectives 2,6)*
- **Pre-college Communications/Recruiting Team:** Chrystal*, Jacobson, Jones *(Objectives 6,9)*
- **Evaluation Team**: Shelley*, Kemis (External/RISE), Mina, graduate assistants *(Objectives 7,8)*

The project logic model identifies the resources, activities, and outputs of these teams. All activities are ongoing in support of the student experience for each scholarship cohort. NSF project reporting is done annually. S-STEM student tracking data collection is done every semester. Project leadership will participate in grantees meetings and a third-year review.

F. STUDENT SELECTION PROCESS AND CRITERIA

Consistent with the requirements of the S-STEM program, the WI-ECSEL Scholars Program will provide scholarships to students who: (1) are citizens of the U.S. (or whose status satisfies S-STEM eligibility); (2) are pursuing degrees in Electrical, Computer, or Software Engineering at ISU, or complementary preparatory degree programs at DMACC and KCC; (3) demonstrate academic potential or ability; (4) demonstrate financial need as defined by the U.S. Department of Education rules for need-based federal financial aid; and (5) are part of a cohort. All three institutions use the Free Application for Federal Student Aid (FAFSA) to determine eligibility for need-based financial aid, with an Office of Student Financial Aid making the calculation.

F.1. ISU Student Selection Process and Criteria

To be considered, all students must demonstrate need (based on FAFSA). At ISU, the scholarship administration will use the existing processes established in the College of Engineering, which maintains a centralized Merit scholarship process for undergraduate students. For prospective students, those with a pre-identified ACT composite score of above 28 are invited to apply for a Merit scholarship award. An email is generated to the email account on file with University admissions to invite the eligible student to formally apply to a secure on line application. Current enrolled students are eligible to apply every January for consideration for scholarships within the college. Departments are allowed to award donor funded scholarships at their own discretion, but generally, transfer students or continuing students must achieve a cumulative GPA above 2.75. All funds are distributed by the Office of Financial Aid.

For WI-ECSEL scholars, a selection committee consisting of the project team at ISU, one existing scholar from each major, and one industry representative will consider a broad set of factors to create diverse cohorts. The current application asks questions regarding educational and career goals, and leadership experience, and will be supplemented with a question asking students to describe how they would like to “change the world” and how their interest in electrical, computer, or software engineering might help them.

F.2. Community College Student Selection Process and Criteria

At DMACC and KCC, an application scoring rubric will be approved each semester by the PI team. An application essay will be used to confirm the student's intent to become a professional in ECSE disciplines, and official transcripts and/or degree audits will be used to confirm academic progress. Continuing students for both Explorer awards and full WI-ECSEL awards must meet all award criteria every semester, including a passing grade in all cohort-related seminars.

To be eligible, students must be enrolled in one of the following programs of study: Computer Science, Engineering, Computer Information Systems, or Electronic Engineering Technology. New DMACC and Kirkwood students who meet the minimum requirements of the scholarship application must submit high school (and college, if available) transcripts. Successful applicants currently enrolled must have satisfactorily completed pre-requisite courses with a minimum "B" grade point average of 3.0 (4.0 scale).

G. S-STEM STUDENT SUPPORT SERVICES AND PROGRAMS

The proposed WI-ECSEL student experience was introduced in Section B, Figure 1. Comprehensive student support services and programs will be provided through both existing and new activities. Existing programs being used in the student experience were presented in Section D. In this section we specifically focus on <u>new</u> program elements to be implemented to support ECSEL cohorts.

ISU Program for Women in Science and Engineering (PWSE)
Student Role Model Program: Create new ECSE-focused hands-on activities with experiential learning kits developed to introduce students to ECSE fields using messaging to appeal to all students. The new learning kits will use proven themes that broaden interest in the field such as robotics and wearables [55] [56]. The kits will be used by various PWSE, ECPE and CC pre-college events. ECSE scholars and student organizations such as Digital Women and IEEE will be involved.
SWE University (pre-transfer): Create a SWE U. experience for prospective transfer students.

Department of Electrical and Computer Engineering (ECPE) and Community Colleges
ECSEL Seminar and Advising: During the first year, an ECSEL cohort will participate in a 1-credit required seminar course that introduces them to the ECSEL program and gets them involved, offers cohort-building activities, initiates ECSE identity and career development, provides role models, and connects scholars with faculty and peer mentors.
Professional Networking and Formation as an ECS Engineer: Through the ECSEL seminar, learning community activities, and extracurricular activities, ECSEL scholars will interact with industry professionals, faculty mentors, and young alumni. Together with these activities and interactions, reflection assignments will help scholars grow personally and professionally. ECSEL cohorts will have an opportunity to travel to professional meetings, such as the Grace Hopper Conference, SWE Conference, Women in Cybersecurity Conference, etc.
ECSE Articulated Courses at CCs: The three institutions will work together to form new articulation agreements to create a more seamless transition into the ECSE programs at ISU.
ECSEL Faculty Mentors: Each ECSEL cohort will be assigned a group of faculty mentors comprised of at least one mentor from each discipline (CprE, EE, and SE) (or disciplinary breadth at CCs). Each faculty mentor group will include at least one female faculty member. Mentor training, including equity training from NAPE through WiSE, will be provided to mentors.
Digital Women Student Organization: Digital Women [57] is a community of women dedicated to encouraging, supporting and retaining women in Computer Science, Software Engineering, Electrical Engineering, Computer Engineering and MIS. <u>Proposed ECSEL addition</u>: Form DW branches at DMACC and KCC.

G.1. Research Activities

Two complementary research studies will be conducted with project activities to examine their effects and contribute to the knowledge base. The studies will 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.

Identity Research (led by Rodriguez). Over the past decade, an extensive amount of scholarship and media attention has been devoted to understanding the unique educational experiences and challenges of women in engineering, with the concept of identity formation in engineering quickly emerging as an important area of educational research. Within this body of work, studies have examined the formation and reconstruction of professional engineering identities, especially those of women, from undergraduate education [58] [59] [60] [61] [62] [63] [64] to career pathways in industry, research, and academia [65] [66]. From this work, scholars have found that engineering identity development influences engineering interest and persistence, particularly for women [67] [68] [69] [70] [63].

Therefore, exploring engineering identity development for women is crucial to understanding how her identity will develop over time and whether or not that student will be validated or rejected as an engineering-engaged female. However, few engineering identity studies have focused specifically on women studying ECSE disciplines, despite the fact that men consistently outnumber women in these engineering areas [71]. The purpose of this research is to explore the engineering identity development of women in ECSE programs. This research is positioned to advance knowledge regarding engineering identity development and inform education practice and policies for ECSE.

The proposed research study will explore how women in ECSE develop and sustain their engineering identities. The study will examine engineering identity development through the use of Social Cognitive Career Theory (SCCT). This theory, grounded in Bandura's social cognitive theory [72], explores how career and academic interests mature, how career choices are developed, and how these choices are turned into action. This is achieved through a focus of three primary tenets: self-efficacy (the beliefs people have about their ability to successfully complete the steps required for a given task), outcome expectations (beliefs related to the consequences of performing a specific behavior), and goals (the decisions to begin a particular activity or future plan) [73].

This research study will utilize a phenomenological approach to examine the lived experiences and engineering identity development of women in ECSE using SCCT. The research team will focus on in-depth examination of the engineering identity development process of these women, capturing key elements related to self-efficacy, outcome expectations, and goals that may contribute to either the challenges to and/or the success of women in ECSE developing and sustaining an engineering identity. The primary methods for data collection will be (1) pre-interview questionnaires, (2) phenomenological semi-structured interviews, and (3) student reflective journal entries. A subset of all S-STEM students (both community college and four-year institution) will participate within the qualitative study over the course of the grant (totaling 55 participants).

Using Seidman's model [74] for conducting phenomenological, individual in-depth interviews, this study will include the perspectives of women participating in the ECSEL program. Students will be interviewed twice a year using purposeful criterion sampling to select participants with valuable insights. The research team will develop a semi-structured interview protocol [75]. Analysis of the data will combine deductive and inductive thematic analysis [76]. Researchers will return to the interview data and use inductive pattern-matching logic [77] to consider emerging codes within existing theoretical frameworks.

Motivation Research (led by Larson and Shelley). To systematically and robustly address the underrepresentation of female students, we posit that ECE faculty need data-driven results to increase their understanding of what drives young women to thrive and persist in ECSE degree programs. Self-Determination Theory (SDT) [78] [79] of motivation can be used to understand how the environment can support young women to seek out ECSE programs and to persist in completing ECSE degrees (see Figure 2). According to SDT, young women who perceive that they have volitional autonomy, are competent, and experience a sense of belonging or relatedness [80] will be self-motivated to engage productively in their coursework, will experience high levels of career well-being and have intentions to stay in the ECSE major [79]. SDT also asserts that the environment plays a crucial role in supporting one's autonomy, competence, and sense of belonging. As can be seen in Figure 2, the environmental supports can be conceptualized as the extent to which they enhance perceptions of autonomy, competence, and relatedness.

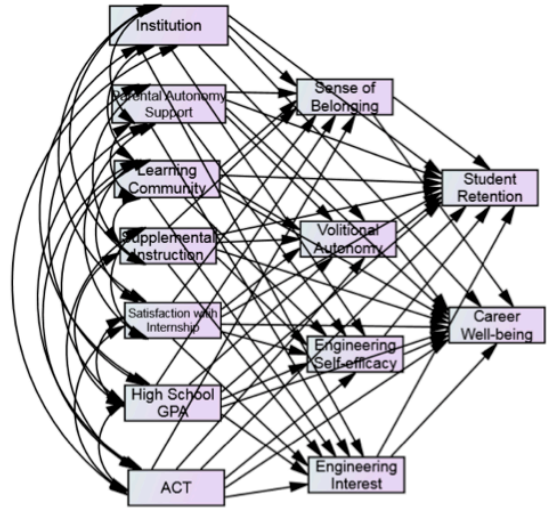

Figure 2. Conceptual Model for Analysis

Perceptions of autonomy and competence have predicted dropout rates of students (e.g., [81]). Moreover, environmental supports have been shown to impact retention. Prior work has shown that the extent to which students perceive that their parents are supporting them making their own choices indirectly affects their satisfaction with their major through their perceptions of volitional autonomy and academic competence [82]. Likewise, environmental supports besides parents have also influenced retention of students. Learning communities have positively related to retention (see [83] for the effectiveness of learning communities at ISU), and supplemental instruction has positively related to retention. Besides parental autonomy support, the environmental supports shown in Figure 2 have not been related to SDT. We would anticipate that these environmental supports would positively affect students' perceptions of competence, autonomy, and belongingness and directly and indirectly affect their satisfaction with ECSE majors and intentions to stay in an ECSE program. We plan to examine the results of the prediction models separately for groups of students identified by type of institution (community college and university).

We will use Structural Equation Modeling (SEM) [84-100] in the form of Confirmatory Factor Analysis to establish the latent structures linking the measured variables available in the dataset and their underlying constructs. We will estimate the SEM structural model using Markov Chain Monte Carlo methods of Bayesian estimation. Additional model estimation will be undertaken using logistic regression to cross-validate the findings from SEM estimation.

G.2. Broader Impacts of the Proposed Work

Project activities support various broader impacts, including the following: opportunities for low-income academically talented students with financial need; partnerships with community colleges, industry, diversity programs, and researchers to broaden participation of women in ECS engineering majors; development of diverse workforce in ECS engineering fields; improved education pathway through the community college into ECS engineering degree programs; engagement with ECS engineering by prospective students, parents, teachers; and capacity-building in cyber security to support national security.

H. QUALITY EDUCATIONAL PROGRAMS

Iowa State University

The electrical engineering, computer engineering, and software engineering B.S. programs at Iowa State are accredited by the Engineering Accreditation Commission of ABET. Our most recent graduate career outcomes survey (six month follow-up) indicates placement rates of 98%, 97%, and 100%, for EE, CpE, and SE, respectively.

Kirkwood Community College

KCC is accredited by the Higher Learning Commission of the North Central Association of Colleges and Schools. KCC is the fourth largest institution of higher education in the state of Iowa, and the second largest public community college. While all students who plan to graduate with an AS are expected to complete the same general education courses, KCC has worked with destination colleges to develop specific programs of study for students who plan to transfer based on the major they intend to pursue and the college or university the plan to attend.

Des Moines Area Community College

DMACC is also accredited by the Higher Learning Commission of the North Central Association of Colleges and Schools. DMACC is Iowa's largest community college, annually serving more than 70,000 credit and non-credit students at six campuses and six learning centers. DMACC will concentrate its efforts for this initiative within two existing academic programs: the Management Information Systems (MIS) AA degree and the Pre-Engineering Program, allows students to take 32 cr. hours at DMACC that will transfer to ISU.

I. ASSESSMENT AND EVALUATION

Project evaluation and outcomes assessment will be led by Mari Kemis, Interim Director of the Research Institute for Studies in Education (RISE) at ISU. RISE is external to the project and has conducted evaluation for numerous NSF grants.

Evaluation will be undertaken by organizing key evaluation questions in a manner that allows for many models of evaluation or methods of data collection. The evaluation effort will be based on the a-e-I-o-u approach [101], which has been shown to be particularly useful in education-related evaluation research. We have found that if the questions below are addressed, the evaluation effectively reviews both the processes and outcomes of a project.

(a)ccountability—Did the project team do what it said it was going to do? Were the activities related to the goals and objectives of the project actually completed?

(e)ffectiveness—How well did the activities meet the objectives of the project? Were the objectives accomplished, in light of the attitudes, opinions, and knowledge of the participants?

(I)mpact—What changes have occurred as a result of the project? How are these changes related to the stated expected outcomes of the project? How have individual and group attitudes/behaviors been affected? What forms of change have occurred at the department, college, and institutional levels?

(o)rganizational context—Which structures, policies, or events affected the project? What helped/hindered achieving the goals and objectives of the project?

(u)nanticipated outcomes—What happened that was not planned for or expected?

Addressing the first three components—accountability, effectiveness, and impact—is particularly important for ascertaining the success of the project. Answering questions related to organizational context and unanticipated outcomes can provide additional evaluation information about likely sustained or propagated effects that the project may have.

Project evaluation will be both formative and summative, with the primary objective to measure the effect of program implementation on student outcomes. Specific evaluation questions relate to the student and program outcomes defined in the logic model. Both quantitative and qualitative data will be collected, using validated sample survey instruments, institutional data on student achievement and growth, focus groups or individual interviews, and document analysis. The project activities and evaluation questions will be investigated using methods appropriate for experimental and quasi-experimental studies, including analysis of variance, analysis of covariance, and logistic regression. Once sufficient data are accumulated in the later stages of the project, further analyses will be conducted using structural equation models. Throughout these analyses, the central concern is whether there is a statistically significant main effect of project participation.

Potentially confounding attitudinal and demographic variables will be accounted for as covariates. Analysis of quantitative data will be conducted using advanced general statistical software, as described in the data management plan.

The comprehensive five-year evaluation plan will focus on: (1) progress toward the project's objectives; (2) the definition, collection, and analysis of quantitative and qualitative data required to evaluate project outcomes from participants and partners at ISU, DMACC, and KCC; and (3) identification of process and context factors to be included in the evaluation plan. Project evaluation will focus on the S-STEM program goals given in section B (SS1-SS3).

<u>Examination of Process and Contextual Factors (Y1-Y5)</u>. [SS2, SS3]. The evaluator will develop interview protocol(s) and conduct annual interviews with team members to examine opinions about activities, progress towards project objectives, and contextual factors.

<u>Understanding of Participating Students' Experiences (Y1-Y5)</u>. [SS1, SS2] The evaluator will develop survey protocols and conduct studies with participating undergraduate students to examine their opinions about the student experience. A data set will be maintained for all participating students that could be useful for research activities as well as evaluation purposes.

<u>Management of NSF's Student Tracking Data (required) (Y1-Y5)</u>. The evaluator will work collaboratively with appropriate ISU and community college student support offices and team members to prepare, manage, and submit on time information required for NSF's data collection activities to track participating students.

<u>Evaluation of Broader Impacts (Y1-Y5).</u> The evaluator will develop instruments and conduct the evaluation to examine results related to broader impacts. Data sources will include review of departmental records, survey questions added to existing surveys to understand attitudes/engagement of pre-college audiences with ECSE, and surveys about the cyber security program.

The evaluation process will include regular meetings with project team members, and submission of progress reports and formative reports at the end of each year. RISE will prepare and submit a comprehensive summary evaluation report at the conclusion of the project.

J. DISSEMINATION

A public project website will be developed and maintained at ISU providing information about the project, the team and partners, project activities, products and results, the scholarship program and application, recognition of scholars, and the NSF acknowledgement. News articles will be sent to scholars' hometown newspapers recognizing the students, as well as informing the public about ECS engineering opportunities and NSF's support for students. Data briefs, an effective practice used with the STEP SEEC project, will be used to document and share results with collaborating institutions and other stakeholders prior to publication. A data brief gives a short summary of data analytics and research studies. Results will be freely available to the public through ISU's open access digital repository. The following conference and journals will be considered for publication and presentation of project and research results: IEEE Transactions on Education, Journal of Engineering Education, Journal of Women and Minorities in Science and Engineering, Community College Journal of Research and Practice, IEEE/ASEE Frontiers in Education Conference, ASEE Annual Conference, Association for the Study of Higher Education, Review of Higher Education, American Psychological Association, and Journal of Career Assessment. Dissemination through large national networks will also be a broader impact. For example, ISU is a member of the NSF-funded Center for the Integration of Research, Teaching, and Learning (CIRTL) Network. Team members have also been actively involved with STEM Central (stem-central.net) through the STEP SEEC project.

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