



The Redshirt in Engineering Consortium: Progress and Early Insights

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Ms. Ann E. Delaney, Boise State University

Ann Delaney graduated in 2016 with her Masters in Materials Science & Engineering with an interdisciplinary emphasis in Public Policy and Administration from Boise State University. Her thesis was entitled, "Nanomanufacturing Outside of the Lab: An Academic-Industry Partnership Case Study." She also received her B.S. in Materials Science & Engineering from Boise State in 2014. In the Spring of 2016, Ann was recognized as part of the first cohort of University Innovation Fellows at Boise State, and has worked as a Fellow to collect and incorporate student feedback into future plans for makerspaces on the Boise State campus. As an undergraduate and graduate student, she has been involved with the Society of Women Engineers, and also taught a materials science laboratory course as a graduate teaching assistant. She has volunteered at numerous STEM outreach activities on and off of the Boise State campus throughout her time as a student and is passionate about increasing diversity in STEM and helping girls and women to recognize that STEM is a path that is open to them if they want to take it.

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Beth A. Myers is the Director of Analytics, Assessment and Accreditation at the University of Colorado Boulder. She holds a BA in biochemistry, ME in engineering management and PhD in civil engineering. Her interests are in quantitative and qualitative research and data analysis as related to equity in education.

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Kevin O'Connor is assistant professor of Educational Psychology and Learning Sciences at the University of Colorado Boulder. His scholarship focuses on human action, communication, and learning as socio-culturally organized phenomena. A major strand of his research explores the varied trajectories taken by students as they attempt to enter professional disciplines such as engineering, and focuses on the dilemmas encountered by students as they move through these institutionalized trajectories. He is co-editor of a 2010 National Society for the Study of Education Yearbook, *Learning Research as a Human Science*. Other work has appeared in *Linguistics and Education*; *Mind, Culture, and Activity*; *Anthropology & Education Quarterly*, the *Encyclopedia of Cognitive Science*; the *Journal of Engineering Education*; and the *Cambridge Handbook of Engineering Education Research*. His teaching interests include developmental psychology; sociocultural theories of communication, learning, and identity; qualitative methods; and discourse analysis.

Dr. Michelle Ferrez, University of California, San Diego

Michelle is currently the Director of the IDEA Engineering Student Center at UC San Diego, Jacobs School of Engineering (Inclusion-Diversity-Excellence-Achievement). Dr. Ferrez has twenty three years of experience on diversity in STEM access, retention, and success programs in higher education (4 year and community colleges), K-12 and graduate student pipeline programs, and the role of four-year minority serving institutions in creating educational equity in STEM. Her primary interest centers on postsecondary success for minoritized women and men in STEM fields. Following this interest, she has conducted research in several areas including the intersectionality of race and gender in engineering; including understanding the culture, climate, and infrastructure of an engineering program (policies, organizational norms, interactions with faculty & peers, etc.) that may reinforce racial and gender stereotypes, engender feelings of racial and gender subordination, and disproportionately validate and privilege members of some racial groups at the expense of others.

Tiffany D. Pan, University of Washington

Tiffany Pan is a Graduate Research Assistant at the Center for Evaluation & Research for STEM Equity (CERSE) at the University of Washington, where she primarily works on evaluating The Redshirt in Engineering Consortium. Tiffany is a PhD candidate in Bio-cultural Anthropology interested in the links between biology, behavior, and environment and their collective effects on human health. She also earned an MPH in Epidemiology and MA in Anthropology from the University of Washington.

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The Redshirt in Engineering Consortium: Progress and Early Insights

Abstract

The NSF-funded Redshirt in Engineering Consortium was formed in 2016 with the goal of enhancing the ability of academically talented but underprepared students coming from low-income backgrounds to successfully graduate with engineering degrees. The Consortium takes its name from the practice of redshirting in college athletics, with the idea of providing an extra year and support to help promising engineering students complete a bachelor's degree. The Consortium builds on the success of three existing "academic redshirt" programs and expands the model to three new schools. The Existing Redshirt Institutions (ERIs) help mentor and train the new Student Success Partners (SSPs), and SSPs contribute their unique expertise to help ERIs improve existing Redshirt programs. The Redshirt model consists of seven main programmatic components aimed at improving the engagement, retention, and graduation of students underrepresented in engineering. These components include: "intrusive" academic advising and support services, an intensive first-year academic curriculum, community-building (including pre-matriculation summer programs), career awareness and vision, faculty mentorship, NSF S-STEM scholarships, and second-year support. Successful implementation of these activities is intended to produce two main long-term outcomes: a six-year graduation rate of 60%-75% for Redshirt students, and increased rates of enrollment and graduation of Pell-eligible, URM, and women students in engineering at participating universities. In the first year of the grant (AY 16-17), SSPs developed their own Redshirt programs, hired and trained staff, and got their programs off the ground. ERIs implemented faculty mentorship programs and expanded support to Redshirt students into their sophomore year. In the second year (AY 17-18), Redshirt programs were expanded at the ERIs while SSPs welcomed their first cohorts of Redshirt students. This Work in Progress paper describes the Redshirt programs at each of the six Consortium institutions, identifying distinctions between them in addition to highlighting common elements. First-year assessment results are presented for the ERIs based on student surveys, performance, and retention outcomes. Ongoing research into faculty experiences is investigating how participation as mentors for Redshirt students changes faculty mindsets and instructional practices. Ongoing research into student experiences is investigating how the varied curricula, advising, and cohort models used across the six institutions influence student retention and sense of identity as engineering students.

I. Introduction

Students from low-income backgrounds are underrepresented in engineering programs, and those who do enter engineering are more likely to struggle academically [1]. In particular, such students may have attended under-resourced high schools and consequently lack the preparation in science and mathematics needed to directly enter four-year engineering and computer science curricula that are designed for students who are calculus-ready. Low-income students also face significant financial challenges in affording college, and may be disadvantaged by lack of familiarity with the norms and culture of higher education [2].

Increasing low-income students' numbers and success in engineering and computer science is an

excellent societal investment, because these fields benefit from diverse perspectives, and because they can significantly raise the socioeconomic status of many families by launching graduates on a stable, well-paid career path. This paper describes the first-year efforts of a consortium of six public engineering colleges that are pursuing a new model to recruit and admit highly motivated but underprepared students from low-income and other challenging backgrounds, and to help them succeed in navigating the path to an engineering or computer science degree.

With scholarship support from the National Science Foundation, the Redshirt in Engineering Consortium was established in 2016 to share best practices among three existing and three new Redshirt programs, and to disseminate the model to other institutions facing similar challenges. The Redshirt in Engineering Consortium takes its name from the redshirt practice in college athletics, in which a first-year college athlete is given a year to prepare to compete at the university level. Correspondingly, the underlying concept of the Redshirt in Engineering Consortium is to bolster academic preparation and provide extra academic support to improve first and second-year retention and to significantly enhance the ability of academically talented but low-income and underprepared students to successfully graduate with engineering degrees.

The guiding principles of the Redshirt in Engineering Consortium are to:

- Increase student interest in and knowledge of an engineering education and career.
- Build a sense of community among Redshirt students and the larger college population.
- Prepare students to succeed in a traditional engineering program during their second year.
- Attract a more diverse student body to engineering.
- Increase the retention of students historically underrepresented in engineering.
- Be a national model for recruitment and retention of underrepresented students.

This paper provides an overview of key elements of the consortium's participating programs, and reports on results for AY 16 – 17, the consortium's first year.

II. Program description

Overview

The Redshirt in Engineering consortium consists of three previously existing programs (Existing Redshirt Institutions, ERIs): the GoldShirt Program at the University of Colorado Boulder (CU-B) and the Washington State Academic Redshirts (WA STARS) Program at University of Washington (UW) and Washington State University (WSU), and three new programs (Student Success Partners, SSPs): the Academic Community for Engineering Success (ACES) program at the University of California, San Diego (UCSD), the SAGE Scholars program at Boise State University (BSU), and the Academic Redshirts in Science and Engineering (ARISE) program at University of Illinois, Urbana-Champaign (UIUC). CU-B originated its Engineering GoldShirt Program in 2009 [3] and has now served more than 200 students. NSF provided early scholarship support through an IEECI grant for 2009-2010 (EEC-0835907). The Redshirt concept was extended to the UW and WSU STARS programs through a 2013 NSF STEP grant (DUE-1317246, DUE-1317349) [4]. The NSF S-STEM award enabled extension of the concept to the three new SSPs.

The NSF S-STEM award to the consortium is providing about \$4 million in scholarship support across the six consortium institutions. Over the five-year period of the award, these scholarships will help about 800 first- or second-year engineering students who have unmet financial need.

Across the consortium partners, the shared Redshirt model consists of seven main programmatic elements that are designed to improve the engagement and rates of retention and graduation of students underrepresented in engineering and computer science. These elements are “intrusive” academic advising and support services; an intensive first-year academic curriculum; community-building; programming to develop career awareness and identification; mentoring by an engineering or computer science faculty member; financial support, including the NSF S-STEM scholarships; and second-year academic support. There is flexibility across institutions in how these core components are implemented, reflecting distinctions in the administrative structure, resources, and student populations at each university.

Organization of the Redshirt in Engineering Consortium

Redshirt consortium collaboration began with a kickoff meeting at CU-B in September 2016, providing participants with an opportunity to meet in person to discuss project details and provide SSPs with initial ideas to begin developing their programs. The meeting included productive conversation among SSPs regarding variations in institutional contexts that could affect the implementation of Redshirt programs. For instance, schools vary in the amount of institutional and industry resources available to support programs like Redshirts. This opened a discussion about strategies for seeking supplemental funding. Schools also discussed different academic climates and registration policies that could impact the way a Redshirt curriculum is implemented, and how variation in the selectivity of university admissions would impact the creation of Redshirt cohorts.

The kickoff meeting helped lay the groundwork for bi-weekly conference calls to share information between ERIs and SSPs – both to help SSPs develop plans to implement their own Redshirt programs, and to help ERIs improve their programs by learning from other successful initiatives at the SSPs. The success of these calls is indicated, in part, by their persistence throughout the first three semesters of the grant. According to feedback from program administrators during first-year evaluation interviews, these phone calls were a very useful platform for the exchange of information. The SSPs were able to get valuable guidance from the ERIs as they worked on developing their Redshirt programs. Program administrators from the ERIs were proud that the lessons learned from their Redshirt experience could help others doing similar work.

First-year curricula and academic programming

To address the preparation gap experienced by the Redshirt students, each university offers them a special summer program before they enter their first year, followed by a tailored first-year curriculum. The summer programs focus on community building, in addition to academic preparation. These programs vary across institutions, with the on-campus experiences ranging from expanded orientation and transition programming sessions lasting a few days to a week, all the way up to a five-week summer engineering institute at UCSD that includes completing a 4-

credit course toward their intended major. This five-week summer institute is open to all incoming freshmen, but NSF S-STEM Redshirt scholars are provided with scholarships to enable them to attend. In addition to on-campus programs, some of the universities have requirements for the students to do summer homework, such as completing Khan Academy units on algebra and trigonometry.

The Consortium institutions all require specific coursework during the students' first year, providing a further opportunity for students to bolster their academic preparation and study skills. All six institutions offer a special seminar covering time management, study skills, career orientation, and development of professional identity. The institutions differ in whether these seminar-style classes are offered for credit or not, but in all cases participation is required. At three of the Consortium institutions (UW, UIUC, CU-B), most Redshirt students take preparatory mathematics, chemistry and physics classes during their first year before enrolling in the corresponding courses required for their engineering degrees. At BSU, Redshirt students commonly take college algebra or trigonometry their first semester and must complete calculus 1 by the end of their first year in order to remain in the program. At other institutions (e.g., UCSD), Redshirt students start from the outset with most courses required for their engineering or computer science major. Depending on the institution, the first-year curriculum is filled out by writing, humanities and social sciences, and engineering design projects classes. Several of the Redshirt programs also require students to participate in workshops or problem-solving sessions to complement their classes in chemistry, mathematics, or physics. At the institutions where the first-year curriculum deviates significantly from the standard engineering and computer science curriculum, it is expected that Redshirt students may take five years to complete their degrees.

Support services and community development

A key element of the academic support provided to Redshirt students comes through “intrusive” advising. At CU-B, UW, and WSU, this takes the form of multiple meetings with Redshirt staff throughout the academic year. The staff at CU-B and UW go so far as to coordinate with instructors and teaching assistants to provide thorough advising for their students. At UIUC, UCSD, and BSU, students receive advising from their program administrators and faculty mentors.

Each ERI implemented a Redshirt-specific faculty mentoring program last year. SSPs are expected to establish a faculty mentoring program once their programs are up and running. At CU-B, WSU, and UCSD, these meetings occur at least once every semester or quarter. BSU has their students meet with their Redshirt faculty mentor five times a semester. In addition to faculty mentoring, some Redshirt institutions have either formal or informal peer mentoring programs.

Redshirt programs provide communal support to first-year engineering and computer science students. Each program serves a limited number of students, allowing for a sense of community. At CU-B and UW, residence halls act as living and learning communities as Redshirt students all live in close proximity to each other. Community-building activities include dinners with faculty, bowling nights, volunteering as a cohort, attending campus events together, industry visits, and

game nights. At BSU, summer programming for new Redshirt students includes a multi-day whitewater raft trip.

Admissions

In the first two years of the Redshirt in Engineering Consortium, all schools except UW and WSU had direct-to-college admissions to Engineering. At UW and WSU, students typically applied to engineering in their sophomore or junior years after completing engineering prerequisites. In January 2018, UW changed to direct-to-college admissions, which is more in-line with the admissions policies at the other Consortium institutions. The majority of engineering students at CU-B, UIUC, UCSD, and BSU are admitted directly to an engineering program from high school and declare a major upon admission, with a smaller number of students at CU-B, UIUC, and UCSD re-applying for an engineering program after first being redirected to a general studies or pre-engineering program.

Admissions and selection processes for the Redshirt programs depend on the schools' engineering admissions policies. At CU-B and UIUC, Redshirt participants are recruited from students who have applied to engineering but were not admitted directly. For these students, participation in the Redshirt program offers an alternate path for admission to engineering. At UW, Redshirt students have historically been offered guaranteed admission to engineering contingent on their full participation in the program, though the policy for admission to the program will be changing with the university's changing admission structure. At WSU, UCSD, and BSU, Redshirt students are recruited from a list of students already admitted to engineering, but displaying low math scores and/or considerable financial need. At CU-B, UW, and UIUC, selection into the program is based as much on academic need as financial need. At WSU, UCSD, and BSU, financial need is the primary factor used to determine eligibility.

III. Assessment framework and initial results

The Center for Evaluation & Research for STEM Equity (CERSE) at the University of Washington serves as the evaluator for the Redshirt in Engineering Consortium. CERSE's evaluation activities include annual interviews with program administrators; observations of Consortium conference calls and other team meetings; analysis of data on academic performance and retention of Redshirt students; and bi-annual surveys of Redshirt and non-Redshirt students at each school [5]. The first year of the grant was intended to be a planning year for SSPs, with ERIs expected to build on existing programming. Therefore, the first-year evaluation was primarily focused on observing consortium-level activities, with some first-year performance and retention results available for the ERIs. In years 2-5, Redshirt students and a comparison group will take a survey both at the beginning of the year and at the end of the year in order to track change over time. Initial findings from the Fall 2017 baseline survey are presented below.

Who are the Redshirt programs serving?

Table 1 provides demographic information from a survey of current Redshirt students at each institution and a group of first-year engineering students not participating in the program. The composition of the non-Redshirt group varies from school to school, with some schools targeting

only those students who are demographically/academically similar to Redshirt students (UW, WSU, BSU and UIUC) and other schools targeting all first-year engineering students (CU-B, UCSD). The number of students indicated in the table represents the number who completed the survey, which includes most Redshirt students and a subset of the potential comparison group.

Overall, compared to students not participating in the Redshirt programs, a significantly greater proportion of Redshirt participants are first generation college students (69.6% vs. 37.6%, $p < 0.001$) and Pell Grant-eligible (87.7% vs. 48.8%, $p < 0.001$). Recruitment of women or gender non-binary participants varied by institution, resulting in only a slight difference in the proportion of women or gender non-binary students between Redshirt students and non-Redshirt students (33.9% vs. 36.6%, not statistically significant). Participation of students who identify as an underrepresented minority in higher education is greater among Redshirt participants than non-participants. Significantly more Redshirt participants identify as Black or African American (19.3% vs. 3.0%, $p < 0.001$) and Hispanic, Latinx, or Spanish Origin (42.1% vs. 21.6%, $p < 0.001$). On the other hand, significantly fewer Redshirt participants identify as Asian (e.g., Chinese, Filipino, Indian subcontinent) (22.2% vs. 42.3%, $p < 0.001$) and White or Caucasian (33.3% vs. 45.0%, $p < 0.05$). There is no significant difference between Redshirt participants and non-participants in the proportion who identify as American Indian or Alaskan Native (4.1% vs. 2.0%, not statistically significant), Native Hawaiian or Pacific Islander (0.6% vs. 1.9%, not statistically significant), or Other (2.3% vs. 2.8%, not statistically significant).

Table 1. Number and demographic description of Redshirt and non-Redshirt survey respondents by institution

		BSU	CU-B	UCSD	UIUC	UW	WSU	Total
n	Redshirt	11	42	21	16	50	31	171
	Comparison	7	26	273	48	177	11	542
% First Generation	Redshirt	54.6	64.3	81.0	75.0	70.0	71.0	69.6
	Comparison	28.6	38.5	36.4	21.7	42.7	54.6	37.6
% Pell Eligible	Redshirt	81.8	73.8	100.0	100.0	84.0	100.0	87.7
	Comparison	57.1	53.9	43.7	34.1	55.8	100.0	48.9
% Woman or Other/Non-Binary	Redshirt	45.5	16.7	47.6	37.5	44.0	25.8	33.9
	Comparison	42.9	53.9	41.2	16.3	32.8	27.3	36.6
% American Indian or Alaskan Native	Redshirt	9.1	9.5	4.8	0.0	2.0	0.0	4.1
	Comparison	0.0	11.5	1.5	0.0	2.3	0.0	2.0
% Black or African American	Redshirt	9.1	21.4	0.0	31.3	24.0	19.4	19.3
	Comparison	0.0	11.5	1.5	0.0	4.0	18.2	3.0
% Hispanic, Latinx, or Spanish Origin	Redshirt	27.3	57.1	66.7	25.0	30.0	38.7	42.1
	Comparison	0.0	57.7	25.6	10.4	15.3	0.0	21.6
% Native Hawaiian or Pacific Islander	Redshirt	0.0	0.0	0.0	0.0	2.0	0.0	0.6
	Comparison	0.0	15.4	1.5	0.0	1.1	0.0	1.9
% Other	Redshirt	0.0	0.0	4.8	0.0	4.0	3.2	2.3
	Comparison	0.0	0.0	2.6	2.1	4.0	0	2.8
% White or Caucasian	Redshirt	72.7	47.6	9.5	25.0	16.0	48.4	33.3
	Comparison	100.0	80.8	32.6	68.8	49.2	81.8	45.0

% Asian	Redshirt	18.2	14.3	28.6	18.8	32.0	16.1	22.2
	Comparison	0.0	26.9	50.6	27.1	39.6	9.1	42.3

Results from the survey of Redshirt participants and eligible non-participants surveyed in Fall 2017 indicate that the Redshirt programs are meeting the goal of recruiting academically talented but underprepared students from low income backgrounds. Overall, Redshirt students seem to be more motivated to pursue an engineering or computer science degree and more prepared to seek out support and opportunities to be successful, but they also feel underprepared in math and science, have less social capital from their families, and anticipate greater financial burden.

Redshirt students are more certain in their intention to complete a major in engineering or computer science, choice of major within engineering, and choice of engineering as a career than the comparison group. Although Redshirt students rated themselves lower in math and science ability, they also rated themselves higher in traits such as self-confidence, networking, interview skills, and resume writing, which are important for seeking out opportunities. Redshirt students have significantly more exposure to a professional engineering environment and were more likely to gain knowledge about the engineering profession from an industry visit (37.4% vs. 23.1%, $p < 0.001$). However, Redshirt students were less likely to have gained knowledge about the engineering profession from a family member (35.7% vs. 48.0%, $p < 0.01$). More Redshirt students anticipate financial barriers to completing their engineering degree than the comparison group (64.9% vs. 45.4%, $p < 0.001$), but they value and are more comfortable seeking support from classmates and instructors.

Redshirt students' perceptions of their first-year progress

In year 1 (2016-17), all ERIs conducted spring surveys that provide student self-reports of academic preparedness, perceived ability, and sense of identity and belonging in engineering. Survey results reveal that, at the end of their first year, Redshirt students at the ERIs viewed their own general ability to succeed as slightly above average. Students were most confident with their ability to work in teams and think critically. Students were somewhat less confident in areas related to professional development (resume writing, networking, and interview skills). Students across the ERIs also felt strongly that they belong to a group of engineering students and were proud to be engineers. However, feelings of attachment to other engineering students and certainty of getting a degree and pursuing a career in engineering were lower at WSU than the other ERIs. There was also a great deal of variation across schools with regard to the subjects that students felt most prepared for at the end of the year. While students at all three ERIs felt relatively prepared for calculus, UW and WSU students felt more prepared for chemistry and computing, whereas CU-B students felt more prepared in spatial visualization, physics, and humanities.

Performance and retention of Redshirt students at ERIs

A total of 67% of WSU STARS students and 98% of UW STARS students were retained in engineering into their sophomore year (cohorts 1 & 2) and 46% of WSU STARS students and 84% of UW STARS students were retained in engineering in their junior year (cohort 1). Additionally, the UW STARS students are seeing academic gains in math and science course

performance along with overall GPA when compared to their peer group. The STARS students at both schools self-reported that the programming mitigated some personal and structural obstacles to their success through the enhanced social and academic supports that helped their transition to college. STARS made a direct impact on individual participants, primarily through the social support and academic support in their transition to college.

The overall second year engineering retention for students at CU-B has been 89% over eight cohorts (ranging between 82-94% by cohort) and 74% were retained in engineering into their third year (seven cohorts). The most recent cohort for which data is available had a six-year engineering graduation rate of 52%, with 65% earning a degree from any major on campus. While this is far from our goal, these results are comparable to those for directly-admitted students who are considerably more prepared for engineering study when admitted.

IV. Conclusions

This Work in Progress paper describes the Redshirt programs at each of the six institutions in the Redshirt in Engineering Consortium. The paper also presents results of the first-year of the grant. During that year, SSPs developed their own Redshirt programs, hired and trained staff, and admitted their first cohort of students. ERIs built on existing programming by developing faculty mentorship components and providing expanded second-year support. Consortium partners shared experience with challenges and best practices through an initial kickoff meeting and biweekly conference calls.

Results of a survey of the students who entered the six Redshirt programs in Fall 2017 indicate that the Consortium is meeting its goal of recruiting motivated and academically talented but underprepared students from low income backgrounds. The three SSPs have successfully launched their programs, tailoring admissions and recruiting to match the variety of admissions policies existing at their institutions and the different student populations they serve. Each program has also provided a distinct summer experience for incoming Redshirt students and integrated them with the varying summer programs their institutions were already offering. Furthermore, although the six institutions have different first-year course requirements for their Redshirt students, common elements include seminars to bolster time management and study skills, and supplemental preparation or support in mathematics, chemistry, and physics. The six programs also share a focus on community building, intrusive advising, and faculty mentoring.

Surveys conducted with Redshirt students at ERIs in year 1 indicated that Redshirt students perceived their ability to succeed as slightly above average, and that they felt a sense of belonging in engineering and computer science and pride in their major. Over time, the Goldshirt program at CU-B and the STARS programs at UW and WSU have established records of retention and academic success that are at least comparable to those of students admitted through standard pathways.

Future assessments of Consortium efforts will collect and analyze university degree and enrollment data, student level data on academic performance and retention of Redshirt students, and student survey data from all six Consortium partners. Comparisons across the six participating institutions will inform how their varied programs influence student retention and

sense of identity as engineering and computer science students. Finally, ongoing research is also investigating how engineering and computer science faculty participation as mentors for Redshirt students changes faculty members' mindsets and instructional practices.

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