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# Redshirt in Engineering: A Model for Improving Equity and Inclusion

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Donna Crystal Llewellyn received her BA (major in Mathematics and minor in Economics) with High Honors from Swarthmore College in 1980. She went on to earn an MS in Operations Research from Stanford University in 1981 and a Ph.D. in Operations Research from Cornell University in 1984. After 30 years at Georgia Tech in a variety of roles, Donna became the Executive Director of the new Institute for STEM and Diversity Initiatives at Boise State University in January 2015. Donna's current interests center around education issues in general, and in particular on increasing access and success of those traditionally under-represented and/or under-served in STEM higher education.

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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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# Title

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# 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 (SSP), and SSPs contribute their unique expertise to help ERIs improve existing redshirt programs. This Work in Progress paper describes the history of the Redshirt in Engineering Consortium; the Redshirt model as a framework for addressing issues related to diversity, equity, and inclusion in engineering; and initial lessons learned from the implementation of the model across unique institutional contexts.


# Introduction[1]

Students from low-income backgrounds are underrepresented in engineering and are more likely to struggle in engineering programs (Eagan 2012, Ohland et al. 2012, Foor et a. 2007). While these students may be academically talented and perform well in high school, many graduate from under-resourced schools that provide relatively weak academic preparation for college. Success in engineering majors depends greatly on a strong pre-college background in math and science, so many students from low-income backgrounds enter college underprepared to begin engineering curriculums. When coupled with a lack of familiarity with the culture of higher education and rising tuition costs, the result is a much higher attrition rate for these students. Ohland et al. (2012) found that economically disadvantaged students matriculate and graduate from engineering programs at lower rates than students from higher-income backgrounds.

In this paper, we will discuss a model for improving the inclusion and retention of highly-motivated but underprepared students in engineering. Evidence from the Engineering 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) suggests that the "redshirt in engineering" model is a successful tool for improving outcomes for students who would be otherwise excluded from engineering. The expansion of the model to three additional schools -- University of California, San Diego (UCSD), Boise State University (BSU), and University of Illinois, Urbana-Champaign (UIUC) -- will allow for an examination of its malleability and potential for further dissemination. Lessons

[1] Note: much of the information in the introduction was drawn from the NSF S-STEM proposal to fund the Redshirt in Engineering Consortium.

learned from existing redshirt programs and the first two years of the Redshirt in Engineering consortium provide valuable insights regarding diversity, equity, and inclusion in engineering.

Four-year engineering and computer science curricula are designed for students who are calculus-ready, but many students who are eager to become engineers or computer scientists need additional time and support to succeed. Providing this type of support is an excellent societal investment because these fields benefit from diverse perspectives, including those of people from low-income backgrounds (Carrigan et al. 2015, Strutz et al. 2012). Further, because a technical degree in engineering or computer science can transform the socioeconomic status of a low-income family in just one generation, providing low-income students support can improve many people's lives. If engineering continues the status quo of focusing primarily on better-prepared students, Strutz, Orr and Ohland (2012) state that "Not only does engineering lose the diversity of experiences that students from different socioeconomic backgrounds bring, but the field commits a social injustice by systematically excluding people from a lucrative profession" (Strutz et al. 2012). Four-year universities must develop ways to support low-income students to receive engineering degrees.

The Redshirt in Engineering Consortium brings together six universities in the Midwest and West who are working to improve the success of students from low-income backgrounds. At these universities, Pell-eligible students in engineering face a variety of challenges. According to 2014 data presented in the NSF S-STEM proposal to establish the Consortium, pell-eligible students are underrepresented in engineering at UW, WSU, and UIUC – the percentages of engineering students who are Pell-eligible are at least 5% lower than the university as a whole (19.5% vs. 25.3% overall for UW; 29% vs. 34% overall for WSU; and 12% vs. 21.3% overall for UIUC). At UCSD, the percentage of Pell-eligible students who leave engineering after the first year is nearly double that of all first-year students (6% vs. 3.3% overall). At CU-B, which has had the Engineering GoldShirt Program since 2009, there has been an increase from 9.8% Pell-eligible in the engineering first-year cohort to 16.0% for fall 2017, however, there is still a gap in the engineering graduation rates of Pell-eligible students (56% vs. 69% overall). At BSU, students face unique challenges: 52% of the students in the college and university are Pell-eligible and approximately two-thirds of the students enter the college of engineering at entry math levels below calculus.[2] By providing intensive support for cohorts of 20-50 students at each school, the Redshirt in Engineering Consortium aims to enhance the ability of students from low-income backgrounds who are academically talented but underprepared to successfully graduate with engineering degrees. Following a description of the development of the Redshirting Consortium and outcomes at CU-B, UW, and WSU, this paper will discuss implications for diversity, equity, and inclusion more broadly.

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[2] These figures are from Fall 2014

# History/Background of Redshirting Consortium

## The Engineering GoldShirt Program - CU-B

Redshirt programs, in which a first-year college athlete is given a year to prepare to compete at the university level, are common in athletics. Following this concept, CU-Boulder originated the Engineering GoldShirt Program in 2009 (Ennis et al. 2010). The program is based on the premise that academically talented students from high schools located in low socioeconomic areas arrive at the university with less academic preparation than other entering students. The Engineering GoldShirt Program provides a *performance-enhancing year* for underprepared students directly admitted to the engineering college. The strategy moves beyond competitive university recruitment of the best prepared students who are highly-sought-after, instead creating engineering capacity from the next tier of capable high school graduates. The students in the program are highly motivated but not yet fully prepared to succeed in CU-Boulder's undergraduate engineering programs (Ennis, et. al. 2010).

The Engineering GoldShirt Program piloted with a cohort of 16 students in 2009 and has since enrolled 28-50 students each year with dozens of graduates to date. Ennis et al. (2010) described the motivation for the Engineering GoldShirt Program, key program elements and reviewed performance in the first year. The key program elements highlighted include targeted recruitment for college-wide diversity that includes having representatives from the Office of Admission involved, the two-week Summer Bridge experience, and GoldShirt curriculum. Components of the Summer Bridge program include fall course placement, orientation to college life, learning technical skills, creating shared core values, interdependent learning and creating close friendships. The academic performance of the first cohort of Engineering GoldShirt students was very good with a median grade point average of 3.44 at the end of their first year. Student feedback was also gathered and presented as related to three goals: (1) increasing engineering student interest and knowledge of an engineering career; (2) building a sense of community among GoldShirt students and the larger college population; (3) preparing students to success in a traditional engineering program the following year. Student feedback on the three goals indicated successful increases for each goal. Students became more knowledgeable about engineering as a career and maintained a strong commitment to earning an engineering degree. The GoldShirt students bonded strongly as a community, had good team experiences and became like family members to one another. The curricular components made students feel more prepare to study engineering.

Key program challenges, student performance outcomes in math and physics, and the broader impacts on the engineering college were explored by Ennis et al. (2011). The student selection process was discussed in more depth and highlighted the challenge in getting gender balance in the program. In addition to an extended description of the Summer Bridge Experience, Ennis et al. (2011) also discussed the impact of residential life and peer mentoring on the program. Student academic placement was outlined and lessons learned from the math and science placement tests and subsequent performance. Again, student feedback was assessed against program goals and the impact of the Engineering GoldShirt Program on the culture in the engineering college is discussed.

Many Engineering GoldShirt Program components were also researched extensively using both quantitative and qualitative methods as part of a larger Inclusive Excellence project, Sullivan et. al (2015). In particular, the preparatory physics class that is part of the Engineering GoldShirt Program first-semester curriculum was studied using a practice-research-practice model to drive change. Multiple factors were used to assess and evaluate the course for continuous improvement; these include the quantitative performance of students on a nationally normed test, student qualitative and quantitative feedback from course evaluations, subsequent course outcome results, and student focus group and interview feedback. Engineering GoldShirt Program students engineering identity formation during Summer Bridge was investigated by Knight et. al (2013). Creation of a Pre-Calculus for Engineers course was described by Ennis et. al. (2013) and then “calculus readiness” and students struggling for legitimacy was further explored by O’Connor et. al. (2015). The Engineering GoldShirt Program transition from a remedial mindset to asset mindset was described by Louie et. al (2017). Tsai et. al. (2017) illustrated the challenge of maintaining awareness and understanding of students as individuals within institutional systems of assessment and record-keeping that treat all students as the same in the interests of standardization, i.e. a *factory model* of engineering education.

## The WA STARS Program - UW and WSU

The Washington STate Academic RedShirt (STARS) Program began in 2013 as a collaborative effort between UW and WSU, funded by NSF’s STEM Talent Expansion Program (STEP). The program, modeled after the Goldshirt Program at CU-B, was created as an effort to ensure that students from economically and educationally disadvantaged backgrounds are not excluded from the opportunities afforded by a state-level initiative to increase the number of Engineering degrees. The state of Washington currently ranks number one nationally in the concentration of STEM-related jobs, but students in Washington, particularly students of color and low income students, are not graduating with the skills they will need to fill these jobs (Washington State STEM Education Alliance 2017). Only 40% of high school graduates in Washington meet STEM competency standards, and only 9% of children born in Washington will end up working in a STEM-related job in the state (STEM Education Report Card 2016). In an attempt to reduce this job-skills gap, the state has allocated funds to increase the number of Engineering B.S. degrees at the UW and WSU.

The STARS program provides first-year students from low-income backgrounds an extra year of academic, financial, and social support to encourage retention in engineering. Students are selected for the STARS program if they show a strong interest in engineering, are highly motivated, and are Pell-eligible and/or attended an under-resourced high school. STARS participants receive a targeted first year curriculum focused on advancing academic preparation in math and science, developing learning skills, broadening career awareness and vision, and connecting with resources on campus; individualized academic advising; social support and community building through activities and residence in a Living-Learning Community[3]; and scholarship funding (Riskin et al. 2015).

WA STARS has been very successful so far, with 67% of WSU STARS students and 98% of UW STARS students from the first two cohorts retained in engineering into their sophomore year. Students also report that STARS has provided them with a great deal of social and academic support in their transition to college. STARS students at UW have also seen academic gains in math and science course performance along with overall GPA when compared to a similar group of students not participating in STARS (Margherio & Branstad 2016).

## The Redshirt in Engineering Consortium - CU-B, UW, WSU, BSU, UCSD, UIUC

In 2016, the leadership team of STARS reached out with the Goldshirt team to build on their success and further disseminate the redshirt model to three new universities - Boise State University, University of California - San Diego, and University of Illinois - Urbana Champaign. Each of these universities had a history of working towards facilitating the success of their engineering students, but had never all worked together before. The six schools came together as a consortium with seven objectives:

- Launch, support, and manage the Redshirt in Engineering Consortium to collaboratively deploy and enhance the redshirt model;
- Provide scholarships to approximately 800 students in the Consortium while broadening participation of underrepresented students in engineering;
- Provide redshirt academic and mentoring support to approximately 800 students in the Consortium across the grant duration; focus on first-year support at the new university partners and second-year support at the existing ones;
- Retain at least 70% of the scholarship students into the second year in an engineering major at the new partners and their third year at the existing ones;
- Engage and train at least 30 engineering faculty to mentor the scholarship recipients;
- Research how the different program elements of the redshirt model impact student retention and success, and how faculty mentors are impacted by program participation; and
- Evaluate the Redshirt in Engineering Consortium and all of its components to improve adaptation processes and document outcomes.

During the Consortium's first year (AY 2016-17), the three existing redshirt institutions (ERIs) expanded support for students into their second year. The three new student success partners

[3] A Living-Learning Community is an on-campus residence where engineering students are housed together. Results from the National Study of Living-Learning Programs show that these communities produce strong academic and social outcomes for students (Brower and Inkelas 2010).

(SSPs) hired staff, planned programming, and developed recruitment and admission procedures. Efforts to launch the redshirt model at new institutions and enhance the model at existing institutions were supported through the ongoing discussion of challenges and best practices during bi-weekly conference calls. In Fall 2017, the three new institutions welcomed their first cohorts of redshirt students. Preliminary findings from the program evaluation and insights from the beginning stages of research into the involvement of faculty mentors shed light on the functioning of the Consortium thus far.

Findings from the evaluation of the Redshirt in Engineering Consortium reveal that the three ERIs continue to provide programming that helps students develop a strong sense of belonging in engineering, pride in being an engineer, and confidence in their ability to succeed in engineering. The consortium's sustained communication has also generated a productive exchange of information between schools, and helped to build redshirt programs uniquely suited to the needs of each institution. At the end of their first year, redshirt students at 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 (Knaphus-Soran & Branstad, 2017).

Research into the impact on the faculty mentors began in Fall 2017 and has just ended its first semester, so there aren't results yet. However, we do have some initial insights into the motivation of faculty mentors engaged with redshirt programs. The primary reason that the faculty mentors gave for agreeing to serve as a redshirt mentor was that a colleague whom they respected reached out personally and asked them to fulfill this role. The other motivations that were shared by a majority of the  faculty were the sense of success that they gain by mentoring students to succeed, and a realization that they were mentored or in some way assisted by someone along their path to being an engineering faculty and a recognition that this made a real difference in their success - they had a strong desire to give back and to share their life experiences. Other faculty mentioned that they could have used a program like this - and so they want to offer it to others.The faculty at the universities where students don't choose a major at admission also stated that this gave them a somewhat unique opportunity to work with first year students. And, several shared that the time commitment was manageable - they felt that the "cost/benefit" ratio was good.

Based on these initial remarks from the faculty mentors, we will be tracking to see how they operationalize their desire to help these students succeed, and perhaps more importantly, how this translates to their work with all of their students.

## What Does the Redshirt Model Mean for Diversity, Equity, and Inclusion in Engineering?

Beyond increasing the success of students from low-income backgrounds, Redshirt programs have goals for gender and racial/ethnic diversity that should help to increase representation of women and underrepresented minorities in engineering. Because there tends to be a large amount of overlap between students from low-income backgrounds and non-dominant racial/ethnic identity groups, all three ERIs are exceeding their goals for participation of underrepresented minorities. Redshirt programs have the potential to help improve diversity in engineering and, perhaps more importantly, provide a framework for achieving more inclusive and equitable learning environments for students from groups historically excluded from engineering.

The Engineering GoldShirt Program has enrolled 289 students over nine cohorts. Each student considered for the program comes from a background underrepresented in engineering, either because of their race/ethnicity, socioeconomic status, being the first in their family to attend college, being from a rural region of Colorado, or because they are women. Of the 289 students, 78% have been from racial/ethnic groups underrepresented in engineering (versus 15% in CU-B's engineering college first-year cohorts during the same time), 30% are women (vs. 28% in engineering college), 56% are first-generation college (16%) and 56% have been pell-grant eligible (15%). The Engineering GoldShirt Program, while a small proportion of first-year students, has dramatically impacted the diversity of the engineering college. The number and percent of underrepresented minority students in engineering has more than doubled since the inception of the program.

In the first three cohorts, WA STARS served 70 students at WSU and 91 students at UW. Students in both programs tend to be from racial/ethnic groups underrepresented in engineering (49% at WSU and 43% at UW), first-generation college students (57% at WSU and 68% at UW), and pell-grant eligible (86% at WSU and 93% at UW) (Knaphus-Soran & Branstad 2016). WA STARS has yet to see the kind of college-wide impacts on diversity made by Goldshirts at WSU, but survey results from UW and WSU reveal that STARS students feel more confident in their own ability to achieve and succeed in engineering, more committed to the field of engineering, and a stronger sense of identity and belonging in engineering than other first year students from similar backgrounds.

Existing redshirt programs have achieved racial/ethnic diversity in the populations of students served, but they have struggled more with increasing the representation of women. In the first three WA STARS cohorts, 20% of students at WSU and 40% of students at UW were women. CU-B has also struggled to reach gender parity in their GoldShirt cohorts with 30% women over the nine cohorts and decreasing representation in the last four years due to a college-wide focus on directly admitting women to the college. These programs appear to be effective at increasing the retention and graduation of under-prepared but otherwise motivated and academically talented students, but it could be that these struggles are reflective of broader challenges in attracting women to engineering. Redshirt programs can only help students who apply - there is clearly more work to be done to encourage women to pursue engineering.

While the Redshirt in Engineering model is designed with students from low-income backgrounds in mind, it provides a framework for supporting the success of students from other groups historically excluded from engineering. The redshirt model targets both personal and structural obstacles to retention - in addition to providing financial and academic support, students are encouraged to develop their sense of belonging in engineering and commitment to pursuing a career in engineering. Giving students the tools to succeed along with a group of peers that help to keep them engaged has potential to make engineering more accessible to students from non-dominant identity groups in general.

## Lessons Learned: Best Practices for Redshirt Programs

While the SSP's are just starting their programs at the time of this writing, there are valuable lessons from the ERI's which can be applied to these and other similar programs.

Early in the CU-B Engineering GoldShirt Program students were recruited that were not directly admissible to the engineering college, but were still admissible to the campus. While a holistic admission review approach is taken, many of these students could be categorized into two groups, one had high school grade point averages and lower test scores and the other had high test scores but lower than admissible high school grades. After a few years of recruiting students from both groups, it appeared that the students with the high grades and low test scores were more successful than their counterparts that had lower grades and high test scores. This results is not surprising, however, to see if this held true beyond the CU-B Engineering GoldShirt cohorts Myers (2016) performed an investigation of the eleven engineering college in MIDFIELD. It was found that students with high grade point averages from high school, regardless of their test scores, had better engineering graduation than those with high standardized test scores and lower grades. Therefore, high school GPA is weighted more heavily in recruitment than test scores for redshirt recruiting.

Another lesson is that it is difficult to recruit women to this type of program so this must be a focus to ensure that female students are well-represented and benefitting from these programs At CU-B, women students considered for the Engineering GoldShirt Program are usually directly admitted at peer engineering colleges because they are very well qualified, hence a recent focus on directly admitting them to CU-B engineering. Directly admitting them decreases the pool of women available for consideration in the Engineering GoldShirt Program. After analyzing their applicant pool very carefully, Myers and Sullivan (2014) found that while men apply from across the preparation and academic achievement spectrum, only highly qualified women students apply to their engineering college (analogous to women only applying for jobs if they are 100% qualified, HP internal report). ERIs have also found that interviewing students as part of the application and selection process helps to filter out students who are less interested in engineering, and therefore may be less likely to be retained in engineering in any case.

CU-B and UW have both dealt with scaling up a program in a short period of time to handle many more students, and CU-B implemented some structural changes to their program to ensure that students still had one-on-one interactions with the Program Director even as they were having less interactions day-to-day due to the scale of the program (Ennis 2011). As more cohorts have passed through the GoldShirt and WA STARS programs, strategies such as multi-cohort social activities and peer mentoring have been developed to engage students who have moved beyond their initial "Redshirt" year.

CU-B has found that the advantages of a program like GoldShirt can reach beyond the students in the program to impact the culture of the entire college of engineering (Ennis 2011). The Engineering GoldShirt Program has been a "game changer" in helping redefine the college's definition of excellence to be one that includes *achieving excellence through inclusion* and better serving all students. This is shown in a new strategic vision and the demographic shifts seen in the college beyond those in the Engineering GoldShirt Program. Engagement with the GoldShirt students has broadened awareness of the college's need to create multiple pathways for access to engineering, including the creation of a pre-engineering pathway through the College of Arts & Sciences. There is also increased awareness of the issues faced by under-prepared, first-generation, low-income, or undocumented students and these issues are being supported by our college in new ways beyond the GoldShirt Program.

UW and WSU have identified several factors that they feel have been instrumental in the success of the WA STARS programs. Proactive, individualized advising for students, covering subjects from academic planning to personal challenges (including family situations) is important for identifying barriers to student success and providing tools to address these barriers. Emphasizing the importance of mastering basic math and science concepts, as well as equipping students with strategies to "learn how to learn," such as individual and group study, time management, and encouraging students to actively participate and ask for help. Community building through small learning communities, summer and social activities, and a focus on developing personal skills and habits to become effective engineering students are also identified as best practices.

While many lessons have been learned from the established programs at the ERI's, there is still room to improve the redshirt model. The structure of the Redshirt Consortium enables the observation of how similar programs develop at institutions with different structures, needs, and situations. Transferring lessons between institutions and collecting data over time to verify the effectiveness of these practices at each institution will teach us about how successful programs like Goldshirt and WA STARS can be adapted to work at a broad range of institutions to expand the diversity of engineering students and engineers.

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