At Home with Engineering Education

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Effects of High School Dual Credit Introduction to Engineering Course on First-Year Engineering Student Self-Efficacy and the Freshman Experience (**Evaluation**)

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Effects of High School Dual Credit Introduction to Engineering Course on First-Year Engineering

Student Self-Efficacy and the Freshman Experience (Evaluation)

Abstract

High school engineering programs and curricula are becoming more widespread partly due to the acceptance of engineering as part of the national PreK-12 science curriculum. Career and Technical Education (CTE) programs often collaborate with community colleges to offer dual credit engineering courses. Additionally, some universities offer for-credit, engineering summer school courses to high school students. Two Advanced Placement (AP) computer science courses are currently taught in high schools and plans are underway for an AP engineering course. As these dual credit programs develop, it is important to understand how they prepare the pathway to an undergraduate engineering major, particularly if they are designed to *replace* the on campus introduction to engineering students in their freshman year and the wisdom of replacing this first-year experience with a high school course is under debate.

Data was collected from 28 first year engineering students at a Hispanic-Serving Institution (HSI) in the American Southwest. All participants took a dual credit introduction to engineering course in high school. Participants were asked about their decision to take the course in high school as well as self-efficacy questions about "fitting in", being prepared and about their decision to major in engineering. Sixty-four percent of respondents reported that their high school course made them more prepared than their peers who did not take the high school course. More than 43% reported that their high school engineering course helped them "fit in" and 53% reported that it made them feel more confident in their decision to major in engineering. Importantly, almost all respondents who did not report a positive effect from their dual credit introduction to engineering course felt neutral about the experience.

1. Introduction

Pre college engineering programs are on the rise. With the addition of an engineering strand in the 2014 *Next Generation Science Standards (NGSS)*, high school students are learning more about the work engineers do. Students learn about engineering methods and principles as they use math and science to solve real world problems; and all this before they attend college [1]. The NGSS national standards guide the development of state standards and in turn determine how PreK-12 students in the United States are prepared for a pathway to STEM degrees in college. In addition to new engineering activities added to science class, various types of dual credit engineering courses for high school students are offered along with plans for an Advanced Placement (AP) introduction to engineering For US All (E4USA) project, are poised to offer high school students rigorous engineering content and the opportunity for college credit [2].

1.1 Background- ENGR 102 HS dual credit program

ENGR 102 HS is one such dual credit engineering course that is modeled after the introduction course for engineering majors at the University of Arizona. ENGR 102 HS is designed to replace the on campus version of the course and allows high school students to get a head start on their engineering degree. After an intense four-day training on the core curriculum, high school teachers deliver the one semester content to their students across two semesters. With the extra classroom time, teachers are able to add multiple hands-on activities and provide extra scaffolding for their high school students. Upon successful completion of the course, students receive three units of college credit and can apply the credit towards an engineering degree. Since its 2008 pilot, over 4000 high school students have taken ENGR 102 HS and of those, 2764 enrolled and received college credit. Each year the ENGR 102 HS program is evaluated; looking at students' engineering self-efficacy, mindset and desire to become an engineer as well as teacher training and effectiveness [3], [4], [5], [6], [7], [8].

Early efforts to invite schools into the ENGR 102 HS program focused on high preforming high schools mostly due to a concern about the quality of our teacher training and preparation of students. There was also worry about the ability of high school teachers to deliver an introduction course. However, careful analysis of teacher performance and student course evaluations have alleviated this concern and since 2011 all schools with a qualified teacher have been allowed into the program. Table 1 shows the enrollment history for the first 8 years of the ENGR 102 HS program, including the 2008 pilot. To date "for credit" enrollments hover between 300 and 350 each year and once these dual credit students come to the college of engineering their freshman undergraduate retention rates remain around 75%.

Cohort Academic Year	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16
# Participating High Schools	1	6	14	20	22	29	38	33
# Participating Districts (+private schools)	1	5 (+1)	8 (+2)	13 (+2)	14 (+4)	16 (+4)	20 (+5)	20(+6)
# Students Enrolled for University credit	20	82	197	295	303	301	317	292
Students Matriculated to UA Engineering	5 (25%)	25 (31%)	38 (19%)	51 (17%)	54 (18%)	42 (14%)	61 (19%)	66 (22%)
@UA Engineering after 1 year	5	24	32	38	41	32	44	49
Freshman Retention rate	100%	96%	84%	75%	76%	76%	72%	74%

Table 1: ENGR 102 HS Enrollment History and Freshman Retention rates by cohort

1.2 A Possible Self-Efficacy Deficit and a Solution

"The Freshman Experience" is a moniker for programs offered at many American colleges and universities intended to help students prepare for the transition from high school to college. In engineering these programs often roll into the introduction to engineering course that new freshmen take. These courses are designed to offer academic content as well as new student resources and support within the college of engineering. These first-year programs foster the participation of students in co-curricular, on campus events such as engineering clubs, department open houses, and guest lectures. Since the launch of the program, ENGR 102 HS administrators have been conscious of the possibility that students who take the dual credit course in high school will miss an important part of their acclimation into the college experience, particularly the cultivation of their self-efficacy as an engineering major. While great effort is made to develop comprehensive curriculum, train teachers, provide classroom supplies and campus tours; high school students who take the introduction to engineering course potentially miss portions of the college's Freshman Experience. This important part of an undergraduates' development would also be missing for students looking for AP engineering credit to replace their introductory course.

To address a possible deficit in the engineering freshman experience that dual credit students might face, a small administrative restructuring of the on-campus introduction to engineering course was implemented. The three-unit, on-campus introduction program consists of a large, once a week, one-unit lecture series class (102A) and a smaller, two-unit lab section (102B). For the lecture series, 500+ freshman engineering students come together in a large hall to learn about different departments in the college. Students are also introduced to resume preparation for internships, study group sessions for math, chemistry, and physics, engineering clubs, plus other college deadlines, events and open houses. Department speakers from each major discipline in the college come and give a talk about their program informing students about research, coursework, and career opportunities, thus helping freshmen choose a major. Additionally, students attend a small, twice a week lab section where faculty deliver a solar tracker activity that introduces autonomous systems and the use of sensors, a design of experiment activity, training with Excel and SolidWorks as well as the solar oven iterative design and build curriculum.

The curriculum delivered in the ENGR 102B lab section is nearly identical to the core curriculum delivered in dual credit high schools. Freshman engineering majors typically enroll in the two, aligned courses, 102A and 102B encompassing all three units. However, dual credit students are placed in a one-unit option called ENGR 196D, which comprises only the once a week lecture series course. 196D students meet in the same hall as all other freshman engineering majors and are not singled out in any way. The 196D option preserves dual credit students' freshman experience while at the same time matriculating their high school dual credit course.

1.3 A New Evaluation Population

Data collected in the ENGR 102 HS course evaluation survey each May tends to be a window into the mind of a future engineering student; however, these students have not yet walked on to the college campus. Thus, new data was collected in fall 2019 to assess the attitudes and opinions of dual credit students once they became undergraduate engineering majors. The administrative team wanted to know: What happens to the engineering self-efficacy of dual credit engineering students who come to the college? How do they fit in? Are they confident in the preparation they received from their high school teachers and in their decision to major in Engineering? This pilot study as well as future program evaluations will begin to uncover answers to these questions for the ENGR 102 HS program.

2. Framework and Literature Review

Engineering first year programs often evaluate their effectiveness by looking at freshman class GPA, persistence and self-efficacy. According to Bandura, self-efficacy is the belief in one's ability to influence

events that effect one's life and control over the way these events are experienced. Bandura's theory offers four sources of self-efficacy; 1) mastery of experience, 2) vicarious experience, 3) social persuasion and 4) physiological states [9]. Each of these sources helps define students' belief in their ability to complete an engineering degree and can inform educators how various treatments can improve their first-year program.

Studies examining pre-college engineering programs and their effect on first year undergraduate student outcomes have been varied and at times inconclusive. Pre-college engineering experiences have been shown to positively influence high school students' decision to pursue a degree in engineering, increased awareness of engineering and the work of engineers, provided context for mathematics and scientific knowledge and applications, helped in the development of engineering habits of mind and increased technological literacy [10]. However, looking for relationships between academic performance and pre-college engineering experiences like FIRST Robotics and Project Lead the Way, Salzman & Ohland found no significant correlation [11]. Other studies have looked for connections between pre- college engineering and undergraduate retention, creativity and problem-solving skills with mixed results [12], [13], [14], [15]. Franz hypothesized that the greater the rigor of a pre-college engineering studies [16]. However, when pre-engineering classes and other types of extra-curricular engineering experiences were examined, results showed that significant differences in self-efficacy were only present between groups of students who had pre-engineering experiences versus students who did not have these experiences. Pre-engineering classes showed no effect.

3. Evaluation

Self-reported survey data was collected in fall of 2019 from freshman undergraduate engineering students during the first 6 weeks of the semester. These 28 participants took ENGR 102 HS in high school and were enrolled in only ENGR 196D, the lecture series portion of ENGR 102, and not the lab section. A 14 question, pilot survey was administered via surveymonkey and questions included five demographic questions, two questions about pre-college engineering experiences, three likert-type questions about self-efficacy, two multiple choice questions about their 196D course and two open ended questions. The complete survey can be found after the references portion of this paper in Appendix 1. Table 2 shows the distribution of participants by race and gender. Students were classified as Underrepresented Minorities (URM) if they self-selected any race or racial combination except white, Asian, or multiracial that included only white and Asian.

Table 2. Participation Demographics by Gender and Race					
	Female	Male	Total		
Hispanic/Latino	1	4	5		
American Indian/Alaska Native	0	0	0		
Asian	0	1	1		
Black/African American	0	1	1		
White	3	14	17		
Multi-Racial	1	1	2		
URM	1	7	8		

Non-URM	4	14	18
Missing	0	2	2
Total	5	23	28

In one of the open-ended evaluation questions students were asked, "Knowing what you know now, are you glad you took ENGR 102 HS in high school? Tell us why or why not." Participant responses are represented by the word cloud below.



Specific comments illustrated common themes or reasons for being glad they took the introductory course in high school, including the lower costs, getting ahead at college and smaller class size. Here are some quotes from participants: "I am glad I took ENGR 102 in high school because it was a smaller class size and it was cheaper." "Yes because I can have less coursework this semester, allowing for a smoother transition." "I am still glad that I took it in HS because I am able to focus more on other classes and get my gen eds out of the way while still knowing what everyone else knows." Another theme focused on selection of engineering as a major, "Yes, I am glad I took ENGR 102 in high school, because I did not know what I wanted to major in, and taking this class helped me decide that I wanted to major in Engineering." One student even pointed out that he was glad because he could start college with a 4.0 GPA.

Three self-efficacy questions were posed dealing with preparation, fitting in and confidence in choosing an engineering major. Results from the self-efficacy questions can be found in tables 3, 4 and 5. Participants were first assessed about their perceived preparation for their freshman year in the College of Engineering. Results can be found in Table 3.

Table 3. Because I took ENGR 102 in High School, I am				
	Less prepared for my freshman year the College of Engineering	About as prepared as n everyone else for my freshman year in the College of Engineering	More prepared for my freshman year in the College of Engineering	
Entire Sample (n=28)	0% n=0	35.7% n=10	64.3% n=18	
URM (n=8)	0% n=0	25.0% n=2	75.0% n=6	
Non-URM (n=18)	0% n=0	38.9% n=7	61.1% n=11	
Females (n=5)	0% n=0	80.0% n=4	20.0% n=1	
Males (n=23)	0% n=0	26.1% n=6	73.9% n=17	

Males and female were compared on their feelings of preparedness. An Independent-Sample Mann Whitney U test revealed no sex differences on this question (Female Mdn=2; Male Mdn=3; U= 26.5, p = .061 n.s., two-tailed). Underrepresented minorities and non-URM were also compared with an Independent-Sample Mann Whitney U test. There were no differences in feelings of preparedness between these two groups (URM Mdn=3; non-URM Mdn=3; U= 82.0, p = .605 n.s., two-tailed)

Participants were then assessed about their perceived fit in the College of Engineering. Results can be found in Table 4.

Table 4. Because I took ENGR 102 in High School, I feel				
	Like I fit in less than my peers at the College of Engineering	Like I fit in about as much as everyone else in the College of Engineering	Like I fit in at the College of Engineering	
Entire Sample (n=28)	14.3% n=4	42.9% n=12	42.9% n=12	
URM (n=8)	12.5% n=1	25.0% n=2	62.5% n=5	
Non-URM (n=18)	16.7% n=3	50.0% n=9	33.3% n=6	
Females (n=5)	20.0% n=1	60.0% n=3	20.0% n=1	
Males (n=23)	13.0% n=3	39.1% n=9	47.8% n=11	

Males and female were compared on feeling like they fit with an Independent-Sample Mann Whitney U test. There were no differences between the two (Female Mdn=2; Male Mdn=2; U= 41.5, p = .348 n.s., two-tailed). Underrepresented minorities and non-URM were also compared. There were no differences in feelings of fitting between these two groups (URM Mdn=3; non-URM Mdn=2; U= 91.5, p = .285 n.s., two-tailed).

Finally, participants were assessed about their confidence in their decision to major in Engineering. Results can be found in Table 5.

Table 5. Because I took ENGR 102 in High School, I feel				
	Less confident than my classmates in my decision to major in Engineering	About as confident as everyone else in my decision to major in Engineering	More confident than my classmates in my decision to major in Engineering	
Entire Sample (n=28)	0% n=0	46.4% n=13	53.6% n=15	
URM (n=8)	0% n=0	50.0% n=4	50.0% n=4	
Non-URM (n=18)	0% n=0	50.0% n=9	50.0% n=9	
Females (n=5)	0% n=0	80% n=4	20% n=1	
Males (n=23)	0% n=0	39.1% n=9	60.9% n=14	

Males and females were compared on their confidence in their decision to major in Engineering fit with an Independent-Sample Mann Whitney U test. There were no differences between the two (Female Mdn=2; Male Mdn=3; U= 34.0, p = .173 n.s., two-tailed). Underrepresented minorities and non-URM were also compared. There were no differences in confidence in the decision to major in Engineering between these two groups (URM Mdn=2.5; non-URM Mdn=2.5; U= 72.0, p = 1.000 n.s., two-tailed).

4. Discussion

Much like a medical doctor, one of the mantras of the ENGR 102 HS team is to "first do no harm." The recruiting advantages of working closely with engineering teachers and students all over the country are clear. However, if students who take the course in high school come to the college unprepared or do not have confidence in their ability to succeed in engineering and drop out, then all is for naught. In this small sample, students were overwhelmingly positive or neutral about their preparation, fit and decision to major in Engineering and only four of 28 students (14.3%) felt that their ENGR 102HS experience led them to fit less than their peers taking the introductory Engineering course on the University campus. These results are promising. An important and clarifying next step would be to compare feelings of preparation, fit, and confidence in the decision to major in Engineering between students who take the introductory course on the University campus to those taking the course in high school.

When comparing subgroups of the sample, there were no differences between URM and non-URM students in any of the three areas. This is excellent given the literature about URM students typically showing less efficacy in STEM areas [17], [18], [19]. As suggested for the entire sample, a comparison of feelings of preparation, fit, and confidence in the decision to major in Engineering between URM students who take the introductory course on the University campus to those taking the course in high school would clarify if ENGR 102 HS is responsible for greater fit. Indeed URM reported higher median fit and equal preparation and confidence in the decision to major in Engineering compared to non-URM. As more data is collected, this difference may reach statistical significance.

Further sub-group comparisons between males and females found no differences in feelings of fit, preparation or confidence in the decision to major in Engineering between the two groups, however, the difference in preparation approached significance even with the very small sample size. In the case of sex differences, the medians revealed a male advantage in preparation and confidence. Only five females were included in the data. Extra caution must be taken in drawing any conclusions. It is possible that more females would create enough statistical power to lead to significance. It is also possible that the sample of five is so small as to completely lack representativeness of the population of females who took ENGR 102HS.

5. Conclusions

Prior work and eleven years of data suggest that offering the dual credit ENGR 102 HS course to high school students is a robust and successful strategy. This new data collected from ENGR 102 HS alumni who are current undergraduate engineering majors has uncovered new questions. More data will be collected in the years to come and it could take the ENGR 102 HS team in new directions as we strive to improve the program.

As engineering education thought leaders make plans for an AP engineering course for high school students there is much to consider. Engineering departments across the country will struggle with the notion of an engineering course that would replace their introductory course for majors. A one unit "lecture series" or similar format could provide the necessary scaffolding for dual credit students, including AP engineering students, who will be showing up on college campuses in the next few years. Future work with the ENGR 102 HS alumni as they move through their freshman experience and on to graduation will inform engineering administrators as they make decisions about matriculation of dual credit engineering courses.

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Appendix 1

ENGR 196D student survey- AY2019-20

Welcome former ENGR 102 HS students! We are so glad you are here at the UA. You have been asked to take this survey because you took ENGR 102 in high school and have now been enrolled in ENGR 196D - Introduction to Engineering Lecture Series: the 1 unit lecture portion of ENGR 102 on campus. Thank you for giving us feedback on your UA experiences and the ENGR 102 HS program. Your responses to this survey are confidential. Your responses will in no way impact your grade in ENGR 196D and will not be linked with your NetID.

* 1. What is your gender?

- Male
- Female
- Prefer not to respond

* 2. What is your ethnicity (select one or more)?

- Hispanic or Latino
- American Indian or Alaska Native
- Asian
- Black or African American
- Native Hawaiian or Pacific Islander
- □ White
- \square Prefer not to respond

* 3. At which high school did you take your ENGR 102 HS course?

* 4. In addition to your ENGR 102 HS course, did you participate in a high school program such as an Engineering Career and Technical Edu (CTE or JTED) program, an Engineering Project Lead the Way (PLTW) program or FIRST Robotics (FRC) ? (check all that apply)

Yes, I was in an Engineering CTE/JTED program in addition to my ENGR 102 HS course

Yes, I was in an Engineering Project Lead the Way program in addition to my ENGR 102 HS course

Yes, I participated on a FIRST Robotics team in addition to my ENGR 102 HS course

No, I did not participate in any of these programs

5. If you answered yes in the previous question (#4) please tell us more: Which high school Engineering program you were in? For how long did you participate? Was it a meaningful experience for you?

* 6. You have been asked to take this survey because you took ENGR 102 in high school and have now been enrolled in the ENGR 196D - Introduction to Engineering Lecture Series. Which of the following best describes this lecture series course so far (choose all that apply)?

- Exciting
- Boring
- Engaging
- Too time-consuming
- Informative
- Too easy
- □ Worthwhile
- Waste of time
- □ Intellectually stimulating
- Too difficult
- Helpful for making decisions regarding my major
- Helpful for formulating my career interests
- Helpful for clarifying my perception of engineering
- □ None of the above

* 7. Please choose the answer that best completes the statement. "Because I took ENGR 102 in high school I am...."

- [©] More prepared for my freshman year in the College of Engineering
- About as prepared as everyone else
- ^C Less prepared for my freshman year in the College of Engineering

* 8. Please choose the answer that best completes the statement. "Because I took ENGR 102 in high school I feel..."

- ^O Like I fit in at the College of Engineering
- ^C Like I fit in about as much as everyone else
- [©] Like I fit in less than my peers at the College of Engineering

* 9. Please choose the answer that best completes the statement. "Because I took ENGR 102 in high school I am..."

- [©] More confident than my classmates in my decision to major in Engineering
- About as confident as everyone else in my decision to major in Engineering
- [©] Less confident than my classmates in my decision to major in Engineering

* 10. We are so pleased that you have decided to continue your studies with the University of Arizona, College of Engineering. Please rate your overall satisfaction with your college experience so far with 0 = terrible, worst ever and 100 = wonderful, perfect, having the time of your life.

* 11. Knowing what you know now, are you glad you took ENGR 102 HS in high school? Tell us why or why not.

12. Please provide additional comments and opinions about the dual credit, ENGR 102 HS program and/or the on campus ENGR 196D Lecture Series course.

13. To receive course credit for completing this survey, enter you official UA NetID: _____@email.arizona.edu

14. We will reach out to you at the end of the semester to see how things are going. How should we contact you?

[©] UA Student email

Other email (please specify)