Work in Progress: Linking Clemson University General Engineering and South Carolina High Schools

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Work in Progress: LINKING CLEMSON UNIVERSITY GENERAL ENGINEERING AND SOUTH CAROLINA HIGH SCHOOLS

This Work in Progress paper describes the statewide program Accelerate, an immersive linkage/transfer pathway for South Carolina high school students interested in engineering. With increases in traditional and transfer enrollment, Clemson University is educating more South Carolina students today than ever before in its 120-year history. Educational attainment in South Carolina for high school is 86% and for secondary degrees is 26.2% [National Center for Education Statistics 2016]. Creating intentional pathways to higher education for South Carolina residents can lead to increased educational attainment and fulfillment of regional and national STEM workforce demands. Our state has drastically expanded in recent years to provide a manufacturing basis for industries in the areas of energy, logistics, aviation, transportation, and healthcare. This has resulted in a substantial need for growth within the engineering workforce.

Science and Mathematics (GSSM) to 1) cultivate and maintain in-state engineering talent, 2) attract more women and minorities into engineering, especially from under-resourced school districts, and 3) keep gifted students challenged while developing collegiate study skills. Beginning in their sophomore year, motivated high school students enroll in an integrated set of courses in mathematics, engineering, English, and science. The engineering courses are taught remotely by the General Engineering faculty from Clemson University. Upon completion of the program and graduation from high school, students earn college credit hours that, upon acceptance, can be applied to an engineering degree at three universities in South Carolina, including Clemson, the flagship engineering program in the state.

Throughout the year, students participate in synchronous online classes and routinely use learning management platforms such as Canvas and Pearson MyLabPlus to access in class activities, homework assignments and recorded classes. Accelerate facilitators at each site enable students to work in their home district while receiving critical mentoring, proctoring and communication services. Accelerate has expanded over the years, starting with five school district partners and growing to eleven districts across the state.

As of Fall 2016, one cohort has graduated the Accelerate program and three cohorts are currently active (from sophomore through senior year). We can now begin to assess program success in terms of program retention on a year-to-year basis, retention of students in South Carolina higher education, and transition into the Clemson University engineering program. In general, we see programmatic retention improvement in the transition between the first and second year of the program. The inaugural cohort graduated 16 students, with 15 of the students attended a South Carolina university and 14 enrolled in Clemson University. Of the 14 Clemson University students, 13 enrolled in a STEM discipline and 12 enrolled in an engineering discipline. In this paper, we further discuss persistence of inaugural students in their first semester at the university and lessons learned for implementing a statewide program. These preliminary findings indicate that Accelerate

is a working, improving, and expanding statewide model for linking public high schools and higher education in South Carolina.

1. Introduction

In 2012, the President's Council of Advisors on Science and Technology (PCAST) requested a tall order for educators to fill: the training of one million STEM professionals over the next decade in order to maintain the United States' global competitiveness (President's Council of Advisors on Science and Technology 2012). The release of this report has spurred countless discussions of pipelines and pathways by educators of all levels. A large STEM workforce, large in both quantity and diversity, is needed to satisfy both federal and state STEM industry demands. In this Work in Progress, we discuss a statewide initiative that aims to connect high school students interested in engineering with state higher education.

Engineering content is increasingly appearing in K-12 classrooms, with one university survey reporting that 89% of students participate in at least one pre-college engineering activity (Salzman, Ricco, and Ohland 2014). Further, they found that high school classes are the most common way that students are exposed to engineering content by a significant margin. Exposure to engineering and preparation for college can be categorized into one of the models described below.

A well-known method of college preparation are the Advanced Placement and International Baccalaureate programs. These opportunities allow students to earn high school credit, and potentially college transfer credits that can be applied to university major completion. Another well-known method of college preparation that occurs countrywide, but enacted at the state-level, is dual enrollment, in which enrollment in community college classes can be applied to major completion at a state institution.

State-specific pathways for engineering exposure are not as common and are in various stages of implementation. For example, in 2009 Kent State initiated a dual enrollment partnership between the university and eleven high schools, in which Kent faculty taught all eleven sites synchronously using Adobe Connect (Larrick 2012). The University of Cincinnati started a similar dual enrollment program in 2012, in which UC faculty taught first-year engineering courses to twelve area high schools.

Summer bridge programs are another method for engineering exposure and college preparedness (Citty and Lindner 2012; Volcy and Sidbury 2013; Vercellino, Christenson, and Morse 2015). These programs are typically short-term, occurring the summer before college enrollment, focus on underrepresented populations, and operate from a deficit model in which at-risk students are identified and offered remediation. It is important to note universities may have their own special transfer and preparation considerations, but large-scale transfer pathways at the state level are not as common.

Engineering education is increasingly moving to technology-enabled nontraditional delivery modes, especially online delivery. There is preliminary success in moving project-based introductory engineering courses to the online environment (James-Byrnes and Holdhusen 2012).

There is also preliminary success in delivering first-year engineering courses in a hybrid flipped format (Everett et al. 2014). A study of lecture capture of a first-year engineering course showed class attendance was not affected and uploaded material was accessed by students as a mechanism of preparing for examinations (Bazylak, McCahan, and Weiss 2012). There is also a growing area of research examining how homework behaviors in high school affect performance in higher education. A two-part study found a positive correlation between homework completion rates in high school and first semester performance of engineering students (Honken and Ralston 2015).

1.1 Accelerate Program Overview

Accelerate was launched in 2013 with private support and is currently funded through corporate partnerships and the South Carolina General Assembly. Delivered by the South Carolina Governor's School for Science & Mathematics and South Carolina college partners, Accelerate is a virtual engineering program that allows students to live at home and continue at their local schools. Classes are live, not pre-recorded, and presented virtually through computer and teleconferencing equipment provided and maintained by GSSM. Importantly, there is no cost to participate in the program. Interested students submit an application, which is reviewed by GSSM faculty and Accelerate personnel. Review criteria are listed in more detail in Table 1.

Table 1. Accelerate program admissions information

Admissions Requirements	**Admissions Considerations**
Legal Resident of South Carolina	GPA
Enrolled in 9th grade at the time of application	Course grades / transcripts
Attends one of the participating partner districts and/or schools	Standardized test scores
Completes Algebra 1 prior to the beginning of 9th grade	Extracurricular and volunteer activities
Projects successful completion of Algebra 2 Honors by the end of 9th grade	Teacher and guidance counselor recommendations
	Mathematics assessment
	Written essay
	Gender
	Ethnicity

In the first year of the program, eight school sites participated (covering five school districts) and this number has expanded over the years to include 17 school sites (covering 14 school districts). With 103 school sites in South Carolina, Accelerate in the pilot stage is currently serving 14% of South Carolina schools.

Accelerate includes integrated first-year college equivalent courses in English, chemistry, calculus, and engineering (Albright, Den Braven, and Parshall 2015), as shown in Figure 1. Multi-course

alignment of first-year engineering classes has been shown to increase student performance and persistence in engineering (Liron et al. 2014).

Classes are conducted synchronously online. Each high school site is equipped with a video conferencing system including one or more wall mounted flat screen televisions, a webcam, and a microphone. Video conferencing software (Vidyo) provides for screen sharing and recording each class session. A variety of options is available when conducting class. The instructor can connect to the classrooms with video and audio. The classrooms are connected, so students can see and hear each other across the sites. The instructor can also choose to share content with the students using built-in screen sharing technology. By using a SMART podium, the instructor can write on the shared content to demonstrate solutions or draw attention to important terms, page numbers, etc. A three-way triangle of interaction between the instructor, the students, and the content results in a greater sense of community among the students compared to static online delivery (Baker et al. 2009).

	9 FALL	9 SPRING	10 FALL	10 SPRING	11 FALL	11 SPRING	12 FALL	12 SPRING
MATH	Algebra II	Algebra II	Honors Pre-Calculus for Engineers		MATH 1060 Calculus of One Variable I		MATH 1080 Calculus of One Variable II	MATH 2060 Calculus of Several Variables
SCIENCE	Intro Biology w/ Lab(1)	Intro Biology w/ Lab(1)	Chemistry I*	Chemistry I*	CHEM 1010 w/ CHEM 1011 General Chem I	CHEM 1020 w/ CHEM 1021 General Chem II	PHYS 1220 w/ PHYS 1240 Physics w/ Calc I	PHYS 2210 w/ PHYS 2230 Physics w/ Calc II
ENGINEERING			Honors Pre-Engineering		ENGR 1520 Engineering Computer Skills	ENGR 1640 Engr MATLAB Prog	ENGR 1150 Engr Design & Modeling	Honors Senior Project
ENGLISH/ LANG ARTS	English I	English I	English II*	English II*	ENGL 1030 Accelerated Composition		Honors Literature of Problem-Solving	ENGL 2020 Major Forms of Literature

Figure 1. Accelerate Curriculum. Courses in BLUE are Honors courses offered by GSSM. Courses in GREEN are Dual Enrollment offered by Clemson University. Courses in Black are offered by and weighted by the local high school. (1) Introductory Biology is required by the state. *To be taken at the home school during the sophomore year.

To support the online course format for the engineering courses, a course management system and an electronic companion site to the textbook are utilized. The course management system chosen is Canvas (produced by Instructure), while the electronic companion sites are produced by Pearson Higher Education and include MyLabPlus. Canvas provides for announcements, grades, and submitting assignments. The MyLabPlus site provides electronic textbook access as well as digital

content and electronic homework problems. Students are provided computers in their classrooms that run the engineering applications including Microsoft Excel®, MATLAB®, and SOLIDWORKS®, all using a secure virtual desktop environment. Facilitators at each site perform classroom duties such as attendance, monitoring, teleconference system setup, and submission of students' handwritten assignments, tests, and projects. The role of proctoring and serving as site liaison is critical, so high school teachers and administrators of the site are typically recruited for this position.

The engineering courses in the Accelerate program are created and taught by the Clemson University General Engineering faculty; the same faculty that teach the courses to traditional freshman on the university main campus. The Canvas course shell used for Accelerate is adapted from the course shell used for on-campus students. Further, the same problem bank is used to generate homework assignments and tests for both Accelerate and traditional students.

2. Program Analysis

The Accelerate Program was established in 2013, with the inaugural cohort enrolling for classes in Fall 2013. Each subsequent fall, a new cohort has been recruited. Currently, one cohort has completed the Accelerate program and graduated high school and three cohorts are currently active, as shown in Table 2.

Table 2. Cohort timelines of Accelerate, inaugural class to present

Fall 2013	**Fall 2014**	**Fall 2015**	**Fall 2016**
Class of 2016 as sophomores	Class of 2016 as juniors	Class of 2016 as seniors	Class of 2016 as college undergraduates
	Class of 2017 as sophomores	Class of 2017 as juniors	Class of 2017 as seniors
		Class of 2018 as sophomores	Class of 2018 as juniors
			Class of 2019 as sophomores

Using Accelerate enrollment data, we can begin to assess program success in terms of program retention on a year-to-year basis (Figure 2), retention of students in South Carolina higher education (Figure 3a), and transition into the Clemson University engineering program (Figure 3b).

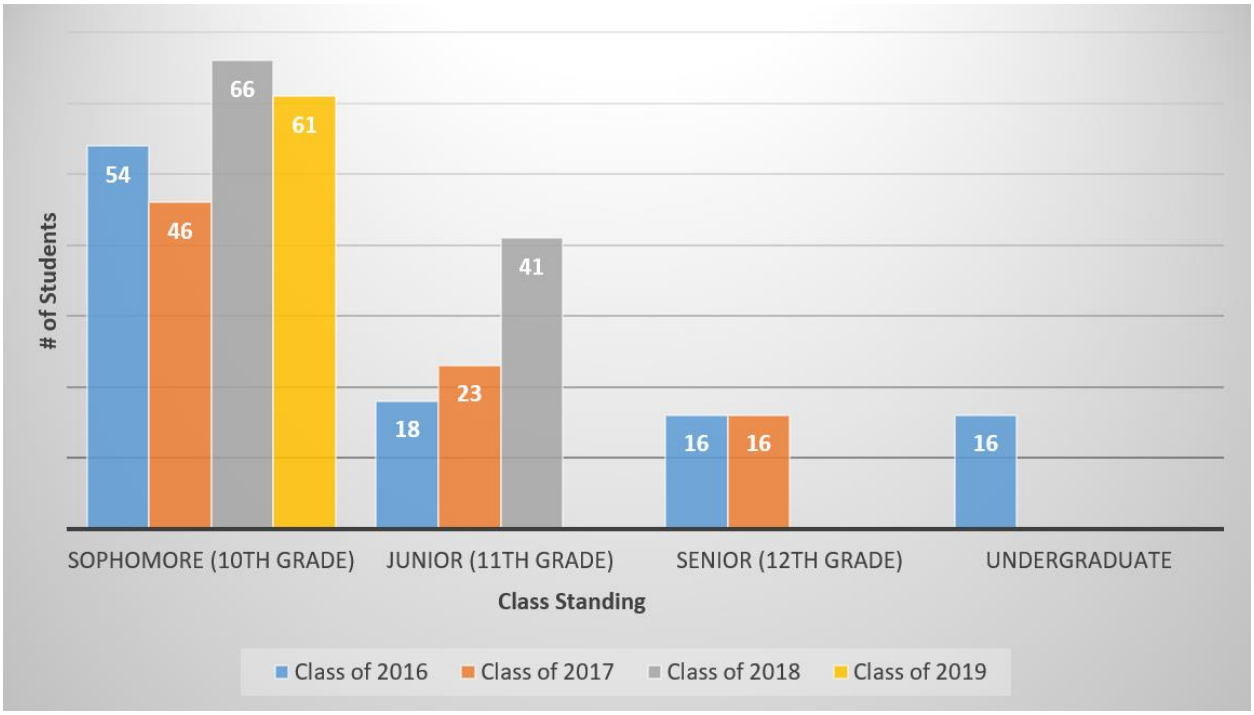

Figure 2. Longitudinal analysis of Accelerate cohort enrollment. Color key corresponds to cohort in Table 2.

There is a drop-off in student enrollment between sophomore and junior year (first and second year of the Accelerate program). We find this trend is true of all three cohorts that have completed that transition; the attrition rates for Class of 2016, Class of 2017, and Class of 2018 being 67%, 50%, and 38%, respectively. This attrition can be contributed to poor performance in the math and engineering courses. The occurrence and underlying reason for attrition of Accelerate students mirrors the attrition trend of traditional students on Clemson University's main campus, and more broadly engineering programs across the United States. Significant attrition of traditional students occurs between their first and second year, and is often due to struggles in math- and engineering-related courses. As the Accelerate program continues to grow and adapt, there has been a decrease in the first-to-second year attrition rate. This decrease is due to a number of factors, including refinement of course delivery and improved student recruitment.

The inaugural cohort graduated 16 students, with 15 attending a South Carolina university and 14 enrolling in Clemson University (Figure 3). Of these 14 students, 13 enrolled in a STEM discipline and 12 enrolled in engineering programs. The gender distribution of the inaugural Accelerate cohort, 31.25% female, is greater than that of the national female enrollment rate in engineering of 21.4% female (Yoder 2015).

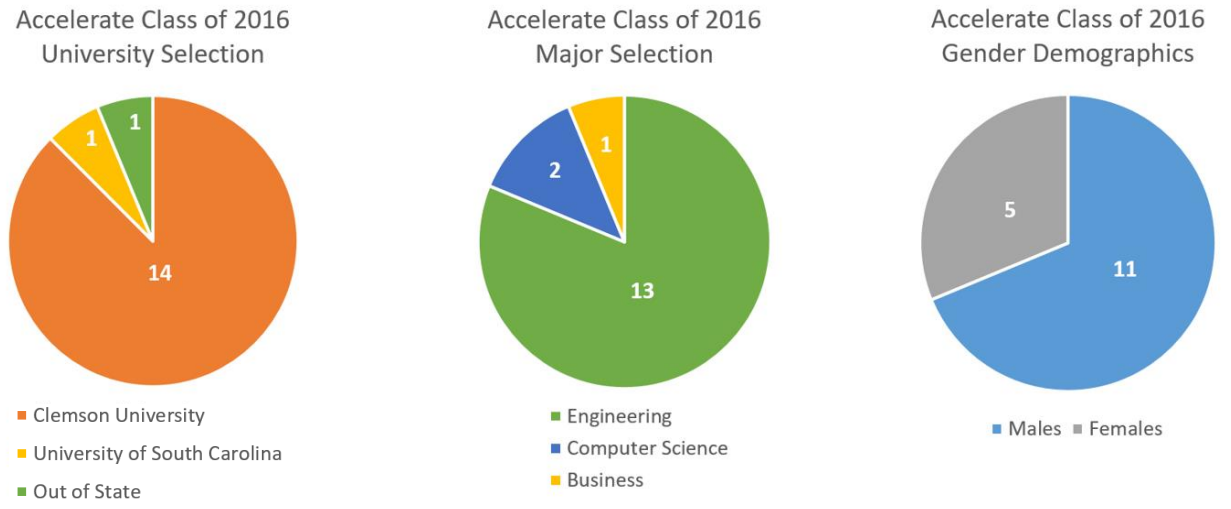

Figure 3. Where did they go? Next steps for the Inaugural Accelerate Class of 2016, looking at university selection, major selection and final gender breakdown.

We are also beginning to analyze student persistence in engineering following the completion of the Accelerate program. To date, this analysis can only be completed using Fall 2016 Clemson University grades for Accelerate Class of 2016 students (Figure 4). Engineering exposure via the Accelerate program, if sufficient, should translate to successful completion of the first semester in the university. We found the average GPA values at graduation from the Accelerate program, for the Fall 2016 term, and the cumulative GPA at the end of Fall 2016 were 3.48, 3.09, and 3.30, respectively. It is important to note the GPA values of Accelerate students at graduation (3.48) is significantly greater than the GPA of traditional Clemson University General Engineering students who have taken the equivalent courses in their first year (3.05). We also see that 100% of Accelerate students who entered as a STEM major for Fall of 2016 have stayed in the STEM field for enrollment of Spring 2017.

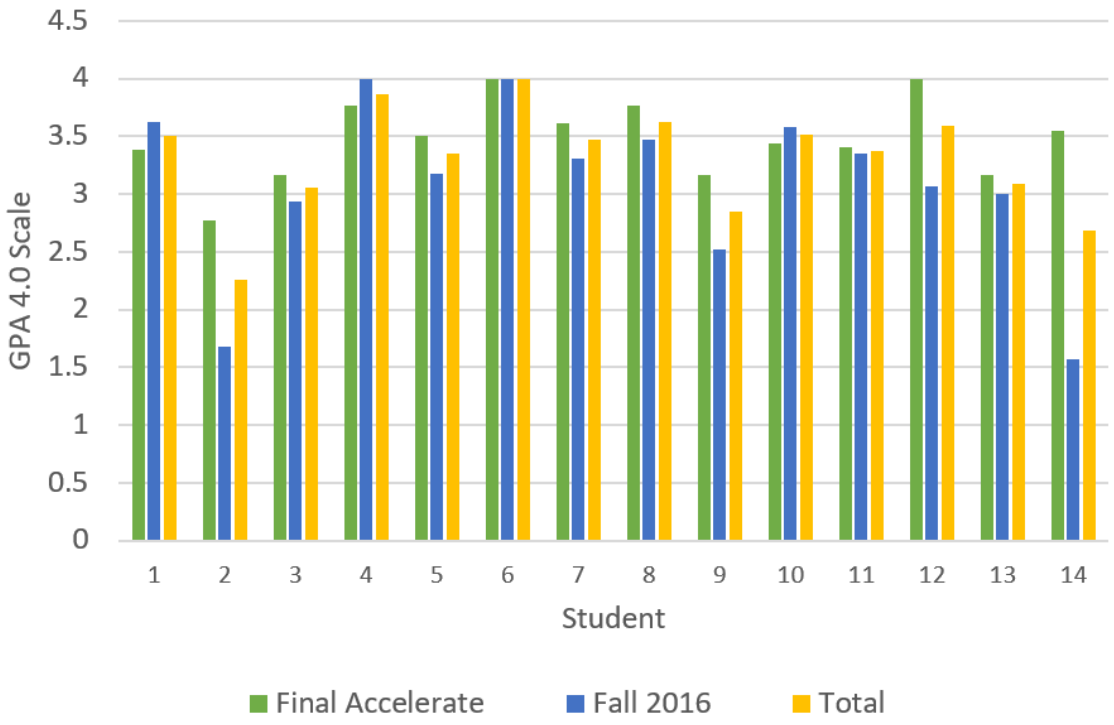

Figure 4. Accelerate inaugural cohort short-term persistence. GPA values for each student at graduation of the Accelerate program, for the Fall 2016 semester, and cumulative GPA (Accelerate GPA + Fall 2016 GPA).

3. Discussion

At the time of the program establishment, very few higher education models existed for Accelerate program administrators and faculty to emulate. Further, the few existing models had not demonstrated long-term success in terms of engineering exposure, retention, and translation to the university. Engineering education literature was used however, to support pedagogical use related to course integration, flipped design, and online delivery.

Engineering at a college level requires in-depth mathematical and scientific knowledge. Many high school opportunities for engineering exposure offer a simplified version of what students should know when compared to college courses. When proposing this program, concerns were raised about the program rigor. This concern is addressed by having university faculty design and implement courses based on the main-campus courses they also instruct. With the presented data, we show that not only do students enter college at a sophomore level due to the advanced credits, but they have the scientific, engineering, and mathematical knowledge that is appropriate to that level to be successful. We certainly agree with others in the education community that time in college should not be shortened to make parents and students happy; it should only be shortened when the same goals can be accomplished in a more efficient manner. By having engineering faculty instruct synchronously statewide, this is one method to standardize engineering

preparedness across the state. An appropriate level of rigor, and therefore engineering preparedness, can be seen by examining the success of the inaugural cohort during the first semester at Clemson University.

As opposed to students taking dual enrollment courses “à la carte” from a university, Accelerate delivers a fully integrated series of courses that satisfies the entire first year of engineering curriculum at a South Carolina university. This approach reduces gaps that can be created in curriculum fulfillment when courses are completed piecemeal.

The use of Vidyo teleconferencing platform allows for scalability of the program, as evidenced by expansion of Accelerate over the years. It has allowed the program to reach more and more students across the state who are interested in engineering. As the program continues to expand, flexibility of scheduling is critical for program success. Sites are located in different school districts within the state. Since each school district sets its own calendar, the Accelerate courses must accommodate as many different calendars as there are participating sites, including school start and end dates, holidays, and teacher workdays.

Students were exposed to a blended format of homework assignments. They received a combination of online problem sets graded automatically and electronically submitted handwritten problem sets graded by Accelerate faculty. Homework completion was facilitated by incentivizing students with quick feedback followed by detailed handwritten feedback. By introducing high school students to the rigor of university engineering while they are still in high school, we see this as an opportunity for early exposure and preparation, leading to improved persistence when they transition to the university.

In order to improve the Accelerate program, other research questions must be answered. Further analysis needs to be conducted on why students leave the Accelerate program, and further, if it dissuades them from STEM fields altogether. Similarly, for students who successfully completed the Accelerate program, did the program affect their decision to continue higher education in South Carolina, or would they have remained in-state regardless? In other words, does the cost of running a statewide program outweigh preliminary student success? This conversation is ongoing in the Accelerate program leadership, and has resulted in an initiative for GSSM to provide site-specific resources for each Accelerate site to improve student success.

4. Conclusions

This study is a continuation of work introduced by Accelerate Program colleagues in 2015. Our preliminary findings indicate that Accelerate is a working, improving, and expanding statewide model for linking public high schools and higher education in South Carolina. This program implements an integrated, synchronous, online model to deliver engineering courses to high school students across the state. Future studies include long-term persistence for the inaugural cohort and similar analysis for all cohorts that complete the Accelerate program. We hope this novel pathway model, of linking high school students interested in engineering with university engineering faculty, will interest Division members. Further, we hope this model will inspire other states to

coordinate state legislatures, high school administrators, and university faculty to create similar statewide pathways. We will continue to perform yearly evaluations, to identify opportunities for program improvement and ensure funding is being used appropriately.

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