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The Path from Community College to Engineering Bachelor's Degree Through Partnerships and NSF S-STEM Funded Scholarships

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Abstract

In the spring of 2014, Governor Bill Haslam signed *Tennessee Promise* into law; making it possible for Tennessee high school graduates to complete two years of community college (CC) free of charge. In the fall of 2016, the first cohort of Tennessee Promise students began the transition from two-year pre-engineering CC curricula to four-year institutions in order to complete their engineering education. As a result of the National Science Foundation S-STEM grant program, Lipscomb University has been able to provide significant scholarship assistance by way of the Enhancing Engineering Talent in Tennessee S-STEM grant that is designed to provide tuition assistance to Tennessee CC students as they transition to Lipscomb's 4-year ABET accredited programs. During the course of this grant, there have been 20 NSF S-STEM scholarship recipients admitted to Lipscomb's engineering college from four different public Tennessee CCs. This student population represents a wide range of academic and life experiences that present unique challenges with regard to their transition into a four-year program.

An important aspect of this grant includes partnering with CCs in the Middle Tennessee area to provide STEM enrichment and early pre-transfer advising. This paper presents a comparison of the state-wide approved Tennessee CC Engineering Pathway curricula with Lipscomb University's engineering curricula in Civil Engineering, Electrical/ Computer Engineering, and Mechanical Engineering and the harmonization of the different curricula. The effect of this program regarding perceived barriers to the success of CC students and CC transfers; changes in faculty and staff perceptions regarding CC transfers; and the effects of the program on CC student matriculation and completion of Lipscomb's engineering program are presented.

Introduction

The National Science Foundation (NSF) created the Scholarships in Science, Technology, Engineering, and Mathematics (S-STEM) program to enable low-income, talented domestic students to pursue successful careers in STEM fields and contribute to the American innovation economy with their knowledge [1]. The NSF provides support to institutes of higher education in a competitive grant process to develop S-STEM programs and encourages four year institutions to collaborate and encourage students to complete 4-year STEM degrees.

In 2015, NSF awarded Lipscomb University an S-STEM grant (Grant #1458735) through a competitive, peer-reviewed grant process. The award, *Lipscomb University—Enhancing Engineering Talent in Tennessee,* began on September 8, 2015 and is expected to conclude on August 31, 2021. The award allowed Lipscomb University to implement a scholarship program designed to not only recruit students from regional, public Community Colleges (CCs), but to also graduate a minimum of 20 of these students with a baccalaureate degree in civil, electrical, or mechanical engineering. For a private institution of higher education (IHE) like Lipscomb University, this was a particularly ambitious goal, given that only 2% of CC students transfer into a private four-year college or university and graduate within six years.[2]

Another challenge was overcoming the different requirements between our community college partners and other four-year institutions in the area. Tables 1, 2, and 3 (below) are a comparison of Mechanical Engineering, Civil Engineering, and Electrical Engineering with regard to typical core engineering curricula for the first two years. When compared to the first two years of engineering curricula offered at ABET four-year universities in the Nashville area, it can be seen that the *Tennessee Engineering Pathways* misses some critical courses necessary for timely completion of the student's engineering degree. (The data presented here is based on each respective course catalogs for the 2020-21 academic year).

Table 1 Comparison of Core Curricula for Mechanical Engineering

	Local ABET accredited				
Core Engineering Curricula – Years 1&2 (Mechanical Engineering)	Lipscomb	TN Tech Univ	Vanderbilt	Tenn State Univ	Pathways
Calculus I,II, & III, Diff Equations	●	●	●	●	●
Calculus Based Physics w/LAB (1 semester)	●	●	●	●	●
Gen Chemistry I w/LAB	●	●	●	●	●
Computer Aided Design (SolidWorks Preferred)	●	●	●		
Computer Programming (MatLAB preferred)	●	●	●	●	
Statics	●	●	●	●	●
Dynamics	●	●	●	●	●
Mechanics of Materials	●				
Basic Circuits Course	●	●	●	●	
Thermodynamics			●	●	
Instrumentation			●		
Hours	41	38	44		29
Course Hours Deficit compared to Lipscomb					12

Table 2 Comparison of Core Curricula for Civil Engineering

	Local ABET accredited				
Core Engineering Curricula – Years 1&2 (Civil Engineering)	Lipscomb	TN Tech Univ	Vanderbilt	Tenn State Univ	Pathways
Calculus I,II, & III, Diff Equations	●	●	●	●	●
Calculus Based Physics w/LAB (1 semester)	●	●	●	●	●
Gen Chemistry I w/LAB	●	●	●	●	●
Gen Chemistry II w/LAB	●	●	●	●	
Computer Aided Design (AutoCAD Preferred)	●	●	*	●	
Surveying	●	●	*		
Statics	●	●	●	●	●
Dynamics	●	●	●	●	●
Mechanics of Materials	●	●	●	●	
Hours	42	42	39		29
Course Hours Deficit compared to Lipscomb					13

Note that Vanderbilt combines CAD and Surveying into a single course and requires Physics II, Thermodynamics, and Transportation Systems in 1st 2 years

Table 3 Comparison of Core Curricula for Electrical/Computer Engineering

	Local ABET accredited				
Core Engineering Curricula – Years 1&2 (Electrical Engineering)	Lipscomb	TN Tech Univ	Vanderbilt	Tenn State Univ	Pathways
Calculus I,II, & III, Diff Equations	●	●	●	●	●
Calculus Based Physics w/LAB (2 semester)	●	●	●	●	●
Chemistry w/LAB (1 Semesters)	●	●	●	●	●
Programming Language	●	●	●	●	●
Circuits I	●	●	●	●	●
Circuits II	●	●	●		
Linear Algebra	●	●	●	●	
Discrete Mathematics (Digital Logic)	●	●	●		
CAD for ECE		●		●	
Hours	42	45	39		33
Course Hours Deficit compared to Lipscomb					9

Note that TSU also requires Statics, Dynamics, and Transport Phenomenon in the 1st 2 years

While this is to be expected when comparing publicly funded community colleges with private institutions, the problem is equally challenging at the two state supported four-year programs used in this comparison.

In order to overcome this deficit, Lipscomb University provided S-STEM students partial funding to take courses such as Mechanics of Materials the summer before the Junior year in order to make the transition more seamless. This also allowed S-STEM transfer students to start their junior course sequence in the fall with expectations of graduating in two years.

Lipscomb University, in partnership with three local community colleges (Columbia State Community College, Nashville State Community College, and Volunteer State Community College), proposed to increase the number of students who successfully transitioned from pre-engineering programs to full engineering programs and completed engineering degrees. The institution would accomplish this by providing comprehensive student support, including targeted recruitment, career awareness activities, transfer transition support, cohesive learning communities, and scholarships. The program's emphasis on an uncommon pathway to engineering reflected both the anticipated attraction of new students plus the shift of students to two-year pre-engineering programs in response to the *Tennessee Promise* initiative, which provides free tuition at all state community colleges beginning in the fall of 2015. The proposed pathway to a senior engineering school was designed to pre-empt the unintended but well recognized consequences of students starting their engineering training at two-year schools by improving student preparedness for transfer, providing structured support for students preparing to transfer, and rapidly establishing connection and community for transfer students at the four-year institution. The awarded S-STEM program provided scholarship support at Lipscomb University for five, six-student cohorts (30 students) over five years and established a pathway from community college to a four-year engineering program that is sustainable after the award cycle.

Lipscomb University developed two primary objectives for the NSF-funded S-STEM program: 1) recruit 30 CC pre-engineering students into Lipscomb's four-year engineering program (six students per year throughout the five-year grant cycle); and 2) retain at least 83% (five of six in each cohort) of scholarship recipients after the first year of support and graduate at least 67% (four of six) of scholarship recipients following an average of five semesters of support by providing financial assistance, career awareness activities, a cohesive learning community, connections to internships, and personal encouragement.

Lipscomb University's eight expected outcomes were as follows:

1) Thirty (30) CC pre-engineering students would receive S-STEM scholarships over the five year grant cycle;
2) At least 20 pre-engineering students per CC, per year, will participate in pre-enrollment activities including monthly engineering awareness activities and targeted advising;
3) Participating CCs will assist Lipscomb University in identifying and tracking associations between: a) student performance in engineering prerequisite courses, b) admission to Lipscomb University's engineering program; c) persistence (associated with fall-to-fall retention);

4) Participating CCs will begin tracking pre-engineering student placement and persistence following program completion (e.g., career placement, transfer to a four-year engineering program, academic success, etc.);
5) At least 83% of students receiving S-STEM scholarships (25 of 30) will be retained after the first year of scholarship support;
6) At least 67% of students receiving S-STEM scholarships (20 of 30) will complete a four-year engineering degree within five semesters of entering Lipscomb University's engineering program;
7) At least 50% of S-STEM scholarship recipients (15 of 30) will participate in an engineering-related internship;
8) At least 90% of S-STEM scholarship recipients who graduate within five semesters of receiving support (27 of 30 students) will enter engineering-related careers and/or pursue additional engineering-related studies.

Table 4: Current status of expected program outcomes

	S-STEM Award Period (2015–2021)	
Expected Program Outcomes	**Goals**	**Current Status**
1. Recruit and Enroll	30 students	22 students (Fall 2016 to Fall 2020)
2. Engage CC students	20/year	40/year
3. CC tracking of student performance in key courses	Begin	Still tracking
4. CC tracking of student success in 4 year programs	Begin	Still tracking
5. LU S-STEM Retention after one year	83%	90% (18/20)
6. LU S-STEM Graduate in five semesters	67%	75% (10/12)
7. LU S-STEM participation in internships	50%	Currently tracking
8. LU S-STEM enter engineering careers or grad school after graduation	90%	Currently tracking 78% in Cohorts #1 and #2 (7/9)

Recruiting Participants

Recruiting techniques for the NSF S-STEM program at Lipscomb University included distributing marketing posters (to all Tennessee CC STEM deans), monthly engineering newsletters (to more than 20 Middle Tennessee CC STEM instructors), and directly on Lipscomb University's engineering website. Materials were made available to more than eight classes during visits by Lipscomb engineering faculty and students, participants engaged in Transfer Admissions Day, and directly to academic counselors. Of the academically talented students with unmet financial need who were recruited into the program, almost 90% (20/22) were first generation degree seekers. Students were also recruited from rural backgrounds. In total, there were five female students (22%) and four (18%) students of color recruited into the program.

Barriers (Actual and Perceived)

- The students are transferring from CCs. Nationally, only 14 percent of entering CC students earn a bachelor's degree within six years. [3]
- Students majoring in engineering have a lower retention/graduation rate than most major fields of students.[4]
- Transfer students, as well as commuter students, are generally less engaged (less connected) in university activities outside the classroom. This has been shown to impact retention and graduation rates.[5]
- The students are commuter students in a mostly residential undergraduate program, they are transferring from a public to a private university, and their classmates have stronger high school grades and ACT scores. (Glynn, 2019).
- A larger percent of the current S-STEM scholars are married: 40% of the S-STEM scholars (4/10) enrolled in 2019-2020 were married and 75% had children. This is significantly higher than the percent of traditional undergraduate students married (less than 5%) at Lipscomb University majoring in engineering.
- The students are first generation students. (20 of the 22 students). First generation and low income students are more likely to begin at a CC (Giancola and Kahlenberg, 2016). Students enrolled at a CC are three times more likely to come from lower-income families than those at four-year institutions. (Randwin et., al., 2011). Students from lower income levels are five times less likely to obtain a baccalaureate degree by age 24 (12%) than those from a higher income level (58%). [6]
- Of the CC students recruited into the program, 100% had attended CC prior to attending Lipscomb University, and all students self-identified that, without the financial support from the NSF S-STEM program, they would not be able to complete an engineering degree.
- Most students in the Lipscomb NSF S-STEM program were seeking an engineering program within driving distance of their homes in the greater Nashville area. Three universities offer comprehensive engineering programs in Middle Tennessee: Lipscomb University, Vanderbilt University, and Tennessee State University. The next closest is a 3+ hour round trip commute, Tennessee Technology University in Cookeville, TN. More than 80% of the S-STEM scholars that participated in surveys and focus groups mentioned that they are: 1) first generation, 2) a commuter student, 3) have outside family responsibilities, and 4) have limited campus interactions outside of the engineering program.

Nine of the S-STEM students in two cohorts were surveyed to determine some of the perceived barriers in an effort to improve the overall program. A five-point Likert scale was used and students were encouraged to provide comments. The *Perceived Barriers Survey* contained questions to address both perceived academic barriers and perceived community barriers. Four questions focused on perceived community barriers, including the acceptance into the Lipscomb University community by faculty, staff, and the university's course requirements in the Bible. Five additional questions sought to clarify how the institution could establish courses and training to assist in academic preparation. The responses are summarized below in Table 5:

Table 5: Results from Perceived Community Barriers Survey

Barriers	Average Score
1. Feel accepted at Lipscomb	1.7
2. Feel comfortable seeking assistance from faculty	1.4
3. Lipscomb is compatible with my faith	2.0
4. Universities religious requirements are a hardship	2.8
5. Would benefit from an overview of MatLab	2.2
6. Would benefit from an overview of CAD	1.9
7. Would benefit from an overview of Canvas	3.2
8. Would benefit from a course on expectations	2.2
9. Prepared by CC to succeed in Engineering	2.7

The results indicated that the S-STEM students feel comfortable at Lipscomb University and the faculty provide a welcoming environment for seeking assistance. This supports the proposal hypothesis that providing an infrastructure and a program of support will improve the likelihood that pre-engineering students will transfer into Lipscomb from CCs and that students who receive support will be more likely than their peers to persist and graduate with an engineering degree. These survey responses also suggest that the students would benefit from an overview of CAD, MatLab, and expectations at Lipscomb. This could be achieved in a few sessions with students after acceptance into Lipscomb. Having current S-STEM students participate or mentor incoming students may also prove beneficial.

Program Evaluation

To create an effective pathway from CC to a baccalaureate degree in engineering, Lipscomb University's S-STEM award focused on addressing: 1) how well is the institution's NSF-funded

S-STEM project proceeding (identifying the current status of objectives and outcomes, assessments of what works, and feedback/recommendations on improving the program efficacy); and 2) project research questions.

The program evaluation focuses on two research questions:

1) *What are the effects of the program on student, faculty, and staff perceptions of known barriers to success for CC students and CC transfers interested in an engineering career?*
2) *What are the effects of the program on CC student interest, application, admission, enrollment, retention, and graduation from Lipscomb University's engineering program?*

Data collection included student enrollment and success data from the project PI, documentation of student applications and other records for the program, and surveys developed by the evaluation team to capture qualitative data on the perceptions of the student. The external evaluator obtained input from students in the NSF S-STEM project at Lipscomb University. This was done to determine the success of the program, to provide recommendations to the PI, and to address the research questions. The input was gathered through individual meetings and focus group meetings. Semi-structured interviews were used in both types of meetings and were based upon research focused on the success and barriers of CC students.[7]

Using the Grit Index in the NSF S-STEM program at Lipscomb University
The Grit Index was given to the current NSF S-STEM students in April 2020. The goal was to determine the level of Grit in these students and see if the Grit index could (1) be a factor in overcoming barriers to success, and (2) be used to identify other CC students that might succeed in Lipscomb University's engineering program.

Background on Grit Index: Angela Duckworth, along with her team at the University of Pennsylvania, developed a series of questions to help define a person's perseverance and passion for long-term goals.[8] This evaluation instrument is known as the Grit Index. It has been used by the U.S. Navy Seals and other highly competitive organizations.[9] Duckworth received the McArthur Foundation "Genius" Award in 2013 for *Transforming our understanding of the roles that **grit** and self-control play in educational achievement.* The Fisk-Vanderbilt Ph.D. Bridge program has shown the Grit index to be 90% accurate in determining which of their first-generation and minority students will successfully obtain a Ph.D. in the physical sciences.[10] One of the main conclusions in the study is that the right mix of persistence and support structures allow students from minority groups to thrive as they pursue their Ph.D.[11] Vanderbilt now leads the nation in the production of minority Ph.D. students in science and uses the Grit Index in its application process. This Fisk-Vanderbilt Ph.D. Bridge program is located five miles from the Lipscomb University's Engineering program.

Results of Grit Index Analysis

The Grit Index was given to the current NSF S-STEM students at Lipscomb University in April 2020. The goal was to measure the level of Grit in these students and determine if the Grit Index

could be used to identify other CC students that might succeed in Lipscomb University's engineering program.

The series of questions in the Grit Index was developed to help define a person's perseverance and passion for long-term goals.[12] The response to statements on persistence and interest items using a 5-point Likert-type scale ranging from 1 = not at all like me to 5 = very much like me. The results of the responses lead to a Grit score of between 1 and 5 with 5 being the most determined. More than 11,000 cadets matriculating to the United States Military Academy at West Point between 2004 and 2014 were given the Grit Index survey.[13] The results showed that the Grit Index score was a better predictor of graduation than GPA, SAT, and all other predictors used. The median grit score for these cadets was a 3.75 out of 5.0.

The Grit Index measures an extremely high level of persistence and determination in the NSF S-STEM students.

Four of the six Lipscomb University NSF S-STEM students had a persistence GRIT median score of 4.2. This persistence score is greater than the median value of 3.75 for the West Point cadets. The S-STEM students identified themselves as a hard worker in the Grit Index.

The results from the Grit Index suggest the NSF S-STEM students see themselves as hard working, valuing perseverance, and are overcoming barriers. The additional high marks and praise given by the students for the faculty and environment at Lipscomb University suggest that the institution has the infrastructure to support the success of the CC students and have selected students who perceive themselves as succeeding and working hard to accomplish the mutual goal.

Program recommendations mentioned in S-STEM student focus group

During the January 2020 focus group meeting, the current students in the NSF-funded S-STEM program were asked for their recommendations on ways the program could be improved. Below are their responses:

- Stronger connection between Lipscomb University's engineering program and key faculty members in pre-engineering programs at local CCs would be beneficial.
- Provide more information to students on engineering internships and engineering graduate schools.
    - Possibly a visit or field trip to a graduate engineering program at Vanderbilt University, Tennessee Technology University or University of Tennessee Space Institute.
        - Two alumni of the S-STEM program at Lipscomb are in graduate school at UT Space Institute in engineering.
- Identify faculty role models at Lipscomb University that are CC alumni or were married during their undergraduate engineering education.
- Possible connections or introductions to other Lipscomb engineering students who are commuters, married, S-STEM, and military veterans.
    - Introductions to other students in the S-STEM program, especially from different cohorts.

Lipscomb University's engineering program did not have a single CC student enrolled prior to the NSF S-STEM program. This program appears to be responsible for all 22 CC students that have enrolled in engineering at Lipscomb University. The current retention rate is 94% and the graduation rate is 83%.

It appears that this project will reach this overall goal of successfully graduating 20 S-STEM supported students in engineering within six years. This is a result of having a higher retention and graduation rates than the proposal levels. The current retention rate is 94% as opposed to the proposed 83%. Of the 18 students that have been enrolled for at least one year, 17 have been retained and have either graduated or remain enrolled in engineering. Additionally, this NSF program has increased

1. The connections to CC faculty
2. The awareness of Lipscomb University as an option
3. The development of an acceptance and nurturing educational environment for CC students
4. The success rate of retention and graduation of CC students.

Transforming the grant program into an institutional model

Since its inception in 2010, the Lipscomb University Engineering Program had no CC transfer students prior to receiving the NSF S-STEM award in 2016. As a result of the award, the total number of transfer students has increased from 0 to 35 students, with 17 CC transfer students being enrolled in the fall of 2020. The project has been transformational, personally and professionally, to S-STEM scholarship recipients, and has also grown to become an institutional model for the transition of CC transfer students. Lipscomb University now has an Engineering Program with high retention and graduation rates with a student population that, traditionally, had previously been identified as having a low rate of both persistence and graduation.

Table 6: Increase of CC Transfers into Lipscomb University's Engineering Program

	2010 - 2015	**2016 - 2020**
CC transfers into Lipscomb engineering	0	35

The Lipscomb University NSF S-STEM Program noted positive effects and increases on CC student interests, applications, admissions, enrollment, retention, and graduation from the engineering program. Increases have also been shown in the quality of CC students recruited into Lipscomb University's engineering program. This includes an increase in:

1) Enthusiasm and motivation of CC students (as documented through student surveys);
2) Engineering Program growth;
3) Expanded connections to CC faculty;
4) Increased awareness that Lipscomb University is an option for post-secondary engineering studies;
5) The success rate of retention and graduation of CC students;

6) The development of an acceptance and nurturing educational environment for CC students.

Lessons Learned and Program Improvement

To encourage growth, the institution could evaluate lessons learned and consider additional actions for program improvement:

1) **Dual-Enrollment:** Partnerships with CCs and HBCUs could be expanded at low cost to recruit transfer students from regional universities that lack an engineering degree. Furthermore, Lipscomb University could create a dual-enrollment engineering program partnership with these and other institutions. Several regional private universities (Belmont University, Fisk University [an HBCU], and Trevecca Nazarene University) have students capable of succeeding in engineering.
2) **Hosting events:** Lipscomb University could increase CC student exposure to (and participation in) its engineering events, including BEST Robotics competition. Students from at least one nearby CC have attended the institution's Engineering Career Fair in 2018; however, participation could be initially expanded to include more middle Tennessee CCs. Lipscomb University has a robust middle- and high-school robotics summer program and is the home to a regional BEST robotics competition. As such, the institution could host a CC robotic exhibit and directly involve CC pre-engineering students as volunteers at the competition to introduce high school students to the Lipscomb University campus, allow them to meet some S-STEM participants from their school, and generate interest in studies within the Engineering Program.
3) **Diversity:** Increase diversity in the Engineering Program by identifying partners who may contribute to increasing the number of females and students of color in engineering. These partners may include Fisk University, an area HBCU.
4) **Overly ambitious goals:** Lipscomb University's goals were overly ambitious as the institution did not obtain the desired number of students participating in the NSF S-STEM program as predicted based on the prescribed interventions. As of spring 2021, 22 CC pre-engineering students have been recruited into Lipscomb University's four-year engineering program through the S-STEM award; however, the goal was to recruit 30. Fortunately, the award was able to graduate 20 S-STEM supported students in engineering within six years, due to higher-than-expected retention and graduation rates.
5) **Strengthen community connections:** The Lipscomb S-STEM scholars are not as connected to the university and engineering program as traditional four-year students. They did not participate in campus orientation and welcoming events during their freshman year; furthermore, they lack the two years of familiarity and connections of their classmates. Additionally, 40% of the S-STEM scholars (4/9) enrolled in 2019-2020 were married and 3/4 had children. Have more senior S-STEM scholars and engineering student leaders describe their experience. Make the student development and SGA office aware of the S-STEM students. Provide a lunch or an online introduction to ensure S-STEM scholars are connected to student groups, student leaders, and transfer student orientation. Given the marital status that we discovered, additional programming can be considered which are more likely to cater to the needs of parent learners, including those presented at times when such programs minimize conflicts with family needs.

6) **Connections within the S-STEM program:** Identify S-STEM scholars as a community. The S-STEM students are not aware of other S-STEM scholars outside of their classes. Develop semester or annual online or in-person events with S-STEM scholars, their CC mentors, families, and guests. Additionally, we could host a feedback session over lunch or online.
7) **Connections to engineering careers:** S-STEM scholars have a limited network of connections to the engineering field. Lipscomb's engineering program is relatively new and does not have hundreds of alumni living in the area. This is being addressed with the addition of Megan Davis as an engineering career specialist helping to address both building the S-STEM community and assisting with engineering networking.
8) **Event for families:** The S-STEM students are isolated from on-campus activities and have busy support roles with families. Several are married. Find an opportunity(ies) to involve the family members in a campus activity.

Conclusion

This paper is a presentation Lipscomb Universities' S-STEM project which has enabled academically talented and financially needy community college students to pursue engineering degrees. The project now in its final year. Lipscomb University has recruiting 100% of the NSF S-STEM funded students from regional community colleges and created a pipeline of CC students which it hopes with university support. During the first five years of this NSF award, the total number of transfer students into engineering at Lipscomb University has increased from 0 to 35 students. This paper describes the lessons learning with the hopes that this project and Lipscomb University's Raymond B. Jones College of Engineering can be a resource to other universities looking to create a pipeline of CC into its engineering program.

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