Full Paper: Promoting First-Year Student Success through the Data-Driven Creation of a Preparatory Engineering Program and an Engineering Math Resource Center

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Katherine A. Grover has served as the USU College of Engineering Data Analytics Team Supervisor for over 5 years, providing the college with actionable student-related analytics. Additionally, she has worked with students as an Academic Advisor for the USU College of Engineering for ten years, serving as the Lead Academic Advisor for the last six. She serves on the Steering Committee for the National Academic Advising Association (NACADA) STEM Advising Community, staying connected to the challenges and trends occurring within STEM fields in higher education. She received her Master of Data Analytics and BS in Biology with a Cellular/Molecular Emphasis from Utah State University.

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Kristina T. Glaittli has spent the last 11 years serving as the College of Engineering retention specialist. In this role, she has developed multiple programs and initiatives to promote student retention and success. She has also served as an advisor to multiple student organizations for over 18 years, including the Society of Women Engineers, Engineers Without Borders, and the USU Engineering Council. Kristina has a BS and MS in civil engineering from Brigham Young University. She began her career as a structural engineer in the aerospace industry where she worked on the Space Shuttle booster rockets and other solid rocket motors. For 10 years she owned and operated an engineering consulting business. After transitioning to academia, she worked for the NSF-funded National Center for Engineering and Technology Education.

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Christian recently joined the Engineering Education Department at Utah State University (USU) as a Professor of Practice in Engineering Mathematics. He just graduated with his doctorate from Utah State in Mechanical Engineering where his research centered on supersonic civilian aircraft and bio-inspired flight. He has taught, or will teach courses, in Compressible Fluid Mechanics, Statics, and Dynamics, two of which are first-year engineering courses at Utah State. He is also the director of the Engineering Tutoring Center and Engineering Math Resource Center, which he founded in 2022 under the direction of the College of Engineering. He is passionate about teaching and mentoring students of all disciplines and walks of life and strives to create an atmosphere of respect and curiosity in his classrooms and in the resource centers of the Utah State College of Engineering.

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Introduction

The Utah State University (USU) College of Engineering has a long history of excellence, and attracts students from within the state, across the country, and around the world. As part of an R1 research institution with the second oldest undergraduate research program in the country, the College of Engineering has a reputation for graduating students who are well prepared for the workforce and graduate school. While the College of Engineering strives to maintain a high level of excellence, USU, as the land-grant institution for the state of Utah, is charged with the responsibility of making education accessible across the state, and therefore has fairly low admission standards, accepting up to 93 percent of those who apply.

To meet both the land-grant mission of the university and the needs of each program, colleges and departments at USU are allowed to set different admission requirements; however, colleges are encouraged to keep admission standards as accessible as possible. To maintain excellence, the College of Engineering chose to set higher admission standards than the university i.e., high school GPA, ACT/SAT composite score, and ACT/SAT math score. The College of Engineering, unlike many universities, chose to allow students to be admitted directly into the engineering program of their choice if they met these higher admission standards. This decision was made to meet the land-grant mission of accessible education. Students who did not meet the engineering admission standards or were undecided on which program to pursue were still admitted into the college under a general engineering designation. Even with these higher engineering admission standards, the rigor of engineering caused many ill-prepared first-time freshmen students to struggle and/or leave the college during their freshmen and sophomore years.

Prior to this study, the College of Engineering had no comprehensive data regarding student success, as defined by graduation, for first-time full-time freshmen students with declared engineering majors. The college thought, anecdotally, the success of declared engineering freshmen students was about 50 percent, which was similar to what was being reported by other engineering programs around the country. [1] Within the college, small and limited analyses had previously been performed to use in areas such as recruiting and grant proposals; however, an in-depth study had not been performed.

To address the lack of data, an Engineering Data Analytics team was formed to study the success of first-time, full-time engineering freshmen. The team consisted of the lead engineering academic advisor, the engineering retention specialist, and two students. The study assessed student graduation and how graduation was affected by high school performance and math readiness. Because of the scope of the study, meticulous care was taken to ensure the data was precise.

Freshmen Graduation Analysis

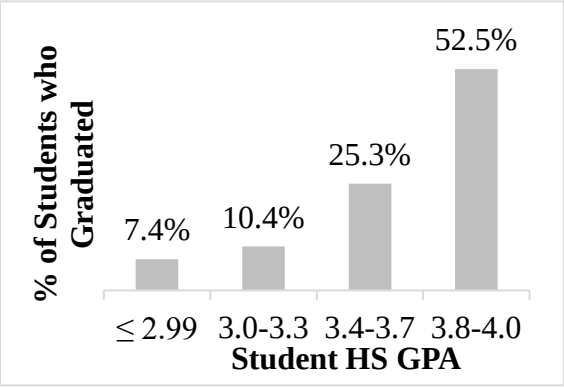
Working with a data analyst in the Registrar's Office, a unique report was created to gather the necessary data. This in-depth information included the incoming College of Engineering freshmen for each cohort year from 2006 to 2013. Institutional data goes back to 2006 when the university began to use the current database system. The dataset also included the student outcomes as of June 2018, including if they graduated, when, and in what degree.

Overall Graduation Results

Once the data was gathered, the Engineering Data Analytics team analyzed the freshmen cohorts and the student outcomes. Initially, the college wanted to know how many of the freshmen had graduated 10 years after starting their engineering degrees. Therefore, the 2006-2009 cohorts were used in this analysis. Of the 1193 incoming freshmen who started their college career with a degree declared in engineering (including general engineering), 34.1 percent (407) had graduated with a bachelor's degree in the College of Engineering after ten years. When three additional cohorts (2010-2012) were added in a follow-up study, the graduation remained around 34 percent. For those that qualified to be admitted directly to an engineering degree, 36.3 percent (377) graduated compared to only 19.6 percent (30) who were admitted to general engineering (either undecided or didn't qualify for admission). Although the female population was smaller than the male population (182 vs 1011), 34.1 percent of both genders graduated.

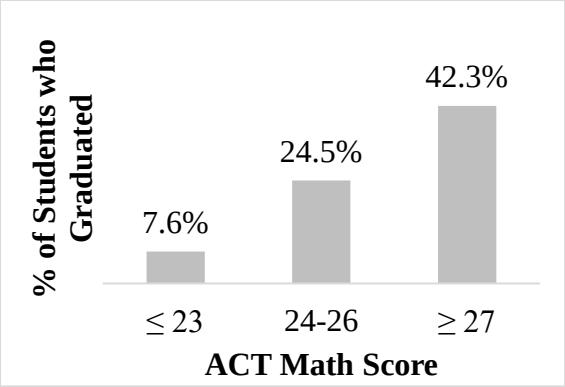
Graduation by High School Performance

Student success, as measured by graduation in the College of Engineering, was then investigated based on student high school performance, i.e., GPA, ACT/SAT math scores, and ACT/SAT composite scores. As most incoming freshmen at USU take the ACT versus the SAT, the SAT scores were converted to ACT equivalent scores for the purpose of this analysis. Additionally, as some students take the ACT and/or SAT multiple times, the highest score received by the student was used in this study. As was expected, the students with higher academic performance in high school were more likely to successfully complete an engineering degree.



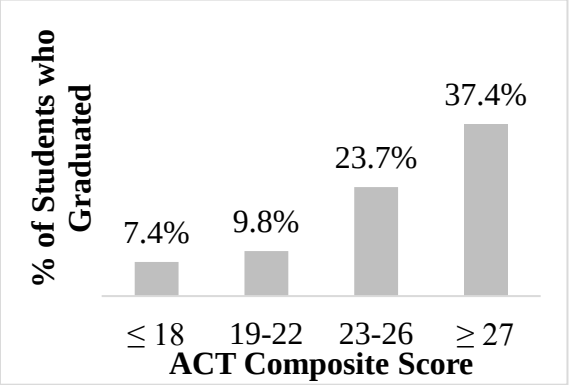
High school (HS) GPA was found to be a good predictor of student success as seen in Figure 1. This indicates students with lower HS GPAs are not as prepared for the rigor of the engineering curriculum. At the time of the analysis, most of the engineering programs at USU admitted students directly to the major with HS GPAs as low as 2.5.

Figure 1: Student Graduation by High School GPA: The percent of engineering freshmen that graduated with a BS in engineering based on their high school GPA.



The ACT math score was also a good predictor of success as shown in Figure 2. In general, the higher the ACT math score, the more likely the student was to graduate. While the overall trend holds true for the college, the impact of ACT math score at the program level varied. Prior to 2019, half the engineering programs required a 27 ACT math score while the other half had no requirement.

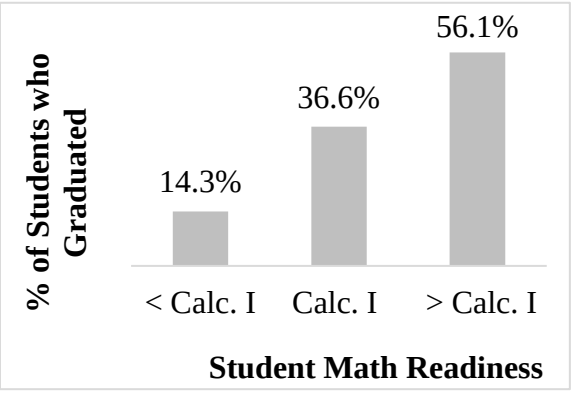
Figure 2: Student Graduation by ACT Math Score: The percent of engineering freshmen that graduated with a BS in engineering based on their ACT math score.



In comparison to HS GPA and the ACT math score, the ACT composite score was not as strong of a predictor of graduation as seen in Figure 3. At the time of the study, all but one of the engineering programs were admitting students directly to the engineering major with ACT composite scores as low as 17. The data from Figure 3 shows that admitting students with an ACT composite score below a 23 may be contributing to the low degree completion of first-time, full-time freshmen.

Figure 3: Student Graduation by ACT Composite Score: The percent of engineering freshmen that graduated with a BS in engineering based on their ACT composite score.

Graduation by Math Readiness



In addition to looking at high school performance, freshmen success was analyzed based on student math readiness. Math preparation was defined by the first math course the student registered for at the university. Of the different factors that affect graduation, math readiness was found to have the largest impact on student success. As seen in Figure 4, each increasing level in math readiness resulted in a 20 percent jump in graduation.

Figure 4: Student Graduation by Math Readiness: The percent of engineering freshmen that graduated with a BS in Engineering by their readiness for Calculus I.

When looking at both the high school preparation and the math readiness, the analysis revealed that the low admission requirements, although higher than the university, were contributing to

low student graduation. In effect, the college was admitting students who, historically, had a very small chance of success.

Outcome 1: Reevaluation of Admission Requirements and Creation of Preparatory Engineering

Reevaluation of Admission Requirements

The information gleaned from this analysis was then presented at both the college and department level. As a part of the conversation, the departments were encouraged to reevaluate their admission standards based on the analysis. After discussion, each of the programs chose to adjust the minimum admission requirements to better align with potential student success (see Table 1).

Table 1. USU College of Engineering Program Admission Requirements (both the old requirements and the new requirements adopted starting Fall 2020)

Program	High School GPA		ACT Math		ACT Composite	
	Old	New	Old	New	Old	New
Biological	2.5	3.0	NA	24	17	23
Civil	2.5	3.0	NA	24	17	23
Computer	2.5	2.7	27	27	17	19
Electrical	2.5	2.7	27	27	17	19
Environmental	2.5	3.0	NA	24	17	23
Mechanical	3.0	3.5	27	25	23	24

The biological, civil, and environmental engineering programs raised the HS GPA and the ACT composite score requirement. Additionally, they created an ACT math minimum requirement of 24 where none had existed previously. The mechanical engineering program, due to the large number of students seeking the degree, chose to raise the HS GPA to 3.5, the highest in the college. Additionally, mechanical engineering chose to lower the ACT math minimum requirement from 27 to 25 as the mechanical engineering specific data showed similar success for students with those scores. The electrical and computer engineering programs chose to raise their HS GPA and ACT composite only slightly to maintain student accessibility. They also chose to keep their ACT math minimum requirement at 27 which is now the highest in the college. These changes went into effect for the Fall 2020 cohort as the Fall 2019 cohort had already been admitted by the time these requirements were finalized.

Creation of Preparatory Engineering

As stated previously, students prior to this analysis were admitted to general engineering, housed at the college level, if they did not meet the selected program's admission requirements or if they were unsure which engineering program to pursue. Having these two different groups under the same designation caused issues for the college as these students had very different needs and were nearly impossible to differentiate. While some needed help selecting a program, others were underprepared for engineering. The term general engineering also caused confusion for the students. Some assumed general engineering was a degree from which they could graduate when

it was actually a temporary designation. Additionally, the term general engineering did not help the underprepared students understand their situation and the effort that would be needed to succeed.

To mitigate these difficulties, the College of Engineering ended general engineering and created a preparatory engineering designation. Students are now required to select a program when applying to USU. Those who do not qualify for their selected program are admitted to preparatory engineering. The term preparatory engineering (and the language/information given to the students in the program) was selected to help students understand they are underprepared and to give the correct perspective of the effort that will be required to move into the program of their choice. To create an alternate pathway to acceptance into the program for the preparatory students, each program selected a combination of courses from their first-year curriculum and set a performance standard i.e., course grade minimum, repeat limit, and engineering GPA. As the requirements are already a part of the first-year curriculum, being admitted to preparatory engineering does not add time to graduation other than what is already added for any remedial coursework needed i.e., remedial math courses.

The preparatory engineering program went into effect in Fall 2020, during the COVID-19 pandemic. Therefore, the creation of some new resources and initiatives aimed at helping these underprepared students was delayed. However, the college has created a new math resource for all engineering students and intends to create additional resources which may include an engineering preparation course, more targeted tutoring, and more directed communication.

Outcome 2: Engineering Math Resource Center Development

The analysis relating to math readiness highlighted a clear connection between student math preparation and graduation in the College of Engineering. These results were compiled and presented to the university president, who allocated funds to hire a new professor of practice position and create an engineering math resource center in the college. The individual hired for this position was to investigate and implement ways to support students in their undergraduate math coursework, help students connect mathematical concepts to the practice of engineering, and create and manage the Engineering Math Resource Center (EMRC).

A review of initiatives at other universities was conducted to evaluate the efforts these centers of higher education had made to specifically support engineering students in their math courses. A resource as specific as an engineering math resource center was not found in any other university, although other resources, including broad curriculum changes (such as those implemented at Wright State University [2]), university-wide math tutoring centers, and summer programs were explored. Therefore, rather than following a previously implemented model for a math resource center, the creation of the EMRC at USU focused on underlying conceptual learning principles. These principles included the importance of self-efficacy, storytelling as a method for student engagement, and presenting math principles in a suitable context.

Based on these principles, the purpose of the USU EMRC is to “help students become self-sufficient learners by building confidence in mathematical capability, presenting math in an engineering context, and connecting students through teaching opportunities”. The preliminary

results and student feedback for the first year of operation indicate that the EMRC is fulfilling its mission and purpose. In the first year of its operation, 255 one-on-one consultations were provided by student employees and the director of the EMRC. From post-survey results obtained after these 30-minute consultations, students reported feeling nearly twice as confident in the math topics covered in their consultation. In addition, 75 percent of the students who completed the survey reported they understood the engineering context of the concepts covered in their consultation.

Conclusion

The reporting of this study as it pertains to the USU College of Engineering is an example of how data-driven decisions can positively affect the success of engineering students. Prior to this analysis, the institution lacked historical data regarding freshman graduation. After collecting a robust data set, graduation was explored both overall and based on student high school performance and readiness for Calculus I. The analysis showed that low engineering admission requirements were leading to a lower-than-expected graduation. Additionally, the results showed that better math preparation resulted in higher graduation. Lastly, the analysis led to an understanding that colleges and universities have many different methods of defining who their students are, and that care must be taken when comparing USU's engineering student graduation with other universities.

The first outcome of this study was the reevaluation of program admission requirements to better align with potential student success. Most admission requirements were increased, including the addition of ACT math score requirements for programs that did not previously have a minimum. For those students that do not meet the engineering admission requirements, a preparatory engineering program was created. Then, an alternate pathway was created to allow preparatory engineering students admission to their engineering program of choice based on performance in predetermined math, science, and engineering courses.

The second outcome of the analysis was the creation of the Engineering Math Resource Center and the hiring of a professor of practice in engineering mathematics. A review of resources offered at other universities found that this approach to support student math learning is novel. Therefore, the center's approach was based on conceptual learning principles, rather than a previously implemented framework. The initial results for the first year of operation have been positive based on post-consultation, student survey feedback.

References

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[2] Klingbeil, N. and Bourne, T., 2012, "The Wright State Model for Engineering Mathematics Education: A Longitudinal Study of Program Impacts," Proceedings 4th First Year Engineering Experience (FYEE) Conference, Pittsburgh, PA, August 2012.