Analysis of Engineering Student Retention Based on Math Placement and Performance

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Colleges face a demographic downturn in the total number of students and incoming students, and within engineering programs, retention is particularly challenging due to the rigor of the curriculum. Mathematical proficiency has repeatedly been cited as a common indicator of engineering student success and retention within the major. This research aims to explore if math placement and performance in mathematics courses are significant predictor of their fall-to-fall retention at the University of Tennessee at Chattanooga. Using a logistic regression model and including math placement test scores, math course grades, and other independent variables associated with student retention, the results of this study showed that only in the first year of college attendance within an engineering program was math placement a significant predictor of engineering retention.
Keywords: retention, education, engineering, math placement, Tennessee

While workers in science, technology, engineering, or mathematics (STEM) disciplines comprise nearly a quarter of the national workforce, the percentage of workers with a bachelor's degree in a STEM field remains below 12% in the state of Tennessee (National Science Board, 2022). Within post-secondary education, STEM majors were previously identified as having challenges with student retention rates, further contributing to gaps between the demand for workers with STEM degrees and the supply (Carnevale et al., 2011; Sithole et al., 2017). Though a range of factors contribute to student retention rates, within engineering, specifically mathematical proficiency is consistently highlighted as a driver of student success within the major and what math course an engineering student is able to enroll in when they first enter their program (Belser et al., 2018; Raigoza, 2017).

Post-secondary educational institutions are consistently interested in methods to increase the term-to-term and overall retention rates of their students while also maintaining strong graduation rates (Letkiewicz et al., 2014; Taylor et al., 2016). While some drivers of success are universal to the student population, such as first-semester grade point average (GPA), engineering students present a different set of challenges focusing on student math and science proficiency and student understanding of, and self-confidence related to, their engineering program and its career prospects (Hall et al., 2015; Veenstra et al., 2008). The difficulty of an engineering program, combined with a looming demographic decline in incoming college students and the increased demand for STEM-educated students, places pressure on post-secondary institutions to first retain students and then support them to graduation (Doerschuk et al., 2016; Harvey, 2021). As the total number of students attending colleges and universities declines, institutions are faced with an increasingly competitive landscape where attracting students is only a part of the equation.

Another demographic consideration for the future of STEM majors is the generational cohort of students entering post-secondary education. The most recent college-age generation, colloquially referred to as Gen Z (Chicca & Shellenbarger, 2018), attending universities exhibit some similarities to their predecessors but have distinct differences from previous cohorts. While no group is characteristically fully representative, Gen Z students tend to have pragmatic and even skeptical mindsets, shorter attention spans, as well as a desire for greater reassurance and support (Chicca & Shellenbarger, 2018). These tendencies, combined with a desire for more interactive learning, convenience, and integration of technology into their education could lead to challenges when students encounter the structure of an engineering curriculum coupled with being slightly behind on their pre-requisite mathematics requirements (Chicca & Shellenbarger, 2018; Sithole et al., 2017; Van Dyken, 2016). These developing factors only underscore the importance of retaining as many incoming engineering students as possible.

At the University of Tennessee at Chattanooga (UTC), engineering students first fundamental math course is MATH 1950-Calculus with Analytic Geometry I, but not all students score high enough on either the ACT or SAT to be able to enroll in this course (Course Catalogs | University of Tennessee at Chattanooga, n.d.). Incoming freshmen and transfer students alike can begin an engineering major, but they may be unable to take engineering courses from a semester to over a year because of math requirements. This gap can be further exacerbated by their performance within the first year, with lower GPA performance amplifying a lack of confidence in their major selection (Hall et al., 2015). This paper builds off the prior work by Van Dyken (2016) and Raigoza (2017) to test what, if any, relationship exists between engineering students' math placement and subsequent math performance and their retention at UTC. Our approach uses a range of known predictors of student retention within STEM and incorporates them in three logistic regressions to analyze a specific subset of students during the first, second, and third years of enrollment. This research will first establish if variables from prior research are still valuable predictors of retention for UTC engineering students and, if so, form a conceptual bedrock for more advanced predictive modeling and risk analysis techniques in future research.

Background

Student retention in post-secondary engineering programs has been studied for several decades at community colleges and universities across the United States (Crisp et al., 2009; Daempfle, 2003; Doerschuk et al., 2016), and some research shows that approximately 40% of students starting an engineering program will change their major (Carnevale et al., 2011). Women and minority students, already underrepresented within many STEM programs, are at an even greater risk of dropping out of the major (Belser et al., 2018; Carnevale et al., 2011). Even prior to college, women and minority students face complex pressures to divert from STEM programs, and once in college, these groups are shockingly underrepresented (Carnevale et al., 2011). Some explanations for these gaps have been articulated, ranging from differences in students' perception of the STEM field to biases, but the reality remains that new students are often filtered out of STEM before they take their first course (Carnevale et al., 2011; Sithole et al., 2017). However, a consistent factor within the literature on engineering student retention is math placement scores and subsequent math underperformance (Sithole et al., 2017; Raigoza, 2017; Van Dyken, 2016).

The question of mathematics and how it connects to student success within engineering has been researched from a variety of angles. Researchers focused on the predictive potential of math placement for engineering students' retention and graduation rates, with research by Raigoza (2017) indicating that students with training in trigonometry and pre-calculus concepts follow a similar, though slightly slower, timeline to graduation as students starting in a calculus course. By contrast, a dissertation by Van Dyken (2016) indicated that engineering students starting with a precalculus course graduated at a rate of only 19.08% compared to students starting in a calculus course who graduated at a rate of 65.41%. Conversely, many students who have the mathematical skills to succeed in STEM choose other majors, indicating that both proficiency and interest are fundamental components in STEM student success (Carnevale et al., 2011; Sithole et al., 2017).

Incoming students of all types face challenges with mathematics as they enter STEM programs. The degree of preparation in mathematics differs from high school to high school, based, in part, on funding and location (Atuahene & Russell, 2016). These differences translate to misalignment between secondary and post-secondary math proficiency, with students passing high school math courses underprepared for college-level mathematics (Abraham et al., 2014; Melguizo & Ngo, 2020). Some challenges can be remediated with innovative teaching methods or targeted intervention, but intervention requires early identification, outreach, and support from a university (Doerschuk et al., 2016; Goodwin, 2017).

Along with math test scores, student GPA in the first semester can be a useful predictor of retention and graduation rates. Though GPA remains a consistently important factor to individual students throughout their time at an institution, GPA within the first semester is associated with departures or retention (Gershenfeld et al., 2015). This impact is magnified by cultural or social factors such as the perception that STEM subjects are "harder" than others or that they can make the same income in the long term from a non-STEM career that is easier and faster (Carnevale et al., 2011; Sithole et al., 2017).

Methodology

To analyze the potential relationship between student math placement, as measured by a student's highest standardized test math sub-scores from the ACT and SAT, and their one, two, and three-year retention rates, data was requested from UTC's Office of Planning, Evaluation, and Institutional Research (OPEIR). Other variables of interest include demographic information such as student GPA, which is truncated to two decimals at UTC (University of Tennessee at Chattanooga, 2022) for each year of interest, if financial aid was awarded to the student, age, gender identity, ethnicity, student admit type (transfer or freshman), and a distance group. Each variable was highlighted from prior research on student retention (Atuahane & Russel, 2016; Hall et al., 2015; Varol & Catma, 2021; Veenstra et al., 2008;). The focus of this research is to establish the probability of retention based on the variables listed in Table 1 to inform future research on interventions to improve student retention.

Table 1
Descriptive Statistics

Variable Name	Data Input	Description
Cohort Year	2015 to 2020	The year a student first attended UTC
Age Group	<19, 19-21, 22+	Grouping of the age of a student in the year they first attended UTC
Gender	Male or Female	Student gender
Student of Color	Y or N	If a student is a student of color (Black, Asian, or Latin/Hispanic) or not
High School GPA	Numerical digits ranging from 0 to 4.00	Final High School GPA
Highest Placement Score	Numerical digits from 0 to 36	ACT or SAT to ACT conversation for highest math sub-score on test
Distance Group	Local, Regional, Out of Region, Unknown	Location of student's permanent address.
Gifted Aid Year 1	Y or N	If the student received financial aid in Year 1
Gifted Aid Year 2	Y or N	If the student received financial aid in Year 2
Gifted Aid Year 3	Y or N	If the student received financial aid in Year 3
Cumulative GPA Year 1	Numerical digits ranging from 0 to 4.00	Cumulative GPA of student at the end of Year 1
Cumulative GPA Year 2	Numerical digits ranging from 0 to 4.00	Cumulative GPA of student at the end of Year 2
Cumulative GPA Year 3	Numerical digits ranging from 0 to 4.00	Cumulative GPA of student at the end of Year 3
Retained Year 1	Y, N, or G	If the student was retained or not in Year 1. G represents graduated
Retained Year 2	Y, N, or G	If the student was retained or not in Year 2. G represents graduated
Retained Year 3	Y, N, or G	If the student was retained or not in Year 3. G represents graduated
Calculus I	A, B, C, D, F, W, S, NC, I, W, o	Letter grade of student in course. A-F standard letter grade. S is satisfactory, NC is not completed. I is incomplete, W is withdrawn. o represents that this course was not taken

Table 1 continued		
Variable Name	**Data Input**	**Description**
Calculus II	A, B, C, D, F, W, S, NC, I, W, o	Letter grade of student in course. A-F standard letter grade. S is satisfactory, NC is not completed. I is incomplete, W is withdrawn. o represents that this course was not taken
Precalculus I	A, B, C, D, F, W, S, NC, I, W, o	Letter grade of student in course. A-F standard letter grade. S is satisfactory, NC is not completed. I is incomplete, W is withdrawn. o represents that this course was not taken
Precalculus II	A, B, C, D, F, W, S, NC, I, W, o	Letter grade of student in course. A-F standard letter grade. S is satisfactory, NC is not completed. I is incomplete, W is withdrawn. o represents that this course was not taken

The data itself comprises students from the 2015 cohort through the 2022 cohort and is specific only to engineering students within UTC's College of Engineering and Computer Science. In the original file, a total of 1844 rows and 33 columns were present. Additionally, math course grade data was obtained for all students in this sample, starting with Precalculus or College Algebra courses and proceeding to Calculus II courses. Four separate adjustments were made to the data: first, removal of all transfer students; second, removal of all students with a null value for retained in year one; third, removal of all students listed as having an unknown location; and finally, combining the grades for College Algebra and Precalculus I into a single column, and the same merging of grades was applied to combine Precalculus and Precalculus II grades.

The removal of transfer students was to focus solely on incoming freshmen students. Removal of the null values was part of the data cleansing process due to uncertainty as to what null values indicated. Students with an unknown location were removed based on UTC's OPEIR notes for this dataset. This set indicated the student either had no physical address or, more commonly, indicated an international student, and these students were removed from the data set even if they were also first-year students. The merging of grades was done due to an institutional change that took place at UTC. Students are not permitted to enroll in both College Algebra and Precalculus I concurrently, and for several years, two separate prerequisite tracks for students existed alongside each other, leading to calculus readiness (Course Catalogs | University of Tennessee at Chattanooga, n.d.).

STATISTICAL MODEL

Many types of statistical analysis are appropriate for this research, as this is intended merely to establish if any relationship exists between math placement and performance and retention. A logistic regression model was selected for this study. Logistic regressions are functions that estimate the probability of an event occurring (a dichotomous variable) based on one or more predictor variables (Field, 2018). In this study, the dependent variable of interest was binary: whether the students retained. Other predictive models, such as support vector machines or naïve Bayes (Huang & Fang, 2013), were considered as well but reserved for future research efforts.

Findings

In this study, a year-over-year retention analysis covering years one, two, and three was performed using logistic regression to mirror fall-to-fall retention. The results were compared to investigate if any predictors were significant in a single year or if any were significant in several years. In each iteration, the prior academic year's retention information was removed as if a student was not retained in year one, they would not appear in year two. The regression for year one was a strong model fit with a McFadden R-squared of 0.3232, but only two variables were both positively sloped, indicating that it increased their probability of being retained and was statistically significant (as shown in Table 2): Highest Placement Score (Pr(>|Z|=0.029) and Cumulative First Year GPA (Pr(>|Z|=0.001). A third variable, Precalculus I (C), indicating a course grade of C in Precalculus I, was significant at the 0.1 level (Pr(>|Z|=0.057) and was negatively slopped. Moving to the regression model for year two, the McFadden R-squared increased to 0.4179. As shown in Table 3, the Highest Placement Score was no longer significant, but the Cumulative GPA for year one remained significant (Pr(>|Z|=0.019), and the Cumulative GPA for year two was highly significant (Pr(>|Z|=3.49e-11). The Distance Group variable (regional) was also significant in this model at a significance level of 0.1 (Pr(>|Z|=0.058).

Table 2
Logistic Regression Year 1

Variable Name	Estimate	Std. Error	z value	Pr(>|z|)
Cohort Year	-0.009	1.28e-01	-7.75e-02	0.938
Age Group < 19	0.238	4.53e-01	5.26e-01	0.598
Gender (Male)	0.390	5.88e-01	6.62e-01	0.507
Student of Color (Y)	0.452	6.11e-01	7.40e-01	0.459
High School GPA	-0.229	8.98e-01	-2.55e-01	0.798
Highest Placement Score	0.055	2.53e-02	2.17e+00	0.029*
Distance Group (Regional)	0.172	5.26e-01	3.27e-01	0.743
Gifted Year 1	0.777	1.22e+00	6.35e-01	0.524
Cumulative GPA Year 1	1.574	4.42e-01	3.55e+00	0.001***
Calculus I (Grade of B)	0.220	6.09e-01	3.62e-01	0.716
Calculus II (Grade of B)	0.151	6.83e-01	2.21e-01	0.824
Precalculus I (Grade of C)	-2.318	1.22e+00	-1.89e+00	0.057
Precalculus II (Grade of B)	1.519	1.07e+00	1.41e+00	0.157

Several math grade variables, again shown in Table 3, became statistically significant at the 0.1 level as well. Calculus II (o), a variable indicating not having completed a Calculus II course, and Precalculus II (D), showing a student completed Precalculus II with a grade of D, were both negatively sloped, indicating that they decreased the odds of a student being retained. Interestingly, the variable Precalculus I (D), where a student completed Precalculus I with a grade of D, was both significant at the 0.1 level and positively sloped. In the final regression for year three, the McFadden R-squared remained strong at 0.433. The high school GPA variable was significant (Pr(>|Z|=0.046), and the cumulative GPA in year three (Pr(>|Z|=0.000).

Table 3
Logistic Regression Year 2

Variable Name	Estimate	Std. Error	z value	Pr(>|z|)
Cohort Year	-0.137	9.05e-02	-1.521	0.128
Age Group <19	0.292	3.02e-01	0.967	0.333
Gender (Male)	-0.078	4.37e-01	-0.179	0.857
Student of Color (Y)	-0.388	3.69e-01	-1.050	0.293
High School GPA	-0.695	5.31e-01	-1.309	0.190
Highest Placement Score	-0.014	4.78e-02	-0.309	0.757
Distance Group (Regional)	-0.642	3.39e-01	-1.894	0.058
Gifted Aid Year 2	0.017	6.61e-01	0.0267	0.978
Cumulative GPA Year 1	-0.951	4.08e-01	-2.330	0.019*
Cumulative GPA Year 2	3.188	4.81e-01	6.624	0.000***
Calculus I (Grade of B)	0.583	6.01e-01	0.969	0.332
Calculus II ("o", not taken)	-1.539	8.44e-01	-1.823	0.068
Precalculus I (Grade of D)	1.580	9.47e-01	1.668	0.095
Precalculus II (Grade of D)	-1.380	7.19e-01	-1.918	0.055

As outlined in Table 4, several math grades were statistically significant as well. Calculus II with a grade of B (Pr(>|Z|=0.021) or a grade of F (Pr(>|Z|=0.018), and Precalculus II with a grade of C was significant at an alpha of 0.1 (Pr(>|Z|=0.062).

Table 4
Logistic Regression Year 3

Variable Name	Estimate	Std. Error	z value	Pr(>|z|)
Cohort Year	0.047	1.80e-01	0.264	0.791
Age Group < 19	0.022	4.72e-01	0.046	0.962
Gender (Male)	-0.492	6.64e-01	-0.740	0.459
Student of Color (Y)	-0.504	5.37e-01	-0.938	0.347
High School GPA	-1.880	9.44e-01	-1.990	0.046*
Highest Placement Score	-0.104	8.14e-02	-1.284	0.199
Distance Group (Regional)	0.223	5.40e-01	0.412	0.679
Gifted Aid Year 3	-1.056	7.01e-01	-1.505	0.132
Cumulative GPA Year 3	3.499	9.10e-01	3.845	0.001***
Calculus I (Grade of B)	18.735	3.04e+03	0.006	0.995
Calculus II (Grade of B)	2.270	9.87e-01	2.298	0.021*
Calculus II (Grade of F)	2.489	1.05e+00	2.358	0.018*
Precalculus I (Grade of B)	0.598	9.95e-01	0.601	0.547
Precalculus II (Grade of C)	1.697	9.10e-01	1.863	0.062

In reporting the findings for the grades in math courses, the Calculus I, Calculus II, Precalculus I, and Precalculus II variables, all possible grade variables, A through F, were not reported due to length. and only statistically significant grade variables were included in Table 3 and Table. 4Additionally, grades of B for each math course were included in Table 3 and Table 4 whether they were statistically significant or not as the reference point for the logistic regression was grades of "A".

Discussion and Conclusion

The results of this research confirm the hypothesis that math test scores are a significant predictor of fall-to-fall retention, but only during the first year of attendance at UTC within an engineering program. After this point, other variables, specifically cumulative GPA, are more significant indicators of student retention. Student grades in mathematics courses were not significant except for occasionally at a significance level of 0.1, and even in these cases, the results conflicted. In the second-year retention model, students with a D for Precalculus II (combined variable) had lower odds of retaining, but students with a D for Precalculus I (combined variable) were more likely to retain. Several explanations are possible for this disconnect. The first is that due to data limitations, the math course grades were not associated with specific dates of completion. When moving from first to second year, the students who were not retained were filtered out of the second-year retention model. Those students who remained might have taken the Precalculus II (combined variable) courses in the second year, or in the first, or at an even later point. This connection is tenuous without further investigation of the semester when each course was taken.

In considering the first-year retention model, cumulative GPA was, as the literature suggested, highly significant in predicting student success (Varol & Catma, 2021). This continued into the second year; however, by the third year, the first semester GPA was no longer significant, though the previous year's GPA was. This is both expected and an area for future research. Because of retention policies at UTC, students with below a 2.0 cumulative GPA for two consecutive semesters are suspended (Course Catalogs | University of Tennessee at Chattanooga, n.d.). As a student is retained and progresses, it stands to reason that they must maintain a GPA sufficient to prevent suspension or dismissal, and as success builds upon success, the cumulative GPA variables would likely naturally remain closely correlated to retention, especially with sequential years. A measure of major GPA, specifically mathematics and engineering fundamentals coursework, could be a means to improve this model (Raigoza, 2017).

Other variables that did not rise to the level of statistical significance, such as distance to the college or ethnicity, are fertile ground for more detailed study. Considering ethnicity, while not significant in any of the models in this study, various other studies actually suggest students of color face a range of challenges within engineering

(Frierson & Tate, 2011; Myers & Pavel, 2011) that contribute to relatively low representation in STEM majors along with challenges retaining students of color (Atuahene & Russel, 2016; Fletcher et al., 2021). While the distance group was significant in the second-year findings, it was not for either the first or third year, which is inconsistent with prior research on the subject, showing that distance was a useful predictor variable in analyzing student retention (Varol & Catma, 2021). Grade information was not connected to a specific term, so it was assumed that students were taking all math courses as early as possible based on the requirements of the engineering program and its prerequisite and corequisite course structure.

Math placement data, while only significant in the first-year model, was determined to be a useful predictor of student retention, but after the first year, its impact swiftly diminished. There is logical consistency to this: a student with a low score will either remediate the issue and progress or move on to a different major or university. Students with higher math placement scores would be at the core of their engineering curriculum by the second year, and their performance in coursework could be more suggestive of success. An option for future research would be to focus examinations on the first year, in particular the students with lower test scores, to determine what separates students who persist and those who do not.

For other engineering programs outside of UTC, this research further underscores the importance of incoming students' mathematical proficiency to their long term success. The relationship between math placement and long-term retention at UTC suggests that different strategies are needed for students who are not math-ready versus those who are not. While this study focused solely on institutional retention, retention within the major is also an area for further research as students with low math placement in their first term might transition out of an engineering program and into a less quantitatively demanding program. Such student major changes might make the significance of math placement and performance even more important to an engineering program to address with targeted intervention strategies before a student switches programs. An additional area of study for other engineering programs to consider is the use of math placement testing in risk analysis modeling for incoming students, potentially allowing a college to identify and contact newly admitted engineering students and provide resources and support to assist in improving their math skills, and thus increase the probability of their retention before they start their first semester.

References

Abraham, R.A., Slate, J. R., Saxon, D.P., Barnes, W. (2014). College-Readiness in Math: A Conceptual Analysis of the Literature. *Research & Teaching in Developmental Education, 30*(2), 4-34.

Atuahene, F., & Russell, T.A. (2016). Mathematics Readiness of First-Year University Students. *Journal of Developmental Education, 39*(3), 12–32.

Belser, C. T., Shillingford, M. A., Daire, A. P., Prescod, D. J., & Dagley, M. A. (2018, September). Factors Influencing Undergraduate Student Retention in STEM Majors: Career Development, Math Ability, and Demographics. *The Professional Counselor*, *8*(3), 262–276. https://doi.org/10.15241/ctb.8.3.262

Carnevale, P., Smith, & Melton. (2011). *STEM: Science Technology Engineering Mathematics*. Georgetown University Center on Education and the Workforce.

Chen, X, Soldner, M 2013, *STEM attrition: college students' paths into and out of STEM fields: statistical analysis report*, National Center for Education Statistics, Washington, viewed 03 Sep 2024, <http://nces.ed.gov/pubs2014/2014001rev.pdf>.

Chicca, J., & Shellenbarger, T. (2018, July). Connecting with Generation Z: Approaches in Nursing Education. *Teaching and Learning in Nursing*, *13*(3), 180–184. https://doi.org/10.1016/j.teln.2018.03.008

Course Catalogs | University of Tennessee at Chattanooga. (n.d.). https://www.utc.edu/academic-affairs/registrar/course-catalogs

Crisp, G., Nora, A., & Taggart, A. (2009). Student Characteristics, Pre-College, College, and Environmental Factors as Predictors of Majoring in and Earning a STEM Degree: An Analysis of Students Attending a Hispanic Serving Institution. *American educational research journal, 46*(4), 924–942. doi:10.3102/0002831209349460

Daempfle, P. A. (2003). An Analysis of the High Attrition Rates among First Year College Science, Math, and Engineering Majors. J*ournal of college student retention : Research, theory & practice, 5*(1), 37–52. doi:10.2190/DWQT-TYA4-T20W-RCWH

Doerschuk, P., Bahrim, C., Daniel, J., Kruger, J., Mann, J., & Martin, C. (2016, April 28). Closing the Gaps and Filling the STEM Pipeline: A Multidisciplinary Approach. *Journal of Science Education and Technology*, *25*(4), 682–695. https://doi.org/10.1007/s10956-016-9622-8

Field, A. P. (2018). *Discovering statistics using IBM SPSS statistics*. SAGE Publications.

Fletcher, T. L., Jefferson, J. P., Boyd, B. N., & Cross, K. J. (2021, January 10). Missed Opportunity for Diversity in Engineering: Black Women and Undergraduate Engineering Degree Attainment. *Journal of College Student Retention: Research, Theory & Practice*, *25*(2), 350–377. https://doi.org/10.1177/1521025120986918

Gershenfeld, S., Ward Hood, D., & Zhan, M. (2015, April 2). The Role of First-Semester GPA in Predicting Graduation Rates of Underrepresented Students. *Journal of College Student Retention: Research, Theory & Practice*, *17*(4), 469–488. https://doi.org/10.1177/1521025115579251

Goodwin, E. (2017). *Using a Math Tutorial Program to Decrease the Number of Failed Grades the First Semester helping the College achieve a 91% First Year Retention Rate*. Atlanta: American Society for Engineering Education-ASEE

Hall, C. W., Kauffmann, P. J., Wuensch, K. L., Swart, W. E., DeUrquidi, K. A., Griffin, O. H., & Duncan, C. S. (2015, April). Aptitude and Personality Traits in Retention of Engineering Students. *Journal of Engineering Education*, *104*(2), 167–188. https://doi.org/10.1002/jee.20072

Harvey, C. (2021). *Teetering on the Demographic Cliff, Part 1: Prepare Now for the Challenging Times Ahead*. Planning for higher education, 2021

Huang, S., & Fang, N. (2013). Predicting student academic performance in an engineering dynamics course: A comparison of four types of predictive mathematical models. *Computers & Education, 61*, 133–145. https://doi.org/10.1016/j.compedu.2012.08.015

Letkiewicz, J., Lim, H., Heckman, S., Bartholomae, S., Fox, J. J., & Montalto, C. P. (2014, November). The Path to Graduation: Factors Predicting On-Time Graduation Rates. *Journal of College Student Retention: Research, Theory & Practice*, *16*(3), 351–371. https://doi.org/10.2190/cs.16.3.c

Melguizo, T., & Ngo, F. (2020, January 7). Mis/Alignment Between High School and Community College Standards. *Educational Researcher*, *49*(2), 130–133. https://doi.org/10.3102/0013189x19898697

Myers, C. B., & Pavel, D. M. (2011). Underrepresented students in STEM: The transition from undergraduate to graduate programs. *Journal of Diversity in Higher Education, 4*(2), 90–105

National Science Board. (2022). The State of U.S. Science & Engineering 2022 (NSB-2022-1). National Science Foundation.

Raigoza, J. (2017). An Analysis of Student Success in Math, Physics, and Introductory Civil Engineering Courses. In The Steering Committee of The World Congress in Computer Science, Computer Engineering and Applied Computing (Ed.), WorldComp 2017: Proceedings of the World Congress in Computer Science, Computer Engineering and Applied Computing (pp. 8-14). Athens.

Sithole, A., Chiyaka, E. T., McCarthy, P., Mupinga, D. M., Bucklein, B. K., & Kibirige, J. (2017, January 16). Student Attraction, Persistence and Retention in STEM Programs: Successes and Continuing Challenges. *Higher Education Studies*, *7*(1), 46. https://doi.org/10.5539/hes.v7n1p46

Taylor, A. T., Olofson, E. L., & Novak, W. R. (2016, August 18). Enhancing student retention of prerequisite knowledge through pre-class activities and in-class reinforcement. *Biochemistry and Molecular Biology Education*, *45*(2), 97–104. https://doi.org/10.1002/bmb.20992

University of Tennessee at Chattanooga. (2022). 2022-2023 Undergraduate Catalog. Retrieved from https://catalog.utc.edu/index.php

Van Dyken, E. (2016, August). *The Effects of Mathematics Placement on Successful Completion of an Engineering Degree and How One Student Beat the Odds*. All Dissertations

Varol, S., & Catma, S. (2021, September 6). Assessing the Impact of a Distance-Based Spatial Factor on Retention in the U.S. Colleges. *Education Sciences*, *11*(9), 508. https://doi.org/10.3390/educsci11090508

Veenstra, C. P., Dey, E. L., & Herrin, G. D. (2008, October). Is Modeling of Freshman Engineering Success Different from Modeling of Non-Engineering Success? *Journal of Engineering Education*, *97*(4), 467–479. https://doi.org/10.1002/j.2168-9830.2008.tb00993.x