Introduction To Engineering Analysis: A Course And Methodology Developed As A Gateway To Engineering And Engineering Technology Degrees

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Abstract
Savannah State University offers 5 Engineering Technology undergraduate and 4 undergraduate engineering degrees. The engineering degree program is through a collaborative effort with the Georgia Institute of Technology. Georgia Tech – Savannah allows a student to obtain a bachelor of science in engineering degree without leaving the city of Savannah and without having to matriculate to the Georgia Tech – Atlanta campus. As a result of partnering with Georgia Tech for engineering programs, Savannah State has had to undergo an extensive curriculum review and modification to develop new courses and revamp existing courses that reflect the same content and rigor as those that are offered on the Georgia – Tech Atlanta campus. One of the courses developed and taught at the Savannah State campus is Introduction To Engineering Analysis (ENGR 1113). ENGR1113 is pre-calculus with an emphasis on an engineering problems oriented approach. At SSU we use this course as the gateway into the engineering and engineering technology majors. Along with other indicators, this course is an excellent measure of whether a student is prepared for engineering or is more geared towards the engineering technology major.

Other measures of academic success were developed and used in conjunction with ENGR1113. Each incoming freshman or transfer student who proposes to major in engineering must at the beginning of the semester take a Science, Technology, Engineering, and Mathematics (STEM) mathematics based exam. This exam is timed, computer based and has two components; college algebra and trigonometry. Within this paper the authors discuss a methodology that was developed to assist in the advisement of students to an engineering technology or engineering major. The method uses the SMET placement exam results, the students math SAT score, the first two exam results of ENGR1113 in the development of a freshman index for engineering and engineering technology students. The paper discusses results of the new course and application of the new methodology used to assist in advising students to an appropriate engineering major. In addition, the paper discusses the lessons the authors have learned thus far from by using the course as a gateway into engineering and engineering technology majors.

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1 Introduction

At Savannah State University (SSU) the engineering programs consist of Engineering Technology and Engineering. The accredited Engineering Technology programs have been in existence at SSU for many years while the engineering program [1] is a collaboration with the Georgia Institute of Technology. Within the engineering programs there are three methods for obtaining an engineering degree; The Regents Engineering Transfer Program (RETP), The Dual Degree Program, and the most recently developed program is the Georgia Tech Regional Engineering Program (GTREP)[2]. The GTREP program allows a student to take freshman and sophomore level courses at SSU while the junior and senior level courses are taught be Georgia Tech Savannah professors either at the GT Savannah campus, or via Distance Learning methods.

It is in response to participation in the GTREP program that SSU had to review and revise the undergraduate curriculum for engineering and engineering technology. During this curriculum revision, in order to offer the same level of instruction as that on the GT Atlanta campus, we revised some courses, deleted others, and created new courses. One area that underwent extensive renovation was that of mathematics. One of the newly developed math courses is titled "Introduction to Engineering Analysis". The course content is pre-calculus with as much an emphasis on engineering application as possible. It is this course that has been developed as a main component of the gateway into the engineering technology and engineering degree programs.

2 Introduction To Engineering Analysis: Pre-Calculus

A student looking to pursue a degree in engineering technology or engineering must be able to prove understanding of a fair degree of mathematics. Many of the courses in the pure engineering discipline have their roots in the mathematics. In the engineering technology program, students have to take a minimum of two mathematics courses; Calculus I and Calculus II. In the engineering program, students have to take a minimum of Calculus I, Calculus II, Calculus III with Linear Algebra, and Differential Equations. It has been noticed within the SSU engineering and engineering technology programs that incoming students can be placed into three different categories. The first category is that of students that have prepared for college by taking AP Calculus and equivalent courses in high school and are ready for college level Calculus I. The second category is that of students that have taken up to Pre-Calculus in high schools. The third category is that of students that have taken algebra and trigonometry in high school yet they show strong academic aptitude and a willingness to apply themselves to their programs of study. Most of the incoming students in the engineering technology and engineering programs fall into categories two and three. Therefore, Pre-Calculus became a natural fit as the first half of two gateway courses into the engineering and engineering technology programs. Most students benefit from taking the pre-Calculus course instead of jumping head first into the Calculus I course. Even if the material is a repeat of what students may have learned in high school or another institution of higher learning, they have the opportunity to become very solid in the fundamentals and to earn a high grade in the course and therefore assist in getting their academic careers off to a good start. The Pre-Calculus course was taught and evaluated in mostly a traditional manner. Goulet[3] shows significant success in developing and teaching a freshman calculus sequence in an outcomes based manner. Future experiments may show benefits of combining outcomes based teaching approaches with the success predictor analysis detailed in this paper.

The content of the Introduction To Engineering Analysis gateway course includes college algebra, graphs, inequalities, functions, exponential and logarithmic functions, trigonometric functions, analytical trigonometry, polynomial equations and complex numbers. This gateway course has proved an excellent indicator of whether a student is capable of handling the rigors of the GT engineering mathematics, whether they are more suited towards the mathematics of the engineering technology program or whether they need to rethink their pursuits of an engineering degree.

3 Analysis

The "Introduction To Engineering Analysis" (Pre-Calculus) course was first taught during the fall semester of the 2002-2003 academic year. The next implementation of the course was the fall semester of the 2003 – 2004 academic year. Calculus I is taught the semester following that of when Pre-Calculus was taught. During the fall semester of 2002 – 2003 there were 11 registered students in the class. In the fall semester of the 2003 – 2004 academic year there were two sections of the Introduction To Engineering Analysis course with 27 students in one section and 29 students in the other. Most of the students in the class were freshmen. Since all engineering and engineering technology students have to take at least up to Calculus II, a decision was made to put both engineering and engineering technology students in the same pre-calculus class. However, there currently exists two separate calculus I and calculus II courses; one set for the engineering technology program and one set for the engineering program.

3.1 A Correlation of Student SAT Math Scores and Classroom Exam Performance

The authors wanted to determine if there was correlation between the students SAT math scores and their performance in the class as well as their performance on the COMPASS exam. Within the analysis of this data the authors made two adjustments to the data set. The first adjustment was to eliminate any students from the data set that took the ACT standardized exam instead of the SAT standardized exam. The second adjustment to the data was to eliminate any student from the data set that did not take all five exams in the ENGR 1113K course during the fall semester. That left the student data set at 29 students.

Table 1: Students Exam Average and SAT Math Scores

	Class Exam Avg	SAT Math		Class Exam Avg	SAT Math		Class Exam Avg	SAT Math
Student1	31.50		Student11	89.80	510	Student21	64.40	410
Student2	94.30		Student12	54.90	510	Student22	70.30	550
Student3	48.30	490	Student13	62.20	520	Student23	76.90	
Student4	84.00	540	Student14	71.70	550	Student24	44.00	410
Student5	60.70	510	Student15	74.80		Student25	94.10	710
Student6	80.20		Student16	67.10	450	Student26	87.90	490
Student7	60.10	450	Student17	69.30		Student27	88.60	470
Student8	70.90	400	Student18	38.80	520	Student28	51.70	570
Student9	85.40	470	Student19	49.30	570	Student29	65.30	500
Student10	51.9	520	Student20	56.5	470			

Looking at the data in Table 1 indicates that there is no significant correlation between the students SAT math scores and their performance in the class as it relates to the in-class exams.

As an example, there were several students with SAT math scores above 500 however, their performance in the class was mediocre to poor. On the other hand there are several students in the class that had SAT scores in the 400 range and they did fair to very well. The authors believe that this indicates that while a students SAT math score may be a good indicator of a students academic aptitude and potential, it is not an exclusive indicator of their ability to perform well in the math classroom. Lam et al[7] investigated whether the students high school GPA and ACT test score would be valid predictors of success in their minority engineering program at the University of Akron. In their study they found that the students high school GPA was a significant predictor in the success criteria of graduation and undergraduate GPA.

3.2 A Correlation of COMPASS Exam Results and Classroom Exam Performance

At the beginning of the fall semester each student that is registered for Introduction To Engineering Analysis must take a COMPASS mathematics computer based examination. The exam covers both college algebra and trigonometry. In addition, each student must take the same COMPASS examination close to the end of the semester. There are two main reasons for students taking this examination twice within the same semester. The first reason is to measure the students mathematics skills prior to the start of the class. The second reason is to measure the effectiveness of the course instruction throughout the semester. In addition to the COMPASS mathematics examination, the authors use the students SAT Math scores and ENGR1113K class exams as an assessment of mathematical comprehension and experience.

The COMPASS mathematics examination results are reported as either one or two scores. If a student successfully completes a minimum percentage (51%) of the initial college algebra based questions on the examination then a single score is assigned. If the student does not successfully meet the minimum percentage of questions answered correctly on the college algebra portion of the examination then the student is automatically led through the second part of the examination, trigonometry. After which when the student has completed the examination two scores are reported; one for the college algebra section and one for the trigonometry section.

The authors wanted to determine if there was correlation between the students average classroom exam scores and their performance on the COMPASS exam. The data for this analysis is shown in Table 2. Again, within the analysis of this data the authors made the same two adjustments to the data set as referenced in the above section.

Table 2: Students Exam Average and COMPASS Exam Results

	Class Exam Avg	Compass Results		Class Exam Avg	Compass Results		Class Exam Avg	Compass Results
Student1	31.50		Student11	89.80	59	Student21	64.40	45/16
Student2	94.30	65	Student12	54.90	58	Student22	70.30	67.0
Student3	48.30		Student13	62.20	38/40	Student23	76.90	50/24
Student4	84.00	72	Student14	71.70	59	Student24	44.00	21/21
Student5	60.70	28/19	Student15	74.80	46/32	Student25	94.10	88.0
Student6	80.20	58	Student16	67.10	44/24	Student26	87.90	50/64
Student7	60.10	57	Student17	69.30	19/21	Student27	88.60	79.0
Student8	70.90	30/16	Student18	38.80	49/27	Student28	51.70	72.0
Student9	85.40	54	Student19	49.30	55	Student29	65.30	29/26
Student10	51.9	44/42	Student20	56.5	25/39			

Upon reviewing the data in Table 2, the authors determined that there was a correlation between the students results of the COMPASS exam taken in the beginning of the semester to their classroom exam average in Pre-Calculus. Within this data set, out of the 13 students that passed the College algebra portion of the COMPASS exam, 9 of them (70%) received an exam average of 70 or better. 7 of these 9 received an exam average of 80 or better.

3.3 Additional Analysis on COMPASS Exam

During the first sitting of the examination in the beginning of the semester, 50 students took the exam and 20 of them (40%) achieved the minimum COMPASS based passing rate of 51 percent. During the second sitting of the examination towards the end of the semester, 37 students took the exam and 18 of them (48.6%) achieved the minimum COMPASS based passing rate of 51 percent. Figure 1 graphically displays the passing rates data. In addition, of the 20 students that took the exam in the beginning of the semester and scored the minimum passing rate of 51%, 5 of them (25%) increased their overall score and the overall score for 9 of the 20 students decreased while 6 of these 9 students scores stayed above the minimum passing rate of 51%. 6 of the original 20 students did not sit for the second occurrence of the exam.

Of the students that did not meet the initial minimum passing rate of 51% on the College algebra placement, 20 of them retook the exam the second time and 18 (90) increased their score on the college algebra portion. 7 of these 18 were above or equal to the minimum passing rate of 51%. Therefore these 7 did not have to retake the trigonometry portion of the exam. Of the 13 students that did have to repeat the trigonometry portion of the exam, 11 (84.6%) increased their scores on the trigonometry portion of the exam.

4 Results

The above analysis revealed two facts. The first trend was that the standardized COMPASS College Algebra/Trigonometry examination was a pretty good indicator of the student's performance in the Introduction To Engineering Analysis course. Every student that passed the College algebra portion during the first occurrence of the exam did not perform well in the class, however a majority of the students (70%) that passed this portion of the exam did do well in the class.

The second fact was the overall improvement of the students as indicated by the COMPASS exam results. The results indicated that during the second sitting of the examination, 37 students took the exam and 18 of them (48.6%) achieved the minimum COMPASS based passing rate of 51 percent. This is higher than 50 students that took the exam during the beginning of the semester and only 40% of 50 students achieving the minimum COMPASS based passing rate of 51 percent. However, if we look at the data it shows that of the 50 students that took the exam in the beginning of the semester, 20 of them achieved a passing grade on the initial college algebra portion. Of these 20 only 14 sat for the second occurrence of the examination. Therefore, 20 of the 50 (40%) students in the first exam occurrence scored at least the minimum passing rate on the initial college algebra portion and 18 of the 37 (48.6%) students in the second exam occurrence scored at least the minimum passing rate on the initial college algebra portion. Of these 18 students, 11 (30%) scored at or above the 51% threshold on both exams. This data shows an almost 19 percentage point increase of obtaining the minimum 51% threshold on the

second exam by the students that did not obtain that threshold during the first exam. In addition, the results show that the data was not skewed during the second exam occurrence by a disproportionate number of those students that achieved 51% or above on the first exam occurrence (11 or 30%).

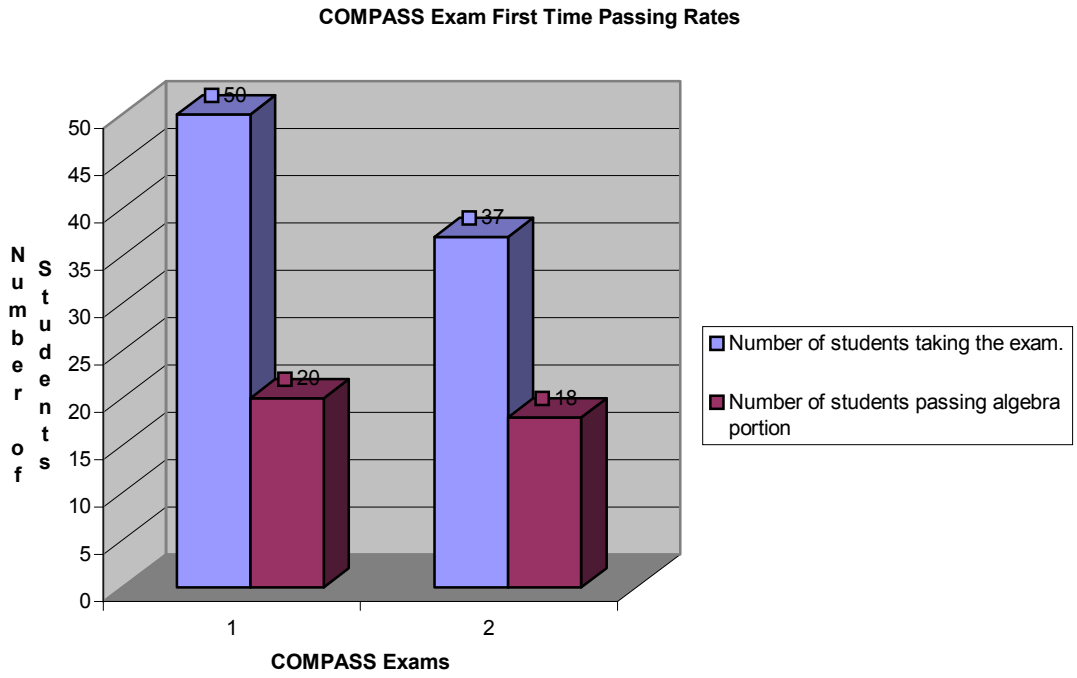

Figure 1: COMPASS Exam First Time Passing Rates

Table 2 shows that of the 55 students that comprised the 2 sections of Introduction To Engineering Analysis, 3 withdrew from the class, approximately 21 are expected to major in engineering, 2 have changed their major to a non engineering major and approximately 29 are expected to major in engineering technology.

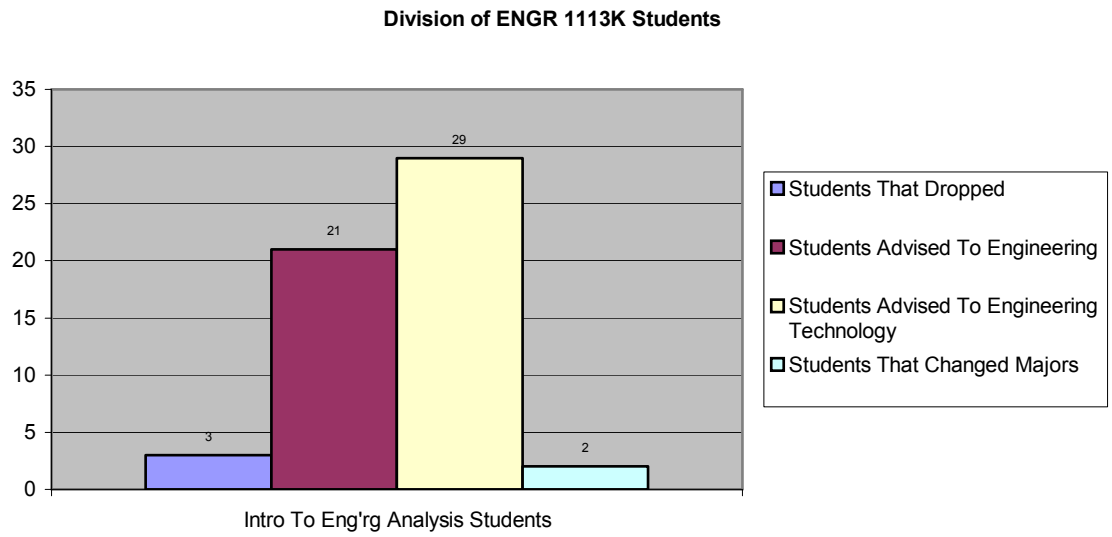

Figure 2: Division of ENGR 1113K Students

5 Lessons Learned

This approach to mentoring and advising students to engineering and engineering technology careers is an on-going process. Therefore, the lessons learned will continue and will be used to direct the development of future activities. One of the lessons learned thus far is that of the requirement of the COMPASS mathematics exam. Up to this point the students received no academic credit for taking the COMPASS exam. Therefore, the students took the exam based upon the request from the professor. In order to get full participation, the instructors may develop a method where the students receive some type of credit for taking the exam. This should assist in making the data more robust and consistent between sittings of the COMPASS exam. The next lesson learned was that the SAT math scores were not necessarily the best indicator of how well the student would perform in the class. It turns out that even though a student may not perform well on the SAT math exam or have a very high GPA, if they commit and apply themselves to their studies they stand a better than average chance of performing well in the classroom.

6 Summary

The engineering programs at Savannah State University consist of Engineering Technology and Engineering. The engineering program [1] is a collaboration with the Georgia Institute of Technology. The authors have presented a strategy for mentoring and advising undergraduate students to engineering and engineering technology majors using an engineering based mathematics gateway course as the key component of a student's mathematical ability. The math course, ENGR 1113K is titled "Introduction To Engineering Analysis" and is essentially Pre-Calculus. This manuscript has detailed 3 components of assessment of a students mathematical capability and therefore their propensity towards either an engineering or engineering technology degree track. These assessment components include the students SAT Math score, the students results on a standardized COMPASS math placement exam, and the results of the exams taken in the ENGR 1113K class. The results of this work have shown that using these three components a

methodology can be developed that is very beneficial towards advising students to appropriate engineering and engineering technology majors.

Bibliography

1.Baker, G.; "Pre-College Preparation of Minority Students for Careers in Engineering"; Transactions of the American Nuclear society; 1984; vol. 46; pp. 35 – 36.

2.Carr, R., Thomas D. H., Venkataraman, T.S., Smith, A.L., Gealt, M.A., Tanyel, M., and Quinn, R.; "Mathematical and Scientific Foundations for Integrative Engineering Curriculum"; Journal of Engineering Education; April 1995, pp. 137 – 150.

3.Goulet, J.; "An Outcomes Oriented Approach to Calculus Instruction"; Journal of Engineering Education; April 2001; pp. 203 – 206.

4.Hildreth, E.; "Advising and Counseling Minority Students in Engineering Technology"; Proceedings of ASEE Annual Conference; Atlanta, GA. 1985.

5.Hundhausen, J.R., and Yeatts, R.; " An Experiment in Integration: Calculus and Physics for Freshman"; Journal of Engineering Education; October 1995; pp. 369 – 374.

6.Hermond, D.; "Measuring The Retention Strategies of a Minority Engineering Program"; Journal of Engineering Education; v. 84; no. 4; 1995; pp. 395 – 400.

7.Lam, P.C., Doverspike, D., Mawasha, R.P.; "Predicting Success in a Minority Engineering Program"; Journal of Engineering Education; July 1999; pp 265 – 267.

8.Mahoney, J.R.(Ed.); "Improving Science, Mathematics, Engineering, and Technology Instruction "; American Association of Community Colleges, Community College Press, Washington, D.C.; 1996.

9.May, G.S., Chubin, D.E.; "A Retrospective on Undergraduate Engineering Success for Underrepresented Minority Students"; Journal of Engineering Education; January 2003; pp. 27 – 39.

10.Meier, R.L., Williams, M.R., and Humphreys, M.A.; "Refocusing Our Efforts: Assessing Non-Technical Competency Gaps"; Journal of Engineering Education, July 2000, pp. 377 – 385.

11.Moskal, B.M., "Validity, Reliability and the Assessment of Engineering Education"; Journal of Engineering Education; July 2002; pp. 351 – 354.

12.Pendergrass, N.A., Kowalczyk, R.E., Dowd, J.P., Laoulache, R.N., Nelles, W., Golen, J.A., and Fowler, E.; "Improving First-Year Engineering Education"; Journal of Engineering Education; January 2001; pp. 33 – 41.

Biography

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