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Creating a First Year Engineering Course Utilizing the SCALE-Up Method

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Earned a Bachelor of Science degree in Mechanical Engineering from Pensacola Christian College and a PhD in Mechanical Engineering from Clemson University. He spent several years teaching in a first year engineering program at Clemson University. He is now a senior lecturer at the University of Texas at Arlington, where he continues to teach first year engineering courses. Combined, he has been teaching first year engineering courses for over five years. His previous research involved thermal management systems for military vehicles.

Creating a First Year Engineering Course Utilizing the SCALE-Up Method

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Abstract - **To meet the growing demands for professional engineers, retaining increasing numbers of engineering students has become a primary focus at the University of Texas at Arlington (UTA). UTA conducted a study that found students were ill-equipped in the areas of problem solving, professional writing, and computer programming. Therefore, UTA has recently created a new first year engineering course focused on improving these specific skill areas using the Student-Centered Active Learning Environment with Upside-down Pedagogies (SCALE-Up) method. The strengths of this method are focused on creating a highly active and collaborative environment that fosters interaction not only among student groups but also among students and their instructors. To foster these interactions, UTA constructed a new classroom that emphasizes active learning and employs undergraduate students as in-class instructional assistants. This paper will explore student performance within the class by comparing many different student groupings, breaking down students by admission status, gender, underrepresented minorities, engineering departments, and concurrent math class. This paper will also present early surveys showing that student perception of this approach to teaching and learning have aided in their problem solving, critical thinking skills, and approach in other difficult STEM classes.**

Index Terms - Active Learning, First Year Engineering, Peer Instruction, SCALE-Up.

BACKGROUND

UTA completed its second academic year of delivering a new first year engineering course designed specifically to address student success and retention. This course, named ENGR 1300 – Engineering Problem Solving, was designed to ensure students have critical engineering problem solving and communication skills, provided they are enrolled in a math course at least at the Pre-Calculus level. In order to adapt to the wide dispersion of learning styles, socio-economic backgrounds, and prior knowledge among students at UTA, ENGR 1300 utilizes the Student-Centered Active Learning Environment with Upside-down Pedagogies (SCALE-UP) method. This method, developed at NC State University [1] and now utilized in many universities [2], focuses on creating a highly active and collaborative environment that fosters interaction among student groups and among students and their instructors.

METHODOLOGY

The complete discussion of the methodology may be found in this abstract [3]; however, for ease of discussion, a brief description is included here. To accommodate the SCALE-UP methodology and its requirements, first, a new classroom was constructed as shown in Figure 1**,** modeled after the one involved in a multi-institutional study [4]. Students are arranged around circular tables in teams of three, and marker boards are mounted around the room. This arrangement allows students to solve problems together, fostering peer instruction, which has been shown to be effective in increasing student success [4]. The arrangement also allows the professor and teaching assistants to easily move among the students as they work on solving problems.

The second key strategy was the hiring of upperclassmen to act as in-class teaching assistants. These assistants offer support during the class by essentially reducing the student-to-teacher ratio, again, providing more one-on-one instruction within the class. Also, in order to increase more one-on-one instruction and to relieve the increasing demand of office hours due to the number of students, the assistants conduct free tutoring sessions in the evenings where they help the students by guiding them through the problem-solving process. The in-class assistants are key contributors in fostering an environment where students are open to learning the material by asking questions of their peers.

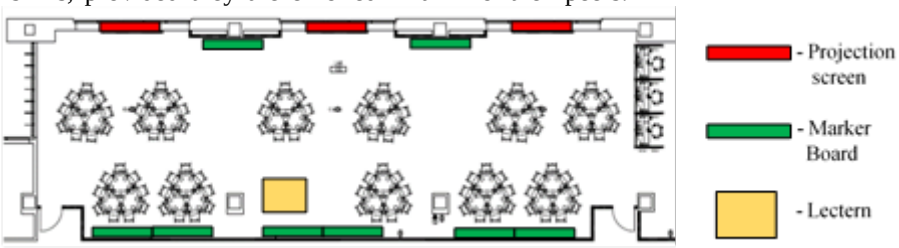

FIGURE 1
CLASSROOM LAYOUT

Finally, the in-class teaching methodology focuses on active learning rather than traditional lecture style learning. Traditional lectures and passive learning techniques have been shown less effective than the active learning strategies employed in the SCALE-UP method [4]. Therefore, this active, problem-based learning method was implemented in ENGR 1300. Mini-lectures are given and then students work in their teams around the marker boards solving real-world engineering, mathematical, and coding problems. This allows them to learn the principles of the class by solving problems, rather than simply relying on notes and examples from the professor. Also, the students have many tools to help them learn robust studying skills, such as a reading guide, interactive online tools, and additional challenging problems for further group study.

RESULTS AND DISCUSSION

To fully assess the effectiveness of this course, retention and graduation rates would have to be explored. However, since the class has been offered for only two academic years, those statistics are unavailable. Therefore, in the interest of this study, this paper will compare the success rates for several student groupings as well as student feedback about the course. In the context of this paper, success will be defined as those students earning a C or better in the course. Also, the results have been normalized according to student group presented. For example, in Figure 3, the graph presents approximately 68% of the total New Freshman in Fall 2015 were successful in the course.

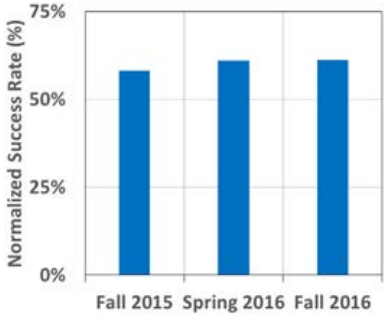

FIGURE 2
OVERALL NORMALIZED SUCCESS RATES

Figure 2 shows the overall normalized success rate for all students. We have seen an increase in these rates across all three semesters, especially considering that the class is designed to be taken within their first semester at UTA. Also, to prove the scalability of these methods, it should be noted that the course increased the size of each section by 27% in Fall 2016 without changing anything else within the classroom. In order to more fully understand the wide ranging applicability of these methods for all our student groups, we must explore the potential factors that may contribute to these success rates.

First, Figure 3 shows the success rates broken down by admission status of our students. For both fall semesters, freshman students enjoyed a slightly higher success rate than their new transfer student counterparts. However, in the spring, the new transfer students had a higher success rate. Deeper and more detailed studies need to be run to understand the background of these students and to help our transfer students.

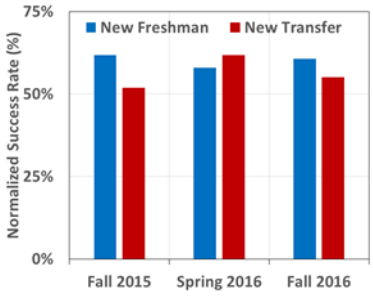

FIGURE 3
NORMALIZED SUCCESS RATES ACCORDING TO ADMISSION STATUS

Further, the Figure 4 shows the success rates broken down by gender. As can be seen, females outperformed their male counterparts across all three semesters, which was further proven by a t-test. This is an encouraging detail as UTA is endeavoring to encourage more women to choose engineering, and ENGR 1300 is able to help build confidence in our female population.

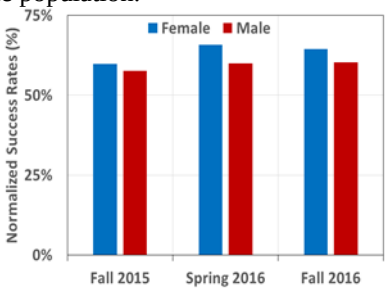

FIGURE 4
NORMALIZED SUCCESS RATES ACCORDING TO GENDER

In Figure 5, the success rates across declared engineering departments is shown. The individual department names have been simplified to aid discussion. It should be noted that Dept. D students have a statistically insignificant number of students. As can clearly be seen, non-engineering majors and the undeclared engineering majors are where a larger percentage of the non-successful students are. Undeclared engineering majors are of particular concern because these are the academically at risk and probationary students, whom we wish to assist in improving. Obviously, more background information is needed to identify key factors that would help these students.

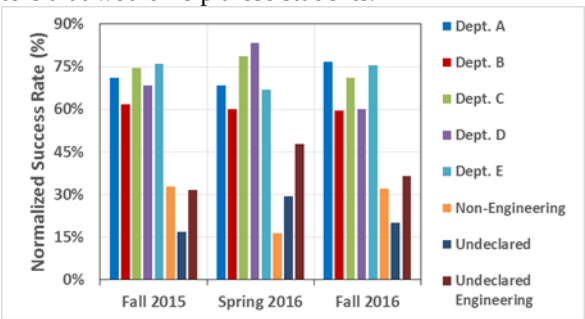

FIGURE 5
NORMALIZED SUCCESS RATES ACCORDING TO DECLARED MAJOR

In Figure 6, the different ethnic groups represented at UTA are explored. Again, it should be noted that the African American are a statistically insignificant group, so, no trend can be clearly identified. It should be noted that all ethnic groups have seen a slight increase across all three semesters. The other point of interest is that the success rates are starting to become more uniform. To continue this trend and achieve more uniformity, more information of some of our minority groups, including enrollment status and other outside factors, needs to be collected and analyzed.

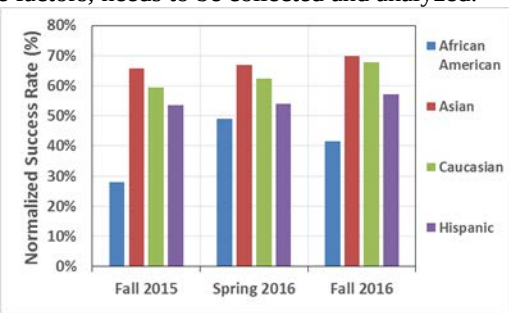

FIGURE 6
NORMALIZED SUCCESS RATES ACCORDING TO ETHNICITY

In Figure 7, the success rates are separated by what math course the students were concurrently taking. The first observation is that as the program has progressed, there is no difference in performance for those in Calculus I and Calculus II. However, the most important fact seen in this graph is the poor performance of our Pre-Calculus students in ENGR 1300. This class teaches no math level above College level Algebra. Therefore, pre-requisite knowledge is driving this issue. One of the reasons for this fact could be the inconsistency of algebra reinforcement in the curriculum. Therefore, strategies such as extra problem solving sessions in the class as well as partnering with the Math department on campus will be tested in order to see if this will aid our Pre-Calculus students and increase their overall success in engineering.

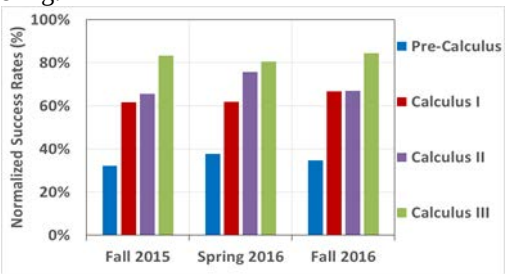

FIGURE 7
NORMALIZED SUCCESS RATES ACCORDING TO CONCURRENT MATH

Finally, student perception is explored. A survey was distributed to the students at the end of the semester to give them an opportunity to give feedback for continued course improvement. The question in Figure 8 was a multiple choice list while the question in Figure 9 was a free response. The main fact shown in these figures is that the students respond well to the methodologies used in the class as well as the tools that they learn, such as MatLab programming. From these results, it is clear that students find the methods and class valuable and interesting to their overall careers.

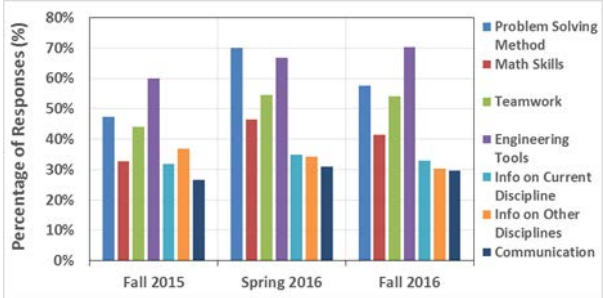

FIGURE 8
SURVEY RESULTS FOR WHAT THE STUDENTS REPORTED LEARNING

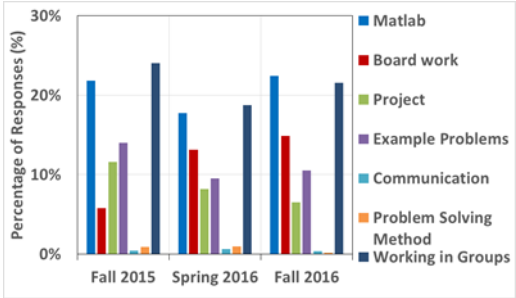

FIGURE 9
SURVEY RESULTS OF STUDENT'S FREE FORM REPORTING WHAT THEY FOUND HELPFUL

CONCLUSION AND FUTURE WORK

In conclusion, ENGR 1300 has shown to be an effective course for first year engineering students by using the SCALE-UP method to aid students in acquiring practical engineering skills. This fact can be seen not only in the increase of success rates but also the overwhelming positive responses of student perception. Further assessment work will be needed in order to understand the role of student enrollment background as well as math reinforcement to aid in enhancing the effectiveness of this course.

ACKNOWLEDGMENT

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