122nd ASEE Annual Conference & Exposition
June 14 - 17, 2015
Seattle, WA
Making Value for Society
Paper ID #11984

Teaching a College Wide Introductory Engineering Course within a Freshmen Year Experience

Dr. Rolfe Josef Sassenfeld, New Mexico State University

Dr. Rolfe Sassenfeld, son of German Rocket Scientist Dr. Helmut Sassenfeld, earned his Doctoral degree in Computer Engineering from the University of Texas, El Paso. He has worked in higher education for 25 years as a Director of Instructional Technology, Computer Science Faculty, and Research Assistant Professor. He is presently an Assistant Professor and Program Coordinator of the Electronics and Computer Engineering program in the Engineering Technology department of New Mexico State University. His research focus is developing and teaching Android App development to engineers and entrepreneurs with innovative tools that can be utilized by programming novices. He is also an instructor and course developer for his college's Freshmen Year Experience.

Prof. John Ross Tapia, New Mexico State University

John Ross Tapia has a focus on student engagement and success for all students in their coursework. John Ross is an assistant professor with the Engineering Technology Department at New Mexico State University. He teaches Civil Engineering Technology courses and is the faculty lead for the Freshman Year Experience/ENGR100 course. His research focus is engineering education. Prior to working at NMSU, John worked at New Mexico's first Early College High school and helped develop the curriculum for their STEM program, he also has 14 years' experience in the Civil Engineering Industry. John Ross has a BS in Civil Engineering, and a MA in Agriculture and Extension Education with an emphasis in technology, both from New Mexico State University.

Teaching a college-wide Introductory Engineering Course within a Freshmen Year Experience

College of Engineering, New Mexico State University
Dr. Rolfe Sassenfeld and John Ross Tapia

Introduction

Retention of engineering students from their freshmen year to graduation is an important issue facing engineering schools today. The academic difficulty of an engineering education takes a toll on enrollment and a significant percentage of students that enroll as freshmen engineers do not reach graduation. Increasing the percentage of students that persevere to graduation is one of the College of Engineering (COE) at New Mexico State University's (NMSU) main goals. The first goal to help students achieve this is the Freshmen Year Experience (FYE) program.

Experiential learning methods are described by much of the literature as a way to further engage students in their coursework and to introduce freshman to some of the basic concepts of engineering. A form of "student-centered education" where the instructor acts as a guide to the experiential learning process is preferred over the traditional class lecture format according to Spencer & Mehler[10]. Hixson[4] refer to this as instructor "role-modeling," where the instructor advises and nudges the students through a thought process. The decisions are ultimately made by the students and they are the owners of their solution. The research presented by Ambrose[1] similarly advocates the use of experiential learning opportunities. To better provide students with timely feedback, the in-class methods of peer instruction, case studies, and simulations lessen the slow response time of traditional grading.

Introductory level classes are described by Koenig[7], that help develop and reinforce basic reasoning skills that are critical in carrying out projects, designs, and experiments later on in STEM coursework. These classroom exercises are designed so that they scale up in difficulty. Hixon[4] calls this a "spiral curriculum," and appears to be very useful with engineering design projects.

Our FYE plan is based in part on implementing these experiential learning methods in conjunction with the retention strategies developed by the ECSEL coalition, Kalonji & Gretchen[6]. The FYE is only the first year of a complete four year plan for increasing student retention. The FYE transitions in the summer to include internships, employment opportunities, group activities, and pre-advising for the fall semester. Students who successfully make it to their second year will experience continued peer-mentoring in their sophomore course load to include assistance with English, Calculus and Physics. The summer prior to their second year the students are offered the same opportunities as the summer before the first year. Plans for the junior and senior years include students hiring as peer-mentors and providing opportunities for the students to participate in undergraduate research.

To achieve our goals the FYE integrates student success strategies into many facets of the student's first year in college. An integral part of this comprehensive approach is the ENGR100 "Introduction to Engineering" course. The data reported in this paper reflects a first pass at our new approach. At this point, it is too soon to know to what extent this course has affected graduation rates; however we can see if our stated goals for the course have been met. Additionally we can look at how many of the freshmen successfully complete their first year in college.

Student retention within the NMSU College of Engineering

Our college of engineering has seven departments and an average undergraduate enrollment of approximately 2100 students. The retention rates for the past twelve academic years of engineering students in our college are as follows. First-year full-time student retention rate is 63.9% (persistence from matriculation to their sophomore year). The second year retention rate (persistence from matriculation to their third year) is 47.2%, and the third year retention rate (persistence from matriculation to their fourth year) is 38.3%. Finally, our four-year graduation rate is 11%, while our six-year graduation rate is 29.3% [5]. These statistics are dramatic and signal an intense need for intervention strategies to assist our students in getting their bachelor's degree in a timely manner.

In an effort to address these alarming numbers, the college is implementing several comprehensive strategies. Among these strategies, four are facilitated by the FYE.

1. Focus on student learning through tutoring/mentoring
2. Student academic enrichment programs in including partnerships with other colleges
3. Curriculum and class enhancements
4. Changes in institutional/departmental policy & faculty development

We will discuss how the FYE and specifically how a new introductory course in engineering supplements these strategies. By utilizing student mentors, a flipped classroom teaching approach, hands on learning, and interdisciplinary team building.

Introduction to Engineering

A newly created college-wide introductory course, ENGR100 has been specifically implemented to further the four strategies listed above. ENGR100 is a required course for all new freshmen in the college of engineering. ENGR100 replaces each of the 7 individual department's introductory course. Combining all of these individual introductory courses required close coordination between the departments. The Mechanical and Aerospace Engineering, Chemical Engineering, Civil Engineering, Electrical Engineering, Engineering Physics, and Engineering Technology Industrial programs met to determine the critical topics that should be introduced to the freshmen engineers. The many topics discussed by the course development team were reduced to the following set of introductory subjects deemed to be important knowledge for all of our engineering students. The technical subjects to be taught in ENGR100 are:

- The Engineering Design Process
- Flow Diagrams
- MatLab and other Software Tools
- Volume/Density

- SI Units
- Newton’s Laws of Motion
- Material Properties
- Ohm’s and Kirchhoff’s Laws
- Ethics in Engineering
- Engineering Research

As can be seen by the list of topics, the course is very ambitious in its efforts to expose the freshmen engineers to the many aspects of engineering.

Course logistics

The enrollment for the course was very large, 221 freshmen engineers took the course in the Fall 2014 semester. One of the priorities of the course was to offer the freshmen more personalized instruction than they typically see in their first year of college. Thus seven sections of ENGR100 were offered. The enrollment in each section was targeted at 25 students; however enrollment numbers and the lack of additional faculty had put the average section size at 31.5. These relatively smaller class sizes allowed for the instructors to provide students with more individualized instruction and were designed to help the students better know the Engineering faculty.

Of the seven faculty that taught ENGR100 sections, all but two departments of the college were represented. Coordinating seven faculty in seven sections was a very difficult task, but the team worked together well and came together to create an exciting experience for the freshmen. Each of the seven initial course faculty was selected based on their previous outstanding teaching evaluations. Although the course material was standardized for all ENGR100 sections each professor provided their individualized teaching style in the course. In analyzing the course’s student evaluation data, there was only a slight deviation in performance and student ratings between each professor.

Course outcomes

The faculty of our college met to discuss and plan for the ENGR100 course and the implementation of the FYE. They established six course outcomes for the freshmen engineers.

1. Engage freshman engineering students in critical thinking and design process while learning important team building skills and ethical approaches to problem solving.
2. Gain an appreciation of and the skills for effective communication, teamwork and ethics.
3. Become familiar with the engineering profession.
4. Develop flow diagram construction and structured programming skills in MATLAB.
5. Learn the use of engineering tools (spreadsheets, drawing software, math, economics, etc.)
6. Become knowledgeable of dimensions (length, time, mass, force, temperature, electric current, energy and power) and related engineering parameters.

Instructional approaches, the flipped classroom

A key aspect with respect to ENGR100's instructional approach was the decision to implement the flipped classroom, often referred to as "Learn before Lecture". The professors were asked to implement this strategy in each of their sections. This approach was chosen as a means of delivering an engaging learning environment that would directly assist in meeting the first and second course outcomes. It was thought that by offering in-class team problem solving activities that the students would be engaged in a somewhat realistic engineering design experience.

Having 24/7 access to the course materials offers the freshman engineering student the ability to view and review course 'lecture' material that is not ambiguous and offers a solid study foundation. A resource that was utilized to implement the flipped classroom approach was Canvas which is the University's online Learning Management system. Canvas is a commonly used online instructional tool that allows students access to all of the course materials. Canvas also facilitates communication and teamwork through messaging tools and the administration of online student teams. The use of Canvas was a beneficial way to communicate and organize all the materials needed for instructional purposes. According to Brame[3] with the correct implementation the flipped classroom strategy can be a beneficial layout to encourage students to prepare for class before arriving. Flipping the class via Canvas provided students with the resources for all the units and objectives covered in the class. Students were able to watch videos, read valuable resources, and work on small assignments prior to coming to class. They can also be assessed on content with multiple assessment tools such as quizzes, and hands on activities when in the classroom Brame[3]. As Atherton [2] states this process allowed students to participate in many of the simpler Bloom's Taxonomy cognitive learning domains outside of class, and gave them the opportunity to engage in the more complex levels of thinking in class.

Hands-on learning

The second instructional method was to have the course be an active learning environment, incorporating this through a problem based learning approach. After the students have had the opportunity to gain knowledge on their own time with the pre-class materials in Canvas, they would come into the classroom and the professors would engage them in group activities and time to work on projects with their team. There were five major team projects that included reverse engineering and improving a coffee pot, estimating and building a pulley lift, creating homo-polar motors, building and measuring electrical circuits, and solving engineering problems with MatLab. Relatively quick 'back of the napkin' calculation exercises were also used for the students to estimate and verify results. With the hands-on activities, the students gained a better understanding of the content. When students are actively engaged in the topic, they have a better chance of success in that unit of study. This active learning approach was utilized to help meet each of the six course objectives.

Interdisciplinary team building

In order to leverage the opportunity that all engineering majors were together in one class, a departmental consensus was reached that ENGR100 should emphasize to the inter-disciplinary aspects of engineering. Therefore, team-building exercises as one of the instructional approaches, was one the most important modules of the class[4]. Not only was this an instructional strategy, but a critical skill that engineering students will need for success in their college career and in their professional life. Team building and teamwork is a crucial component to help students succeed in college and also help them succeed in the workplace. Teamwork is an essential part of the curriculum and the faculty worked to find methods and learning activities to help students become better teammates and produce quality group work.

Student mentors

The final instructional approach implemented was the use of student mentors to assist with daily classroom activities and establish their role as mentors to the new students[8]. We were able to obtain financial support to pay the mentors for their participation in the program. This may be one of the largest areas of success in the course. Not only are our freshmen getting to know upperclassmen and feel comfortable going to them with questions, but our mentors are starting to develop a sense of leadership and feel partly responsible for others' success. We grouped 16 freshmen to every mentor. The faculty worked to mix the groups to have multiple disciplines in each group. The mentors held office hours and attended one of the ENGR 100 sections. Each faculty member had two mentors assigned to them to handle their 31-32 freshman ENGR100 students

Integration of ENGR100 with freshmen English, Math, and Physics courses

To complement the FYE it was decided that we should take a comprehensive approach to the student's first-year class schedule. The integration of engineering topics across the curriculum is an approach that allows freshmen engineering students to think of engineering topics outside of the context of an engineering classroom. The approach used was based on previous research such as[9] where multiple departments coordinated to offer interdisciplinary projects.

Coordination with the department of English was utilized to keep the students together as cohorts to the greatest extent possible. All of the students shared the same sections of ENGR100 and ENGL111 (Rhetoric and Composition). We are currently in the process of seeing if it is possible to include MATH190 (Pre-Calculus) and MATH 191 (Calculus I). The instructors of ENGR100 met weekly with the faculty of the English department. This coordination allowed the ENGR100 faculty to develop hands-on examples incorporated aspects related to topics of the other course. Having an English 111 section of engineering students, allowed them to tailor their exercises and examples to better include engineering-domain specific problems. The department of English was extremely helpful and craved input for the most appropriate type of engineering related assignments.

First ENGR100 course outcome data results

At the end of the fall semester, both the students and instructors were surveyed to assess their understanding and evaluation of how each of the six course objectives was met. A review of the student surveys was conducted in order to identify areas of deficiency in the course objectives/outcomes.

Table 1. Student survey results

Course Objectives	Excellent	Very Good	Good	Fair	Poor	Avg student Score	Number of students who responded to objective
	Percent of Students scoring the objective						
Engage Freshman engineering students in critical thinking and design process while learning important team building skills and ethical approaches to problem solving	30%	34%	29%	6%	1%	2.86	176
Gain an appreciation of and the skills for effective communication, teamwork, and ethics	30%	36%	24%	8%	1%	2.86	176
Become familiar with the engineering professions	24%	39%	24%	10%	4%	2.69	176
Develop flow diagram construction and structured programming skills in MATLAB	9%	19%	27%	31%	15%	1.76	176
Learn use of engineering tools (spreadsheets, drawing software, math, economics, etc.)	9%	18%	33%	30%	10%	1.85	174
Become knowledge of dimensions (length, time, mass, force temperature, electric current, energy and power) and related engineering parameters	31%	40%	26%	3%	1%	2.97	166

Table 1 (above) shows the results of the student survey with respect to meeting the course outcomes. The students provided a rating for each course objective. The results in the table reflect the cumulative average of all seven sections of the ENGR100 course. The average student score has been calculated for each course objective with excellent being a total of 4 points and poor being 0. An analysis of the data from the student surveys showed the faculty did a fairly good job with objectives 1, 2, 3, and 6. Looking at objectives 4 and 5 and reflecting on why our student outcomes were not as successful as we would have liked, both students and faculty indicated there was not enough time spent on the objectives. As a faculty, we will continue to assess our student outcomes to ensure that we are working toward an efficient curriculum that helps students succeed in their desired engineering studies, while continuing to improve the success of the FYE to retain students in the College of Engineering.

Freshmen persistence

Another important facet of the FYE is the continued contact and involvement with the freshmen throughout their first year in college. The freshmen utilize their upper-class mentor to assist in their non-engineering courses as well. Due to the ASEE conference timeline we will not be able to know our freshmen's persistence to their sophomore year until after the summer conference in Seattle. We do have encouraging data that can be shared regarding the cohort of freshmen students who took ENGR100 in the fall of 2014. Out of the 221 freshmen students enrolled in ENGR100, 203 are currently enrolled and taking classes in an engineering discipline during this spring's semester. The 18 out of 221 that did not persist in engineering to the second semester represents an 8% loss. The faculty and administration strived for 0% loss between semesters. However, as was previously mention the college experienced a 63.9% persistence rate last year, which represents a 30.1% drop. This is why we believe the relatively small initial drop of 8% is promising.

Faculty observations and revisions for following semesters

Table 2 (below) shows the results of the faculty (who taught the course in the fall of 2014) survey with respect to meeting the course outcomes. The faculty were asked to rate each course objective just as the students were. The results in the table reflect the cumulative average of six of the seven sections of the ENGR100 course, and again we calculate the average faculty score based on excellent being a total of 4points and poor being 0. With reviewing the results of the faculty three objectives are just above a "C" average and the others are below. Many of the comments and suggestions from faculty were that a few of the projects controlled most of the time, and that there was not enough time allotted to effectively teach the MATLAB and Engineering tools course outcomes. All the faculty wanted the course to succeed and are willing to continue to help with curriculum writing that will help benefit all students in the course. We may also look at rewriting the objectives for the fall of 2015 in a way that we can actively measure at the end of the term. As for this spring semester of 2015 we have kept the same objectives.

The following is a collection of the faculty's observations and recommendations after teaching ENGR100 during its first iteration. These recommendations either have or will be implemented for the spring offering of the course.

1. Faculty scheduling and team size. There should be fewer instructors teaching the course by exploiting the advantages of multiple sections. From a teaching team standpoint, the large team was hard to coordinate and manage. It has been suggested that fewer faculty be used and have them teach two sections of the course each. This has the benefit of a smaller more cohesive Instructional team and provides the faculty members an opportunity to refine the course material by teaching twice a day. To avoid a subset of the seven academic departments not being represented in the teaching team, departments should rotate on a semester or yearly basis.

Table 2. Faculty survey results

Course Objectives	Excellent	Very Good	Goo d	Fair	Poor	Avg Faculty Score	Number of faculty who responded to objective
	Percent of Faculty scoring the objective						
Engage Freshman engineering students in critical thinking and design process while learning important team building skills and ethical approaches to problem solving	0%	33%	0%	33%	33%	1.33	6
Gain an appreciation of and the skills for effective communication, teamwork, and ethics	17%	17%	50%	0%	17%	2.17	6
Become familiar with the engineering professions	17%	17%	17%	17%	33%	1.67	6
Develop flow diagram construction and structured programming skills in MATLAB	17%	17%	17%	17%	33%	1.67	6
Learn use of engineering tools (spreadsheets, drawing software, math, economics, etc.)	0%	0%	0%	33%	67%	0.33	6
Become knowledge of dimensions (length, time, mass, force temperature, electric current, energy and power) and related engineering parameters	0%	50%	33%	17%	0%	2.33	6

2. Provide additional teaching materials. Faculty teaching this course desire additional teaching materials, examples, videos, projects, and in class exercises etc. Developing these supplemental materials is important for instructors so that they have the opportunity to utilize the most appropriate material as they see fit. This provides for variety and innovation in teaching. It would also be difficult to persuade colleagues to teach the course in the future if it was totally pre-canned and prescribed in detail.

3. Difficult coordination with English, Math, Physics. Coordinating with 3 departments outside of your college on a weekly basis is also somewhat difficult. Specific tasks and discussion are

necessary to make the most of so many people's time. Engineering instructors should have a clear understanding of writing rubrics.

4. Student team issues. Whenever students are put into teams issues may arise. For example a team member is not putting effort or showing up to team meetings. Students may be causing other issues that need to be attended to. It is important to have a flexible approach to team creation and team assignment grading.

5. Better assessment. Additional assessment tools are required to achieve a better understanding of which strategies were the most successful. As we continue to develop the FYE the implementation of the clicker questions, as a form of assessment, will be utilized. With the use of the clicker, we can gather data on the spot and evaluate what students comprehend and whether additional resources and time are needed.

6. Design challenges. As we continue to assess students' outcomes we are looking to also add impromptu design challenges in the class where students have a certain time and criteria to design-build-test. To increase student involvement, these design challenges throughout the semester will test knowledge learned. As appropriate give students a more rigorous challenge once they have been introduced to the topics and objectives.

7. Study skills. We are learning that freshman students come to us with all different types of learning habits and study skills. We cannot assume that everyone in the class knows how to efficiently work with a group of other students. We have established a need for guidelines and the development of this important skill.

8. Student mentors. As we did not normalize how the mentors were to be used in the fall, every faculty member utilized these students a little differently. We have since changed that method this spring and every mentor hosts a workshop with their students once a week. The workshop was built into the course credits and student's schedules. The ENGR 100 students are utilizing the mentors in a positive way and this is helping our students to master all of their objectives.

9. Realistic teaching timetable. In addition, we will need to modify the class schedules to provide a more functional flow of assignments. As the spring semester will indicate we have already changed the order, and have significantly added the needed time for these objectives. We feel that MATLAB is a significant unit to cover since it gives all students some structured programming skills. Since ENGR100 is the introductory class to many of the departments, this is an essential skill in many of the disciplines

Conclusions

To improve graduation rates our college has created and implemented a comprehensive plan to increase student persistence and all undergraduate levels. The introduction to engineering course ENGR100 plays an important role in the overall strategy of student involvement. Numerous pedagogical approaches were utilized in an effort to provide the freshmen with an all-encompassing freshmen year experience. Initial data indicates that more is not necessarily better, especially when it comes to teaching a class of wide ranging engineering topics. The data also shows that where properly targeted, the students indicate that these pedagogical strategies are effective in meeting several of the course objectives. Preliminary numbers provide encouragement that the strategy of student involvement will indeed improve retention at the freshmen to sophomore level. Student and faculty feedback will continue to provide guidance in the design and goals of ENGR100.

References

[1] Ambrose, S.A. (2013). Undergraduate Engineering Curriculum: The Ultimate Design Challenge. *The Bridge – National Academy of Engineering.*

[2] Atherton J S (2013) *Learning and Teaching; Bloom's taxonomy* [On-line: UK] retrieved from http://www.learningandteaching.info/learning/bloomtax.htm

[3] Brame, C., (2013). Flipping the classroom. Retrieved from http://cft.vanderbilt.edu/guides-sub-pages/flipping-the-classroom/.

[4] Hixson, C., Paretti, M., Lesko, J., & McNair, L. (2013). Course Development and Sequencing for Interdisciplinary Entrepreneurship Education. *National Collegiate Inventors and Innovators Alliance.*

[5] Internal report provide by the university's Office of Institutional Studies.

[6] Kalonji, Gretchen (1995), ECSEL Coalition techniques and results for improving retention, Washington Univ., Seattle, WA, USA

[7] Koenig, K., Schen, M., Edwards, M., & Bao, L. (2012). Addressing STEM Retention Through a Scientific Thought and Methods Course. Journal of College Science Teaching,

[8] Meyer, M., & Marx, S. (2014). Engineering Dropouts: A Qualitative Examination of Why Undergraduates Leave Engineering. *The Research Journal of Engineering Education, 103*(4), 525-548.

[9] Roedel, R.J., Evans,D., Doak, R.B., McCarter, J., Duerden, S., Green,M., and Garland J. (2001) Projects that integrate engineering, physics, calculus, and English in the Arizona State University Foundation Coalition freshman program

[10] Spencer, D. & Mehler, G. (2013). Opportunities in Engineering Education. *The Bridge – National Academy of Engineering*. Summer 2013, 24-30. Retrieved from http://www.nae.edu/File.aspx?id=88638