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Effect of an Introductory Engineering Technology Foundations and Applications Course on Students' Performance

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Abstract

Student graduation and retention rates are among the metrics that many academic institutions of higher education closely monitor because of their impact on the success of recruiting students and in some U.S. states, they can impact the level of state government funding of public academic institutions. For these reasons, many academic institutions explore innovative ways to improve their graduation and retention rates to levels as high as 95%, respectively. An example of an innovative and transformational approach to improving these metrics is presently taking place in a mid-western university, and the cornerstone of this approach are the development and implementation of engineering technology foundations and applications course for all incoming students. While this course uses active learning approaches and team projects, the scope of their contents distinguish them from similar courses that seek to achieve improved graduation and retention rates. For instance, in this course, soft skills such as technical writing, use of Excel, developing an individual academic plan of study, cooperative education, internships, cultural diversity, quality, safety, and ethics are covered. Basic technical skills covered include math, mechanical, electrical, and computer engineering technology. The rationale for this course is to expose students to these subjects and topics before they enroll in core engineering technology courses such as applied statics.

Assessment of learning:

While the author plans to conduct this study for at least a four-year period, when the students presently taking the engineering technology foundation course would be graduating so as to compare their graduation and retention rates with those of former graduates, preliminary results presented in this study compare performance of students taking the engineering technology foundation and application course with those of their classmates who were not presently enrolled in this course but were enrolled in the same 100-level engineering technology course.

Introduction

The seemingly low graduation and retention rates in the US have triggered national concerns because of their perceived negative economic impact on the nation, emanating from claims[1,2] of skilled labor shortages in some sectors of the economy, for example, the manufacturing and construction sectors. Since a majority of the skilled labor pool comes from academic institutions, it seems unlikely that low graduation and retention rates will ameliorate the situation, particularly, since students' enrollment in 4-year degree-granting postsecondary institutions has fallen slightly in recent years.[3] About graduation and retention rates, the National Center for Education Statistics (NCES) reported that the 4-year graduation rate for first-time, full-time bachelor's degree students at all 4-year postsecondary institutions in the US was 39.8% for students starting in fall 2008[4] while the retention rate (the percentage of students returning the following fall) was 80% in 2013[5] for first-time, full-time bachelor's degree students at all 4-year postsecondary institutions. Because students' graduation and retention rates are among the important metrics for measuring students' success at academic institutions, many studies have been conducted on them. For example, a search of the American Society for Engineering Education (ASEE) website with the words "undergraduate student retention" produced 8,150 hits. Similarly, a search with the same words at a university library database returned 1,397 hits from peer-reviewed journals for a period covering 1970 to 2017, and 235 of those hits were from the Journal of Engineering Education. Several authors[6-14] identified several factors that may have contributed to low graduation and retention rates in engineering and technology programs, and these factors include large class size, poor math and physics skills, lack-of-supporting community, gender, ethnicity, social and economic status, and low motivation. But for a majority of these authors, poor math and physics skills seem to be the most common factors that have the greatest impact on students' low graduation and retention rates. Therefore, these authors have used several approaches to improve students' math and physics skills. While the authors of this study have used similarly approaches to improve students' math and/or physics skills, there seems to be room for further improvement. Thus, in a mid-western state university, a transformative freshman engineering technology course was recently introduced to engineering technology, manufacturing engineering technology, and mechanical engineering technology majors in fall 2016. The reason for the new course was based on feedback from a traditional gateway course and input from industrial partners. Essentially, the new course consists of three modules. Module 1 focused on general (not dependent on discipline) critical skill sets required for success in academe and industry, Module 2 emphasized mechanical and manufacturing engineering technology skills, and Module 3 dealt with basic electrical circuits and electronics.

Background Information

During the summer of 2016, several instructors from different university campuses met to develop the learning outcomes and objectives for a 100-level course in engineering foundations and engineering applications. Based on these learning outcomes and objectives, each faculty created syllabi appropriate for their campuses depending on class size, demography of their students, and availability of laboratory resources. At the author' campus, the size of the engineering technology program was rather size small compare to other campuses; the program had about 35 students with a mission to reach out to students, who for genuine reasons cannot get a college or a university engineering technology education in a large campus environment. Most of these full-time students commute to classes daily. The new freshman engineering course consists of a lecture-recitation component titled "Engineering Foundations" (see Appendix A) and a laboratory component titled "Engineering Applications" (see Appendix B). The two components were taught back-to-back on the same day, and the class met twice a week. The advantage of the back-to-back format was that students were able to apply immediately concepts covered in lecture-recitation component. According to the students, they thought the format gave them the opportunity to make the concepts real and less abstract, and secondly, it helped them to understand and retain better the topics covered in class. In the following sections, the authors will describe the course content in module 1, 2, and 3. The contents of these modules can be found in Appendix A and Appendix B. Students was assessed by exams (an exam was given at the end of each module), class activities, and lab reports.

Module 1

As shown in Appendices A and B, module 1 contains introductory skills that were deemed necessary for success in any college/university degree programs. These include how to the use of a word processing application software, and Excel spreadsheet and its graphing features. After ensuring that students were able to use these computer application software, they were required to use them to type all assignments and reports except when required to show the details of extensive math calculations. Also, the students learned chronological and functional types of resumes and created their personal resumes. For all of them, this was their first time of creating a resume. Information about looking for jobs through memberships in professional organizations such as the Society of Plastics Engineers (SPE) was covered. Students developed their personal plan of study (POS) from the degree requirements of their respective majors. This exercise made them realize the reasons why they take certain non-major classes for their degree program. The class discussed the advantages of cooperative education, industrial internships, and team-based work. Students were introduced to the subject of ethics, and in particular, about professional engineering ethical codes. A distinction was made between ethics and morality; ethics is about external standards while morality often deals with internal (one's own) standards. Finally, students were introduced to number notations, SI units, significant digits and factor-label method of converting units.

Module 2

The focus of module 2 was on basic skills for mechanical engineering technology and manufacturing engineering technology. These skills include proficiency in basic math such as algebra, geometry, trigonometry and graphing. The applications component required that these skills be used to analyze and report experiments in the tensile testing of steel and plastics specimens, in testing the load bearing capabilities of 45º and 60º trusses, Figure 1. In thermodynamics, students were introduced to water phase diagram and its applications in the dry freezing process to preserve items such as food and drugs, Figure 2. For Fluid Power, students experimented

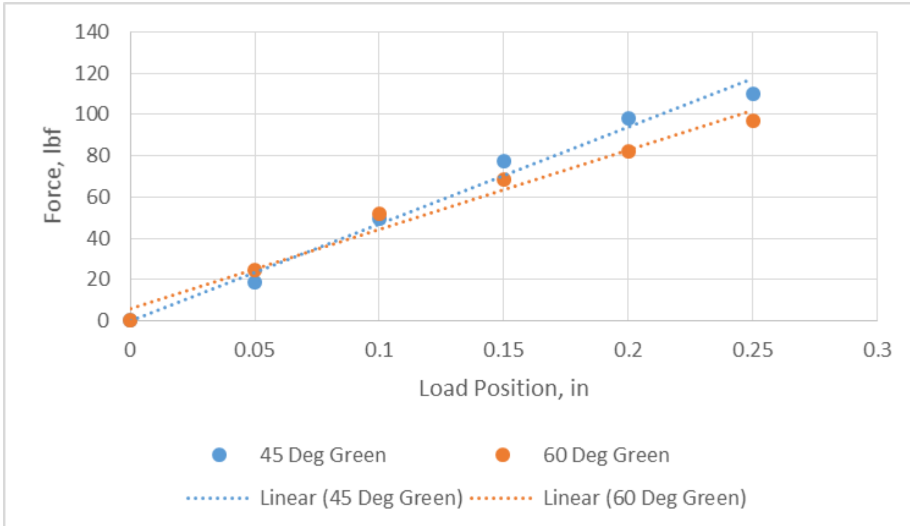


Figure 1. Effect on angle of truss members on its load bearing capability

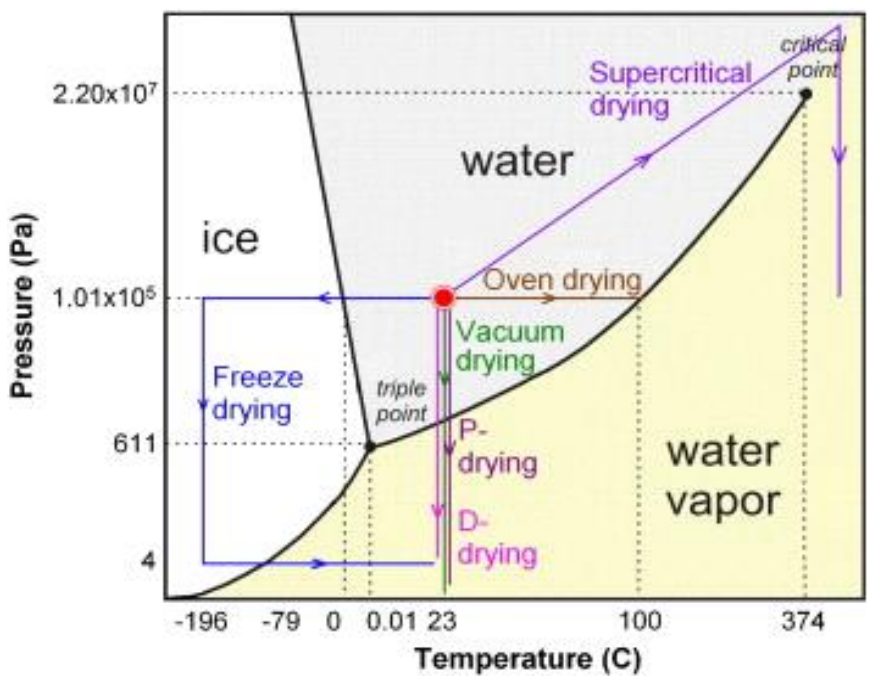


Figure 2. Water phase diagram and freeze drying. Reference: freezedryinc.com

with pressure compensated variable displacement pump and learned how to collect data and present the data graphically as shown in Figure 3. For metrology, students used Vernier calipers and micrometers to determine the variability in the longitudinal and radial wall thicknesses of

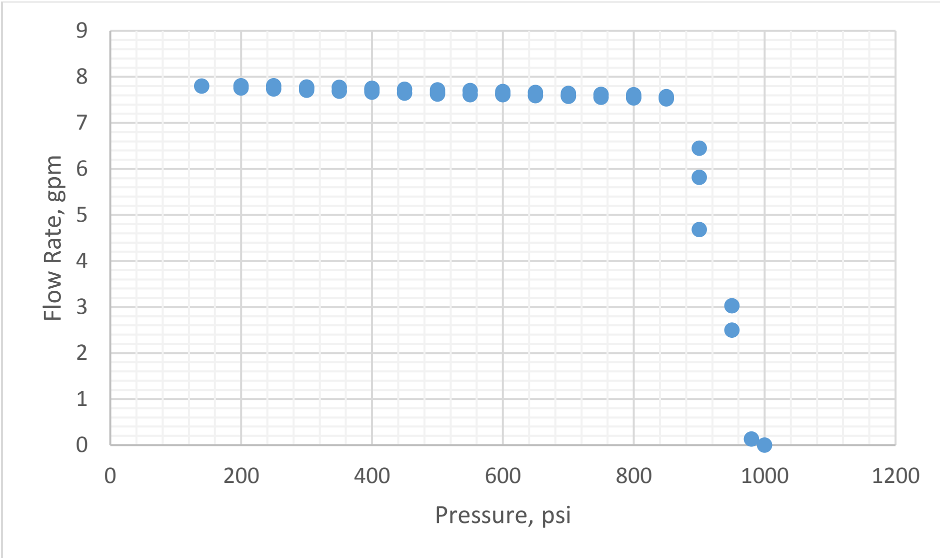
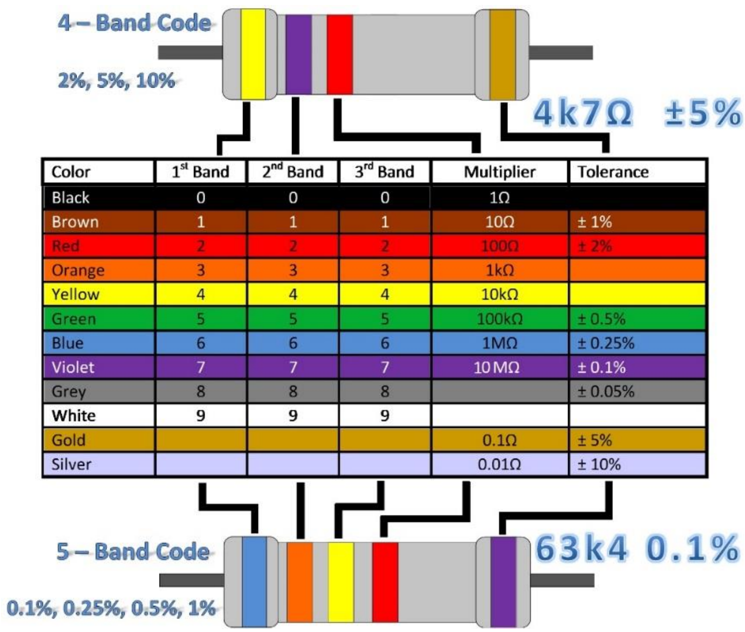


Figure 3. Pressure compensated variable displacement pump

extrusion-blow-molded plastic bottles by taking seven longitudinal measurements and seven radial measurements and calculating their means, range, and standard deviations.

Module 3

Module 3 emphasized basic electrical circuits and covered topics such as conventional and electron theory of electrons flow in a closed circuit. Students worked on building series and parallel dc circuits, learned how to use a digital multimeter (DMM) to measure the value of the resistance of resistors, the current in a closed electrical circuit, the voltage drop across resistors, light emitting diodes (LEDs), and batteries. Using a signal generator and an oscilloscope, students learned the difference between dc and ac voltage signals. Ohm's law was also covered in this module. An attempt was made to determine the speed of sound with the signal generator, oscilloscope, a loudspeaker, a microphone, and a meter ruler. In addition to using DMM to measure the resistance of resistors, the students learned how to use color codes to determine the value of the resistance of resistors. Figure 4 shows an example of the color code used for this exercise. Figure 5 shows an example of schematic electrical diagrams that students worked on. This diagram was generated by a web-based simulation software by Circuit Lab®, www.circuitlab.com.



Color	1st Band	2nd Band	3rd Band	Multiplier	Tolerance
Black	0	0	0	1Ω	
Brown	1	1	1	10Ω	± 1%
Red	2	2	2	100Ω	± 2%
Orange	3	3	3	1kΩ	
Yellow	4	4	4	10kΩ	
Green	5	5	5	100kΩ	± 0.5%
Blue	6	6	6	1MΩ	± 0.25%
Violet	7	7	7	10 MΩ	± 0.1%
Grey	8	8	8		± 0.05%
White	9	9	9		
Gold				0.1Ω	± 5%
Silver				0.01Ω	± 10%

Figure 5. Color codes used to determine the resistance of resistors

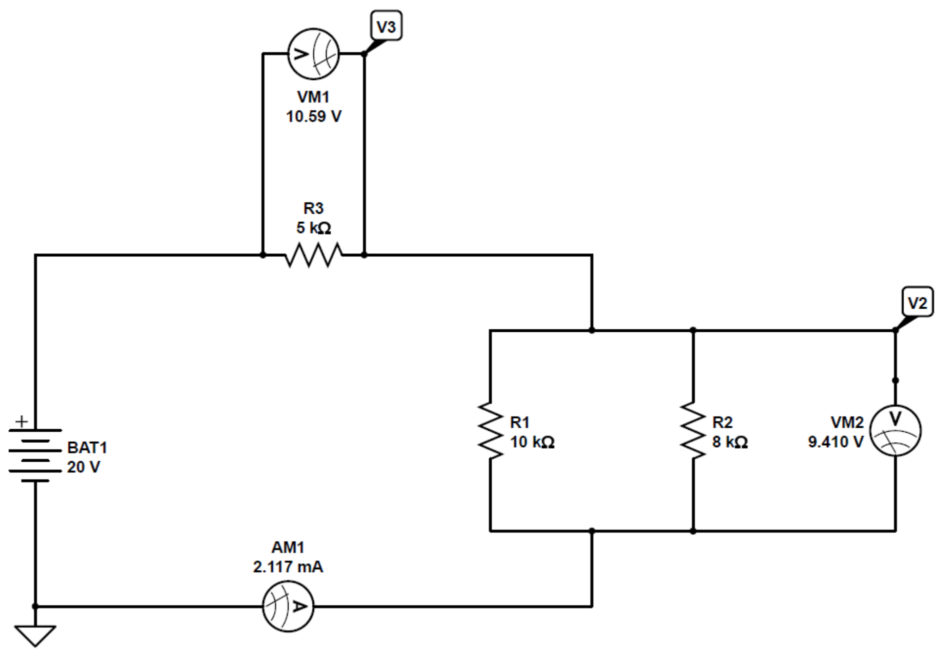


Figure 6. A schematic diagram of an electrical circuit

Assessment

Retention Rate

All the students that took this class in fall 2016 returned for the spring semester indicating a retention rate of 100%. As indicated earlier, this study is planned for a four-year period but was started in fall 2016. Therefore, there are no results to report on the graduation rate at this time.

Students Evaluation

Students rated the engineering foundations' recitation and engineering applications components of the course at 4.7/5.0, respectively, while the lecture portion of the engineering foundations component was rated 4.3/5.0. Overall, the students were, at least, 86% satisfied with the course.

Comparison of Students Performance

The performance of students who took the engineering foundations and applications course were compared with other freshman students that were yet to take the course, but both the groups of students were enrolled in the same 100-level mechanical engineering course, a plastics technology course. For the former group (enrolled in the engineering foundations and applications course) their average score in the plastics technology course was 86.9±5.6% while it was 88.0±1.5% for the latter group. This result suggests no significant difference between these groups of students. However, it is too early in the assessment process to reach a definitive conclusion from this result.

Learning Outcomes

Regarding of learning outcomes, the average score in the course was 88.4±2.9%, which seems reasonable. Since this is a long-term study (4 years and greater), the author will examine if there exists any correlation between the average score in the course and graduation & retention rates.

Conclusion

Based on the retention rate and students' evaluation results, it appears that the new engineering foundations and applications course were well received by the students that took the course in fall 2016. A clearer picture will begin to emerge as more freshman take this required course in subsequent semesters. But for now, students seem to like the course because of class delivery format, which gave them immediate opportunity to experiment with engineering concepts covered in the lecture component of the course. The format also encouraged them to work in teams, which they found advantageous because they were able to teach and learn from each other. Also, they did not find the course intimidating because they understood right from the beginning of the class that the primary purpose of the course was to expose them to materials they will see again in subsequent courses. So, the course was not presented as a “do or die” course. This aspect of the course gave the students the confidence to experiment with new ideas and learn new materials in a somewhat relaxed environment.

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Appendix A

Class Topics and Schedule for Engineering Foundations

Week	Topics	Handouts
1	**Module 1: Introduction, Goals, and Basic Tools** GFSA (Given-Find-Solution-Answer)	*Topics 04 & 05
1	Number Notations, SI Units, Significant digits	Topics 04 & 05
2	Calculator operation, Factor-label method of converting units, Spreadsheet use	Topics 08 & 09
2	Word Processing	
3	**Professional Basics:** Professional communications, resume, memos, proposals, etc	Handouts from previous course in Technical Communications
3	Degree requirements and Plan of Study (POS)	From PPI Richmond
4	Teaming, Internships, COOP, Careers	
4	Ethics, Global/Societal Responsibilities	ABET Outcomes and Handouts
5	Quality and Safety	Handouts from previous course on safety
5	Review for Exam 1	
6	**Exam 1**	
6	**Module 2: MET/MFET Basics**: Algebraic techniques	Topics 6 & 10
7	Algebraic techniques	Topics 6 & 10
7	Geometric techniques	Topic 23
8	Geometric techniques	Topic 23
8	Trigonometric techniques	Topic 24
9	Trigonometric techniques	Topic 24
9	Logarithmic analysis techniques	Topic 17
10	Logarithmic analysis techniques	Topic 17
10	Graphic analysis techniques, Factor-Label Unit Conversion	Topics 12 & 16
11	Review for Exam 2	
11	**Exam 2**	
12	**Module 3: Electrical Computer Engineering Technology Basics**	**BF: Chapters 1, 3, & 4
12	DC: Voltage, Batteries, Current, Resistance, Ohm's Law	**BF: Chapters 1, 3, & 4
13	Resistance, Power, AC Voltage and Signals	BF: Chapters 4 & 9
13	Series DC Circuits & Parallel DC Circuits	BF: Chapters 5 & 6
14	**Thanksgiving Break**	
14	**Thanksgiving Break**	
15	Binary and Hex Numbers & Digital Logic	
15	**Review for Final Exam**	
16	**Final Exam**	

*Topics are from MET 162 Manual
**BF = The Science of Electronics , DC/AC by David M. Buchla and Thomas L. Floyd, 2005

Appendix B
Class Topics and Schedule for Engineering Applications

Week	Topics	Handouts/Assignments
1	**Module 1: Introduction, Goals, and Basic Tools**	*Topics 04 & 05
1	Number Notations and SI Units	Topics 08 & 09
2	Calculator operation, Spreadsheet use	ACME Project – PPI Columbus
2	Word Processing	
3	**Professional Basics:** Professional communications	Handouts from previous course on Technical Communications
3	Degree requirements and Plan of Study (POS)	Handouts from PPI Richmond
4	Teaming, Internships, COOP, Careers	Handout from PU on Transformation
4	Ethics, Global/Societal Responsibilities	ABET Outcomes and Handouts
5	Quality and Safety	Handouts from previous courses in safety
5	Review for Exam 1	
6	**Exam 1**	
6	**Module 2: MET/MFET Basics**: Safety, MSDS	Lab Safety Policy
7	Tensile and Compression Testing	MET Lab Handout
7	Tensile and Compression Testing	MET Lab Handout
8	Thermodynamics	MET Lab Handout
8	Thermodynamics	MET Lab Handout
9	Fluid Power	MET Lab Handout
9	Fluid Power	MET Lab Handout
10	Metrology: Statistics, Range	MET 14400 Lab 1 Results
10	Metrology: Resolution, Precision, Accuracy	MET 14400 Lab 1 Results
11	Review for Exam 2	
11	**Exam 2**	
12	**Module 3: ECET Basics:** Safety, MSDS	**BF Chapter 1 *** MS Chapters 1 & 2
12	DC Voltage Measurements, DC Voltage Sources	**** PP Expt: 2-1, 2-2
13	Resistance, Current, & Power	PP Expt: 3-1, 3-2, 4-1, 4-2, 4-3, 4-4 and 4-5
13	Resistance, Current, and Power	PP Expt: 5-1, 5-2, 5-3, 6-1, 6-3
14	**Thanksgiving Break**	
14	**Thanksgiving Break**	
15	AC Sources, Signals, and Measurements	PP Expt:15-1,15-2, 15-3
15	**Review for Final Exam**	
16	**Final Exam**	

- *Topics are from MET 162 Manual
- **BF = The Science of Lectronics DC/AC by David M. Buchla and Thomas L. Floyd, 2005
- ***MS = Grob's Basic Electronics – Fundamentals of DC and AC Circuits by Mitchel E. Schultz
- ****PP = Grob's Basic Electronics Experiments Manual by Frank Pugh and Wes Ponick, 2007