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Assessing and Developing a First Year Introduction to Mechanical Engineering Course

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Assessing and Developing a First Year Introduction to Mechanical Engineering Course

There are numerous articles that describe activities and course models to increase the student's awareness, enjoyment, and retention in engineering during the first year. At The Citadel there has been great effort in developing a new mechanical engineering program with emphasis on nesting course design and activities with the program curriculum. The Citadel is classified as a small school with the student population evenly split between in-state and out of state (including most other states and a few foreign countries). With regional needs in Power and Energy, Manufacturing, Aeronautics, Composites, and Mechatronics, the new mechanical engineering program was designed with upper level focus areas to meet these needs. This new Introduction to Mechanical Engineering course's organization is designed to provide a general understanding of each of these mechanical engineering areas, so that freshman can make an informed decision when selecting electives. Since there are many misperceptions of what engineers can or should do, another goal of the course is to increase the students' awareness of engineering. The course accomplishes many goals for freshman mechanical engineering students including: an overview of the different areas of mechanical engineering available at the institution, introduction to engineering concepts, and attractive opportunities available with internships and employment after graduation.

This paper details the execution of several documented ideas into a successful freshman Introduction to Mechanical Engineering course. The course design combines benefits of both team and individual requirements. It contains both small hands on activities as well as short term homework style assignments. The hands on activities and projects are designed to foster teamwork in an open-ended problem solving environment. Formal assessments include individual as well as team homework problems, presentations, and group projects / activities throughout the semester. Several of the individual and team homework problems contain elements of multiple mechanical engineering areas, giving them a "tree-top view" of mechanical engineering as they work their way through several focus areas.

The objectives of this paper are to explain the lecture and lab content delivered during the time spent with each focus area, to provide a description of the hands on activities, to assess the first semester program results quantitatively and qualitatively, and to discuss the importance of the results and the future potential of the program.

Introduction

One of the challenges in the teaching profession is to motivate and inspire students to learn. There are numerous examples to motivate students as expressed by Barbara Davis. These range from incorporating different teaching methods to various ways to organize the course such as de-emphasizing grades, giving feedback, and influencing student preparation[1]. Chickering and Gamson argue that time on task and active learning leads to better understanding[2], or more importantly, as Vogt illustrates "time expending the necessary mental effort." Vogt continued in her study to show that student self-efficacy had "very strong effects on effort and critical thinking where academic confidence had insignificant effect." What she meant by this was that a

students' view that they could accomplish the work in a class was a greater factor in a students' effort and in the critical thinking that they did in a class than was their general academic skill[3].

Students need to be actively engaged in their chosen professions as soon as possible. A recent program review at UT Tyler indicates that students who are in exciting active freshman engineering experiences are more likely to stay in engineering and those that do not take the course are more likely to change to other majors, especially when struggling in the math and science courses. The activities should be open-ended play-type experiences that help a student grow their creativity while at the same time require them to develop necessary engineering skills such as technical writing, lab report writing, and data collection. The ability to get into design experiences (K'Nex, Lego, and WPBD) without waiting until completing junior and senior courses adds to the students desire to continue on to the junior and senior years and sometimes persevere through the freshman and sophomore humanities core, math, science, and engineering science courses[4].

Keeping the students engaged in their chosen major can carry them through the many Core (English, history, politics, social sciences, etc.), mathematics, basic science, and engineering science courses (statics, dynamics, etc.) during their freshman and sophomore years before they even start to take the majority of their mechanical engineering specific courses in their junior and senior years. Many times the excitement for engineering is necessary just to get the students through their freshman year when they experience numerous life changes[4].

Conceptual Framework

The School of Engineering has had a proud record of significant contributions at The Citadel since its inception in 1842. The Civil and Environmental Engineering Department was established in 1912 and became accredited in 1936. The Electrical and Computer Engineering Department was established in 1941 and became accredited in 1976. The Mechanical Engineering Program was added in 2014 with the first mechanical engineering courses (MECH) offered in the fall. The School of Engineering will apply for accreditation of the new Mechanical Engineering program as soon as the first mechanical engineering students graduate in May 2016.

The new Mechanical Engineering Program of Study offers focus areas in Power and Energy, Manufacturing, Aeronautical Systems, Materials (Composites), and Mechatronics. It is available to the regular daytime student population as well as to the evening students transferring from community colleges (2+2 programs). The full-time evening Mechanical Engineering program mirrors the current full-time evening 2+2 programs in Civil and Electrical Engineering. The new program courses have been prepared using the ABET engineering accreditation criteria, and the new team of mechanical engineering faculty is working on collection, assessment and evaluation of the courses in order to provide a quality educational experience for students. Currently, Introduction to Mechanical Engineering is offered to the freshman and sophomore students. The authors believe that a transparent, well-understood process of continuous data collection and course assessment and evaluation is critical for the success of the new program. Early improvement and goal-oriented changes will also keep the program viable in the long term. Once a course is taught, it is essential that each faculty member reviews and critiques the

assessment instruments and assessment indicators used to evaluate the course. This ensures the validity of not only the course material, but the evaluation materials as well[5]. The course evaluation materials will be archived and used in the program evaluation process for the future ABET accreditation.

All freshmen engineering students are required to take an Introduction to Engineering course in their respective major. The Introduction to Mechanical Engineering course was offered for the first time in the fall of 2014. The number of students who enrolled as mechanical engineering majors was double the anticipated number and created some anxiety on resourcing the new program in subsequent years.

As a new mechanical engineering program being offered for the first time in the fall of 2014, not all of the planned faculty has yet been hired to fulfill the needs of the program or the student's interests. It is critical that the current faculty communicate with the students about the constraints facing a new program. For instance, the number of current faculty must match the required teaching load based on the student population. Similarly, hiring faculty to oversee and develop one of the focus areas may not be necessary if there is little student interest or demand for one of these areas. One tool that the current faculty developed to monitor student interest and use to allocate resources is a simple survey administered every semester. At the program level, it provides insight to how many sections there will be in particular courses in future years and assists in prioritizing faculty hires with particular mechanical engineering backgrounds.

Additionally, the survey has shown the instructors and advisors how much a little introduction to different areas of mechanical engineering can influence student interests. Students may have taken an Introduction to Engineering course in high school, but really know very little about the breadth of mechanical engineering and even less about some of the specialties. By providing an overview of each one of the five focus areas and some activities for each, the students have a descriptive and active experience for the five focus areas and can make an informed decision their junior year on which one to pursue.

Research Questions

One goal of the new course content is to develop additional interest in mechanical engineering and determine a specific focus area for future studies. Another goal of the course was to ensure the students had a positive experience in the new course and program. Results of an end of the course survey show the evaluation of the course objectives. Additionally, student evaluations of the instructors were very positive. If a program places their worst teacher with the freshmen, the students will make quick comparisons with the teachers they have from the multiple departments within the institution and may decide to change majors based on the quality of the teaching alone[6].

1) Can student interest in a focus area be influenced by a simple awareness of the sub-disciplines in mechanical engineering?
2) Will the course meet its objectives - how will freshmen mechanical engineering students receive the new Introduction to Mechanical Engineering course?

Course Overview

The mechanical engineering faculty at The Citadel recognizes that graduating engineers will be expected to function effectively on multidisciplinary teams where effective skills related to team work, collaboration and communication will be necessary and valued. The Introduction to Mechanical Engineering course is intended to expose students in the freshman year to an engineering design environment with multiple solutions that emphasizes team work, communication and the interdisciplinary nature of solving engineering problems. At the same time, the faculty wanted to expose the students to the different focus areas that will be offered in the curriculum. The course attempts to cover a range of mechanical engineering and introduce the students to some basic engineering tools and principles. The instructors attempt to generalize the teaching to motivate and educate a body of diverse students. Since students come from a variety of backgrounds, the range of students and abilities is advantageous to all concerned. The engineering principles allow the instructors to make connections and draw analogies and demonstrations across different areas. A course schedule is in the Appendix.

Course Description: Introduction to Mechanical Engineering.
The engineering design process is demonstrated through use of practical problem-solving methods for mechanical projects. Course subjects include mechanical engineering career paths, ethical canons of the engineering profession, and requirements for professional licensure. Course assignments, conducted within a collaborative learning environment, focus on creative engineering solutions through technical analysis, teamwork, communication skills, and professionalism. As a foundation for sustained success in mechanical engineering, additional course topics include: lifelong learning, time management, community and professional service, and career development. Laboratory: two hours.

Course Objectives: Students who successfully complete the course requirements should be able to:

1) Explain the engineering profession and engineering ethics.
2) Use technical communication skills to explain the results/analysis of introductory laboratory exercises.
3) Explain engineering analysis and design.
4) Analyze data collected during laboratory exercises.
5) Analyze the impact engineering has had on the modern world.
6) Design a simple engineering device, write a design report, and present the design as part of team.

Course Activities:
Aeronautical - Airplane Contest: Students receive a short lecture on the fundamentals of flight and are allowed to build a paper airplane from one of six standard designs. They can use different papers, materials (paper clips, tape, etc.). All materials have a different cost. A formula is used to calculate their score based off of distance flown minus the weighted cost of time used to build and materials used.

Manufacturing – Field Trip: Students toured the campus facilities repair shop to learn about different equipment, their use, and safety.

Composites – Guest Lecture: One lecturer who spent over 30 years in the industry discussed composites and their application.

Power and Energy - Gear Train Design: Students had to build a gear train from Legos to lift a 2.0 pound weight in the least amount of time. Their design was iterative, often finding a solution that worked, and then improving it to be quicker.

Mechatronics – Lecture: This was a continuation of the Power and Energy block with the student gear trains powered by electrical devises. Students received an overview of Mechatronics and their applications

To help ensure a beneficial engineering activity, it is important to ensure that tasks are reasonable for students based on knowledge, supplies, and time required. Giving students projects which are very wide in scope, or quite undefined, can make it challenging for students to initiate a solution. Additionally, projects which require a great deal of specialized supplies and construction may not be feasible given the budget, workspace, and time constraints of the freshman students. These freshman engineering projects were designed to complement students' classroom education while supplementing it with team based, collaborative problem solving in a professional setting.

In addition to introducing the focus areas of the mechanical engineering program, the course also seeks to prepare students to become professional engineers. Several lectures are devoted to engineering ethics, professional licensure, and case studies of engineering design failures. Additionally, skills necessary to be a successful engineer such as technical writing, verbal communication, and time management are also covered.

Survey and Findings

The method included student survey data that was collected during the first and last days of class and focused on measuring student's interest level in each of the five focus areas. The data from approximately 77 students was included in this study. Throughout the semester, the students received lectures on each area and some hands-on activity if coordinated and scheduled. At The Citadel, the main goal in the course for freshmen about each focus area was not to persuade them toward any particular focus area, but rather present them with information to make the most informed decision that can make, and hopefully lead to a satisfying and rewarding career.

It was extremely important for the validity of the study that every student understood that individual data would never be used against a student, especially if the student was interested in a focus area that was in another instructor's specialty. This was explained to the students at the start of the semester and before each time the survey was administered. They also understood that the faculty needed the data to plan and resource. Students were very agreeable to contribute to the effort as long as they could see results of the data. Figure 1 shows the results of the surveys from August and December 2014.

With an aeronautical manufacturer in the local area and the support activities generated by that industry, it was no surprise that the initial majority of freshmen expressed aeronautical engineering as their number one choice. Speaking to many students and their parents before the beginning of the academic year showed there was much interest in this area. By December, the interest in the aeronautical focus area had decreased.

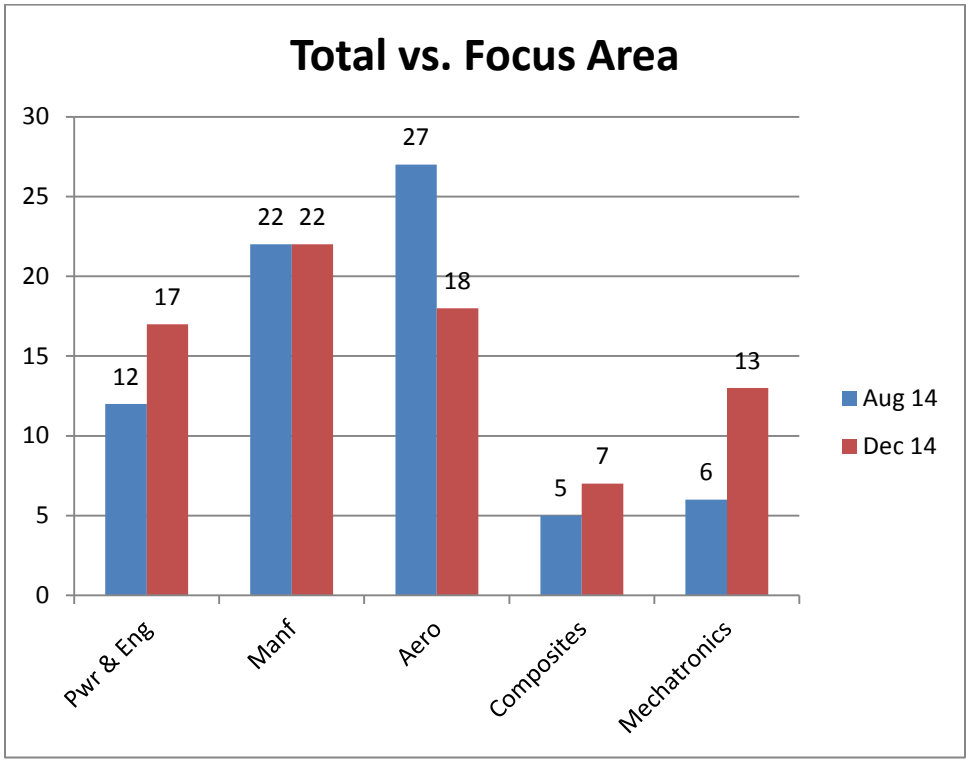

Figure 1: Focus Area Interest

The first question of this paper was to examine if student interest in a focus area be influenced by a simple awareness of the sub-disciplines in mechanical engineering. Figure 1 shows that the Manufacturing focus area remained the same, but the other four focus areas leveled. The Aeronautical area had the only decline. Students did see guest presentations from several employees in the aviation business, all which were well received. However, students did change their interests to other focus areas.

The course achieved the goal of providing freshman engineering students with a better understanding of the individual mechanical engineering focus areas. The structure and content of the individual lectures and hands on activities were effective in delivering the necessary instruction to achieve this understanding of the different areas. Responses provided at the beginning and end of the semester show a definite and measurable increase in student awareness and understanding of the mechanical engineering profession. Students indicated in free text comments about the lectures and hands-on activities the appeal or perception changes they had

concerning the focus areas. This means that critical information provided by specialists in the focus areas was effectively conveyed to the student population.

Since not all focus areas included hands-on activities, there was the potential to bias students towards some areas more than others. Plans for future iterations of the course include a hands-on activity in each area to minimize any impact this may have. In fact, there was overwhelming feedback from students to include more hands-on activities throughout the course. While not every focus area received the same amount of time in the classroom, there does not seem to be a correlation between time spent on a focus area and changing student interests. It will be interesting to see if any correlation exists between changing student interests and different hands-on activities in each focus area through several offerings of the course.

Many students have already started to tailor their courses and internship opportunities based on the introduction to these focus areas. Some now have new understandings of the breadth of some of the focus areas such as: 1) power and energy applies to vehicles, not just the power grid; 2) composites and advance materials have far reaching applications in several industries; 3) mechatronics is not entirely robotics, mechatronics has far reaching applications in manufacturing, control of vehicles, and instruments; and 4) manufacturing is more than just processes and without it, nothing comes to market.

The second question is will the course meet its objectives - how will freshmen mechanical engineering students receive the new Introduction to Mechanical Engineering course. The effectiveness of the course was measured by a survey of the course objectives. Assessment in terms of student feedback was solicited by surveying 100% of the entire freshman mechanical engineering class. Figure 2 shows the results of the survey concerning course objectives.

The survey is significant because the results are unbiased since the majority of the class is made up of first year students, who never used The Citadel's End of Term Survey. The results are high, all above 4 points on a 5 point Likert scale (Table 1). The highest score came from question number 5 rating the impact of engineering on the modern world. Although no pre-course assessment was conducted by the students or instructors, answers provided at the end of the semester on exams and surveys show a definite and measurable awareness and understanding of the engineering profession as it relates to ethics, communication, team work, and engineering problem solving.

Table 1: Assessment Scale

1	2	3	4	5
strongly disagree	disagree	neutral	agree	strongly agree

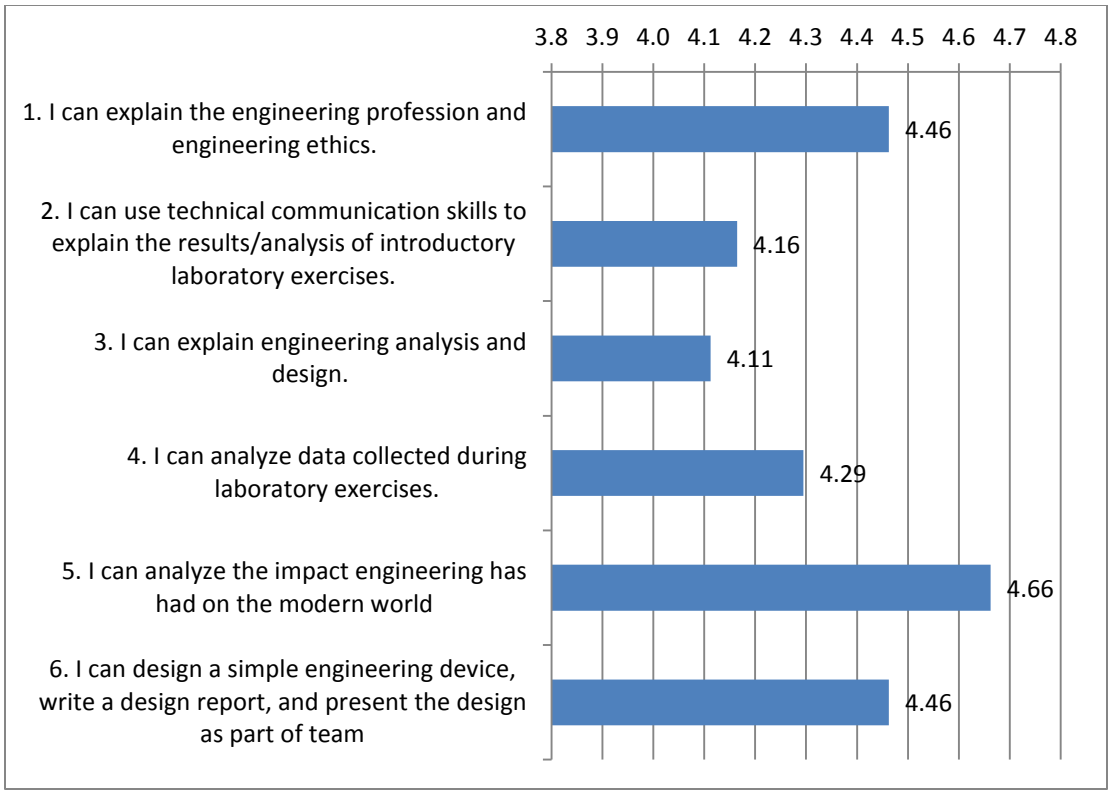

Figure 2: Course Objectives

Using the same Likert Scale, students were asked to evaluate their instructors through 14 different questions on an end of the course survey. Student evaluations of the instructors were very positive. Figure 3 shows the average of the 14 questions for each of five sections in the Introduction to Mechanical Engineering course. Any new, growing program must ensure its best instructors are in front of new students. At the minimum, instructors must perform above average for new students in order to keep them engaged and excited about engineering. As mentioned earlier, if a program places their worst teacher with the freshmen, the students will make quick comparisons with the teachers they have from the multiple departments within the institution and may decide to change majors based on the quality of the teaching alone[6].

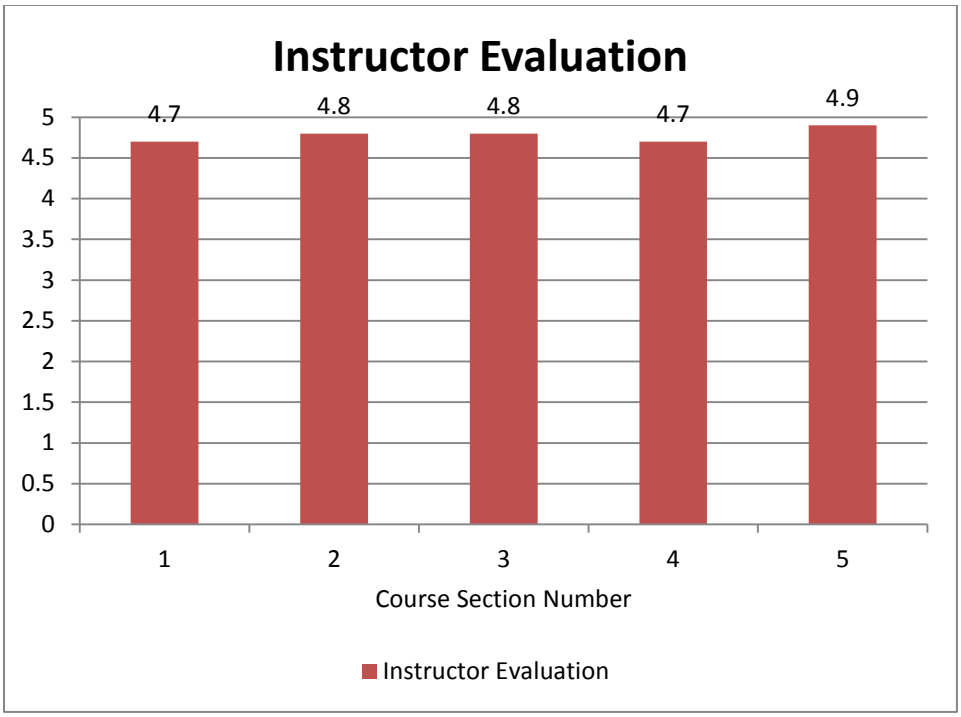

Figure 3: Student Evaluations of Instructors

Questions concerning the faculty's effectiveness included:

Q1. My professor displays a clear understanding of course topics.
Q2. My professor seems well-prepared for class.
Q3. My professor speaks audibly and clearly.
Q4. My professor displays enthusiasm when teaching.
Q5. My professor makes good use of examples and illustrations.
Q6. My professor makes effective use of class time.
Q7. My professor begins and ends class on time.
Q8. My professor is readily available for consultations.
Q9. My professor effectively challenged me to think.
Q10. My professor communicated the subject matter effectively.
Q11. When I have a question or comment I know it will be respected.
Q12. I would recommend taking a course taught by this professor.
Q13. I would enjoy taking another course from this professor.
Q14. I would rate my professor as an excellent teacher.

Conclusions

In this present study, it is difficult to arrive at conclusions on how this course affects freshman mechanical engineers in the long term. The program will continue to monitor the statistics to ensure this exciting, fun, challenging freshman engineering course continues to have a truly dramatic impact on the decisions and interests of mechanical engineering freshmen as well as increasing numbers retained through graduation. The students want to have fun while learning

about engineering. This includes learning about the history of engineering, the design processes, and a little about the mechanical engineering focus areas within the program. Even though there is only one year of data, the course appears to connect the students to the mechanical engineering profession sooner than normal. Based on the data collected this year, the instructors concluded that the orientation to the five focus areas is extremely important for the students to make an informed decision when choosing a focus area their junior year. Helping students to connect to their profession is critical since the majority of the engineering courses are taught during the last two undergraduate years. The students do not ask for the course to be easy when their future will have lots of challenging engineering courses. They know that becoming an engineer is not the easiest path to a degree, and the pay and benefits of being an engineer do not always motivate a student to stay to graduation. What everyone wants is a little excitement each day about going to class, a little reminder of why they chose mechanical engineering, through fun and challenging experiences that prepare them for their future. The student feedback was a simple way to show the faculty their interest and reinforce some good elements from the course structure.

Recommendations for Further Research

The first area for future research is to corroborate the results with future cohort classes in mechanical engineering. The sample population in this study was 77 students, and it was the first group of freshman mechanical engineering majors. Further research is needed to show if the same results are true with new students who might have other interests as they visit campus and speak to the current group of students. Other research could focus on instructor activities to raise the overall course objectives evaluations and to determine the best techniques as well as the most effective means to introduce the five focus areas to the students. Furthermore, retention should be monitored to determine if the course has any positive or negative effects on student perceptions.

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Appendix

Course Schedule and Topics

Class	Topic	Before class:	Due in class:
1	Introduction	1.1, 1.3, 1.6, 1.7	
2	The Mechanical Engineering Professional		Memo 1
3	Ethics	2.1 - 2.4	
4	Design and Teamwork 1	3.1 - 3.6	HW 1
5	Design and Teamwork 2	3.7 - 3.10	
6	Junkyard Airplanes 1		HW 2
7	Junkyard Airplanes 2		Airplane Design
8	Engineering Communications	4.1 - 4.4	Airplane Report
9	Myers Briggs Personality		
10	Estimation	5.1 - 5.8	
11	Bridge Construction Project		HW 3
12	Fundamental Units	7.1 - 7.8	
13	Universal Units	8.1 - 8.11	
14	Measurements Exercise		HW 4
15	Midterm		
16	Professional Licensure and Growth		
17	Time Management	Pg 277-279	
18	Manufacturing	Handouts	Measurements Report
19	Machining	Handouts	HW 5
20	Engineering Materials	Handouts	Manufacturing Report
21	Power and Energy 1	Handouts	
22	Power and Energy 2		Materials Report
23	Gear Design Project 1		
24	Gear Design Project 2		Gear Design
	Fall Break		
	Fall Break		
25	Alternative Energy 1	Handouts	
26	Alternative Energy 2		
27	Resume Workshop		Power and Energy Report
28	Course Review		Resume
	Final Exam - Scheduled by Registrar		