First Year Engineering Curriculum at Youngstown State University

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Introduction

The first year engineering curriculum at Youngstown State University is a two-semester sequence of courses taken by qualified first year students of all engineering majors. This sequence was started about five years ago and has undergone yearly evaluation and fine-tuning as we try to get the best possible experience for our engineering freshman. This paper outlines the evolution to our current course make-up including the elements we feel are positive and beneficial to the program as well as those that did not facilitate the success of our program. It also specifies, in more detail, the current structure of the freshman engineering program at Youngstown State University.

Background Information

Prior to beginning the current freshman engineering program at Youngstown State University the engineering curriculum structure for the engineering freshman was typical of most engineering schools at the time, i.e. mostly courses in math, physics, chemistry, communications, and social studies. A survey of engineering course was required and it was a two quarter hour lecture course in a large auditorium with about 200 students. Each engineering program was responsible for about two weeks of the course and used the time to try to sell their particular program to the students. There were no prerequisites and no technical content, just a survey of the particular field of engineering with occasional speakers on other topics of interest. As the quarter went on student interest waned and to get the students to come to class and pay attention got to be a chore. Course assessment data and informal student interviews showed that this mode of introducing our freshmen to engineering had serious shortcomings.

The typical engineering freshman subjected to this exposure of courses was comparing the rigorous math and science courses being taken to this survey of engineering course and was not very favorably impressed with engineering. Many students who were originally interested in engineering lost interest and transferred to other fields; especially math, computer science, and chemistry here at YSU. Even more discouraging was that many of the students transferring were the top students who wanted what they viewed as a more challenging major. Approximately

60% of our beginning engineering freshman remained in engineering at the beginning the sophomore year.

A new dean of engineering arrived in 1995 and was very concerned about declining enrollment in engineering at YSU. Low retention of engineering freshmen was quickly identified as a potential problem area and research into a solution began. A Freshman Engineering Task Force was formed and work began to review the current program and make recommendations for an improved freshman engineering program. Student exit interviews were reviewed and approximately 60 current engineering students met with task force members for input. The work by Ray Landis [1] and others on novel freshmen engineering programs was also reviewed and the improved retention rates shown were the driving force to modify the existing programs.

The first decision was to require the freshman engineering program courses to be taken by all engineering majors; chemical, civil, electrical, industrial, and mechanical engineering here at YSU. Courses were given up by all the majors in order to get the required space in the curriculum. Three courses were developed, one for each quarter, and each course was worth 3 quarter hours and included a laboratory component. The courses were designed to incorporate features that would maintain students' interest in engineering and develop useful skills for later parts of the engineering curriculum. Faculty resources would need to be about the same as required for the courses replaced so that the program could be instituted without requiring the addition of new faculty.

The factors determined as fundamental to a successful freshman engineering program were established and as much as possible incorporated into the new courses. These are listed below:

1. The courses needed to give the student hands on exposure to doing engineering type activities so that their interest in engineering could be nurtured.
2. For improved success in the curriculum, it was thought that freshmen students needed to get to know other freshmen students in their major and form study and social groups to enhance student success.
3. With a large commuter student population, freshman should be exposed to University activities to try to discourage a return to high school friends and activities. This would encourage student retention at the University.
4. The courses should make use of some of the math and science materials presented in the calculus and physics and chemistry courses so the student could see the need for a strong math and science background.
5. Modern computing applications were needed with appropriate computer skill development.
6. Students should learn to work effectively in groups; especially with other students who they initially did not know and who have different intended majors.
7. Technical report writing should be introduced.
8. A freshman faculty and coordinator would need to be established so that consistency in the program could be maintained. Faculty need to be good at working with students.

9. Design the program so students have one on one contact with engineering faculty as much as possible.
10. Use student lab assistants who are engineering majors with all majors represented, both men and women. Encourage one-on-one contact with the lab assistants to provide counseling, a friend, and potentially a role model.
11. Provide an exposure to all the engineering programs so that students could decide more intelligently on an engineering major. If engineering is not for the student this is to be respected and the class not a failure if a student intelligently decides to change to another major.
12. Provide an introduction into proper time management and proper study skills.
13. Provide an introduction to internship and coop opportunities and procedures.
14. Provide an overall nurturing environment to ease the transition from high school student to college engineering student.

Transition from Quarters to Semesters.

When the freshman engineering program was instituted at Youngstown State University, the university operated under the quarter system. Under the quarter system there were 3 courses developed which the students took each of the 3 quarters of the freshman year. The first course was an introductory course that was a modified freshman engineering orientation course. The second course was basically a CAD course and the third course was a structured programming course. These courses were really updated and revised courses that had previously existed in the engineering program, but they were significantly modified in an attempt to satisfy the goals listed in the previous section.

The courses were conducted under quarters for 3 years and then there was a transition to the current semester system which began in the fall of 2000. The following section describes the current semester version of the freshman engineering program. In addition, they incorporate much of what was learned in the initial years the program which was offered under quarters.

Current Course Structure of Freshman Engineering.

<u>ENGR 1550 Basic Engineering Concepts (3 SH)</u>
The first course in the current sequence at Youngstown State University is ENGR 1550 Basic Engineering Concepts, offered only in the Fall Semester. The three semester hour course is comprised of two lecture hours and three laboratory hours per week. The course replaced the previous survey course. In the lecture portion, all registered freshman engineering students, up to 200, meet together in a large auditorium. The room features curved, classroom riser seating with tables as a workspace and a visual presenter and computer connected to a projection system. The projection system is comprised of a large screen at the front of the auditorium and nine ceiling mounted televisions dispersed throughout. For the laboratory portion, several three hour lab sessions, limited to 40 students each, are offered. The lab is conducted in the college computer laboratories, set up in a more traditional classroom fashion with four or five computers per workspace table. These rooms also feature a visual presenter and computer connected to a projection system. Four or more lab assistants, who are upper-class engineering majors, assist a

faculty member in the lab sessions. Prerequisite/concurrent requirement for this course is a math course of pre-calculus or higher level.

There are several distinct sub-goals of this first course; however they are all intertwined when focusing on the main goal of successfully transitioning the first year student to becoming part of the YSU engineering community. As such, a multitude of topics are covered with, in many cases, subtle success skills being imparted. While presenting and teaching several engineering/technical skills, the course effectively introduces the student to engineering and to the university, and finally helps to develop survival skills needed to be a successful engineering student. For textbooks an electronic book is made from McGraw Hill with topics from Excel, MathCAD, and PowerPoint. Supplemental handout materials are used for other topics.

Survey/Seminar Lecture Series

A portion of the lecture is still formatted in a survey/seminar fashion. However, great care has been added to ensure that each seminar is meaningful and useful, as well as interesting to the student. One seminar series is comprised of the engineering programs offered at YSU. Each program presents information about their field of engineering during a one-hour lecture. The faculty member presents a concise lecture on his/her particular field and the current opportunities within it. In addition, upper-class students and student representatives of that program's engineering technical society, i.e. ASME, talk about their design projects and the upcoming society functions. The freshman students find the information given by the higher level students very informative as they enjoy listening to what a student is doing or will be doing in his/her particular major. Finally, the freshman students are invited to and encouraged to participate in student organizations and activities, at which they can make more contacts with upperclassmen in their field of interest. This connection to other students in their major helps to form a support group for both school study groups and social activities.

Another seminar series is comprised of support/service organizations associated with the university in general, which are openly available to all students. In order to enhance the students' chances for success in all their classes, university personnel from the Center for Student Progress lecture very early in the semester on on the proper way to manage time and proper study methods for success. A large part of the Center's services is dedicated to the first year student, providing peer assistants that are actually in the student's college and mid-term grade reporting. They also present information on the multitude of services they offer the student free of charge; for example a support group for the non-traditional, older student. Career service personnel lecture more toward the end of the semester supplying information on what employers' desire of coop and internship students along with the skills required by employers of engineering graduates. They provide the students with the procedure that they must follow in order to participate in university sponsored job interviews or internship/coop positions. They also give information on other services that they offer; for example help with writing a resume'. These presentations show the freshman students that there is a university wide network that is available to help them achieve as students and as graduates.

Design/Analysis Based Lecture Overview

The balance of the lecture portion of the ENGR 1550 Introduction to Engineering course is conducted in a design/analysis based lecture format in which the currently assigned project is used as a springboard for the lecture topics. There are typically three or four out-of-class design/analysis projects that span the semester. A brief introduction is given on the entire design process as broken into six steps: 1) Problem Identification 2) Preliminary Ideas 3) Refinement 4) Analysis 5) Decision 6) Implementation. This is done with the intention of relating to the students that there is a methodical approach to design and problem solving that doesn't rule out creativity. This format allows for all aspects of any project they will encounter as an engineer to be addressed, from the first brainstorming session to a prototype machine to the final technical design report. Through the process, the students discover first hand how the application of math and science principals fits into engineering design and analysis as well as how to systematically complete design and analysis at a level fitting of an engineer.

While discussing the design process, the majority of time is spent explaining the importance and application of the analysis step. The goal is to show how engineers use mathematical formulas to predict and evaluate design performance. This step was revisited as each new project was assigned so that the laws and formulas that were applicable could be discussed. Originally, the equations were presented to the students in lecture form as they might see in a dynamics or fluids class. Much confusion ensued. Surprisingly, the vast majority of them had never applied even simple mathematical formulas to model physical phenomenon and very few were taking college physics the first semester. To aid in understanding, when possible, a small experiment is brought in, and equations are presented and discussed as they occur in the experiment. For example, when explaining the application of Bernoulli's equation, two funnels were brought in, identical to each except for the diameter of the exit hole. After the equation was written on the board and water was added to one of the funnels, the students could then visually see why the pressure terms cancelled out and why the velocity of the liquid at the top of the funnel could be approximated as zero. They then could understand how to algebraically solve for the exit velocity of the liquid. The students realized, much to their surprise, that the velocity of the exiting liquid did not depend on the diameter of the exit hole. It was at this point that both funnels were filled to the same height so that the concept of flow rate and how it depended on the exit diameter could be discussed. This technique greatly improved the students understanding of the connection between the formulas and the actual events.

Past experience with the project-based class, which requires a write-up of each project, has also shown that the students are particularly ill prepared in generating a logical, structured technical report. Therefore, much structure is given as to what would be expected in the report while leaving it up to the individuals as to how they would accomplish this. The students are first presented an overview of technical report writing. Comparisons are made to other types of writing so that they can see the importance of presenting technical data and information in a structured, organized fashion. The major components, 1) Introduction 2) Report Body and 3) Conclusion, are discussed in general. Once the students understand what their report should accomplish, a structured list with explanations of what is expected in each component can be given.

The projects are a group venture with teams consisting of four members each. The students are allowed to form their own teams. Even still, the vast majority of teams consist at least partially of members who have had no prior interaction with each other. To add to this, Youngstown State is predominately a commuter university, making it difficult to form teams in which the students have similar schedules outside of class. Therefore, class time is taken to discuss team dynamics using the Tuckman Model [2]. This is done with the intention that by being exposed to the pros and cons of teamwork and to the evolution that teamwork follows, unproductive team dynamics will be minimized. By the third project, most students have found others that they work with effectively and have formed new support groups that will help them succeed in their subsequent studies. In addition to the information presented in the lecture, the completed projects draw from the skills also taught in the lab setting. Therefore, the laboratory setting will be discussed before further elaboration of the design projects.

Laboratory Software Skills and Miscellaneous Assignments

Software skills within the lab are comprised mostly of programs already familiar to the typical university student. However, the students are instructed in their use with an emphasis on the usefulness of the program to engineering. For example, an MS Word assignment is presented with the requirement to use equation editor and tables, something the vast majority of students do not know how to use. The MS Excel assignments include correct use of formulas and functions, graphing of engineering equations, and logical if-then statements. The students learn effective web search techniques and web page construction, and they are required to make a personal web page that can be updated throughout their schooling at Youngstown State. The entire list of the students' url addresses is available on the engineering server web page so that a student can contact any other student in the class (inclusion of email address is a requirement on the web page assignment). The students also receive three to four week instruction in Mathcad, a mathematical solver software program almost all of the students are not familiar with. Assignments include simple engineering problems for the student to solve. Bonus points are given to students that use Mathcad to "check" assignments from their math class. The final skill presented in the lab classes is an introduction to basic programming logic through LEGO® Mindstorms™ kits. The student teams are required to build their robots out of the LEGOS provided and then program the RCX controller that ultimately starts/reverses/stops motors based on inputs from touch and light sensors and from internal timers.

The laboratory time is also used for lab tours of program laboratories at which the students can see some of the hands-on lab experiences they will be doing as a higher level engineering student. This further helps to expose the students to the various fields of engineering. Local plant tours, when available are also included during lab time.

Design Projects

The design/analysis project requirements vary from year to year, therefore four characteristic projects are discussed as follows.

One design project that has been used in this class is an index card structure designed to support as much weight as possible at the lowest relative cost. The twist to this project is that it is an

optimization design in which the strongest design is not necessarily the best. The students are given general information in class on the analysis of structures which culminates in the analysis of a simple truss design. They are also lectured about the pros and cons of designs from an economic point of view. The teams are then given the design requirements and the formula for determining the cost of their structure. Typically, a structure costs $1.00 for each index card used plus $0.50 for each fold in the card plus $0.75 for each staple used. During testing of the structures in the lab, a piece of plywood is placed on top of the structure and then bricks are piled on top. The winning design is the one that has the largest bricks held to structure cost ratio. After the competition, failure modes are discussed; for example many structures fail due to instability rather than strength. The students are required to submit a technical lab report of their design, including information from the early design stage through the final results of testing.

Another design project, which has become an annual design competition, is a Rube Goldberg project in which the students are to design a machine that will time three minutes as close as possible without going over. The students are required to have at least ten unique events in their machines, of which three must be a lever, a funnel, and a ramp. These three events are required so that the students can see how an engineer would use mathematically models to predict their performance. During the lecture, the students are instructed in the applications of the Law of Conservation of Energy, Principles of Levers, Equations of Motion for constant acceleration, and Bernoulli's Equation. Using the appropriate equation, the students have to predict the time of the portions of their machine that contain the three required events. They then experimentally determine the actual time that those particular portions of the machine take. In the comprehensive technical design report, the students are required to present their theoretical analysis, using Mathcad®, and to compare the theoretical prediction to the experimental findings. They are to address and discuss any discrepancy. The report details the entire design process and methodology the students followed. This project as a whole further introduces the students to the engineering concept of mathematically modeling a design based on the appropriate scientific principles.

One analysis project used to introduce engineering principles to freshman students was the analysis and testing of potato cannons. The students are again required to conduct a web search, with an emphasis on the scientific principles inherent in this type of machine. In the lecture, the students were given the basic thermodynamic information regarding combustion as well as the appropriate equations for projectile motion. During the lab, potatoes of known mass were fired from the cannon at three different elevation angles and the linear distance traveled was recorded. For fuel, propane gas was quantitatively added via a calibrated syringe to the combustion chamber so that the students could observe how different amounts of fuel affected the potato gun. Ultimately, the project required the students to determine the kinetic energy of a potato fired from a cannon fueled by propane and air and to compare this energy to theoretical predictions based on combustion chemistry. They also were required to use their newly developed Excel skills to analyze the data; for example, they plotted the kinetic energy versus percent fuel in the combustion chamber. With this graph, the students could see that the results of the experiments accurately showed the upper and lower explosive limits of propane in air and the volumetric ratio which propane and oxygen were in stoichiometric proportion. Finally, the students were required to write a formal technical report of their findings.

Another analysis project used to introduce engineering principles to freshman students was to investigate the problem of predicting the height a model rocket can obtain and compare this prediction with the actual height achieved by a model rocket launched by the group. Within this project, the students are exposed to engineering laboratories as they experimentally obtain model rocket engine thrust characteristics. The application of Newton's Second Law to rocket flight provides a good introduction of this basic principle. In addition, since the equations developed do not lend themselves to a closed form solution, students are introduced to approximations and numerical solutions. Students need to formulate a computer program using MS Excel to solve the problem of predicting the height of the rocket. Finally the students actually build the model rocket, design a method of measuring the height achieved, and field test it to obtain a measured height to compare with the predicted results. The results are analyzed and conclusions reached about the sources of inaccuracy in the entire project. This project finishes with a technical lab report.

Enrichment Requirements

Enrichment activities are also required as a small portion of their final grade, typically five percent. The students must attend at least three university sponsored athletic events, theater performances, on campus speakers, professional society meetings, etc. A list of typical activities is given on the class web site. In all cases, for credit students must attend the event with another student in the class. This requirement has in the past been severely questioned by students. It became important to explain that engineering isn't just math, science, and computing; that they need to also be able to effectively interact with a diverse work force and work in a team setting. Most, if not all, engineering job assignments have a social component and YSU graduates need to be prepared to perform well in that part of their job. In addition, it is explained to them that by attending these events with classmates, life long contacts with other engineers can be established which can be very beneficial once entering the work world.

Originally, the enrichment component was a requirement in all three freshman-engineering courses. Because of the continued complaint from students about outside schedules and time commitments, it was decided to use the enrichment requirement only in the first semester (ENGR 1550). By the end of this class, most of the students have already started and formed a new network of friends and colleagues. Also, initially for credit a lab assistant or faculty member would be present at the event and students were required to sign in with the class representative. With over 150 students, this got proved too cumbersome and was therefore relaxed and an honor system of reporting via e-mail was established.

ENGR 1560 Engineering Computing (3 SH)

The second course in the sequence is ENGR 1560 Engineering Computing. It is offered only in the Spring Semester. This three semester hour course replaced various computing and CAD courses in the different curriculums. The course meets for an equivalent two hours lecture and three hours of lab per week. It is scheduled as a combined lecture/lab course typically three days per week at one and a half hours per day. This class is typically limited to thirty students and is conducted in a computer lab classroom where each student has a computer. The instructor has a visual presenter and computer connected to a classroom projection system so that lectures can be

tutorial based. A lab assistant is present for the entire class to assist the instructor. Prerequisite is ENGR 1550 and concurrent Calculus I.

The goal of this course is somewhat different than the ENGR 1550. Most of the students that continue with this second class of the series have decided that they would like to pursue the field of engineering. Therefore, the focus is turned away from introducing the engineering profession and turned more toward imparting important computer skills. It is expected that this class will help the students become somewhat proficient with computer programming, CAD 2D drafting, and CAD Solid Modeling. The computer programming language currently used is Visual Basic which is covered for about six weeks of the course. For CAD 2D drafting, AutoCAD is used and this exposure lasts about five weeks. This is followed by about three weeks of solid modeling using Solid Edge. For text books "AutoCAD Companion" by Leach is used along with internally developed handout materials for Visual Basic and Solid Edge. The class is conducted by beginning each session with a fifteen to thirty minute lecture, dependent on the subject material, followed by an assignment which is to be done typically by the end of class. The instructor and lab assistants circulate in the room to assist the students.

In this semester, there is typically only one design project required. However, the project is comprehensive utilizing all three of the computer skills presented in the course. It is a group project consisting of about four students per team. Along with design aspect the teams are required to submit a comprehensive technical engineering report and make a Power Point presentation describing their design and the design process. The presentations are taped so that the student can view and self critique his/her presentation. As a sample, one year the teams were required to design a deck to add to one of the teammate's house. The students had to measure the actual house before beginning the design. The project included AutoCAD drawings of their design, including but not limited to, a plane view of the overall layout of the deck to the existing structures on the property, as well as front and side views of the finished structure. The students also had to create solid models of the detail components, such as decorative railings. Finally they had to write a Visual Basic program that calculated the actual perimeter of their deck and the approximate area of any deck with four to eight sides.

One issue we would like to change, but cannot at this time is switch away from 2D drafting with AutoCAD and go to a more 3D solid modeling approach with a Solid Edge type package. Local industry is still tied closely to AutoCAD so we have had to continue with it so as to enhance students' chances for internship and coop opportunities. As this changes locally we would surely switch to a solid modeling approach with drawings developed from the solid model instead of using a 2D AutoCAD type package.

<u>ENGR 1555 Engineering Drawing and Visualization (2 SH)</u>
An optional course in the sequence is a non degree credit ENGR 1555 Engineering Drawing and Visualization (2 SH). This course is offered all semesters of the year including summer. This course replaced a high school makeup course in pencil and paper drawing for those students who did not have a previous exposure to 3 view drawings. This course was added late in the freshman program development when it became apparent the students in the CAD part of 1560 could not visualize the traditional 3 view drawings done in the class. This course meets 1 hour

of lecture and 3 hours of lab per week. It is typically scheduled as combined lecture and lab for 1 hour per day 4 days per week. This class is held in an auditorium with a visual presenter and computer connected to a projection system and students have tables as a work space. Class size varies with each offering with up to 70 students per class and approximately 1 lab assistant for about 25 students. There is no prerequisite.

The goal of this course is to develop the students' ability to visualize a part given the traditional 3 view drawing and to understand the standard drafting conventions used in engineering to document engineering designs. The course does not use any drafting equipment; only sketching is used to create drawings. A text and combined workbook is used for the course ("Engineering Graphics Text and Workbook" by Craig and Craig, Schroff Development Corporation). The course begins by giving the student an isometric of a part and having them create the standard 3 view drawing. Next the 3 view drawing is given and the isometric required. This is followed by section views, auxiliary views, dimensioning, tolerancing, threads and fasteners, and finally assembly drawings. There is a final design project where students design a multipart system and have to create detail and assembly drawings.

The class is conducted by generally beginning each session with a 5 to 15 minute lecture followed by an assignment which is to be done by the end of class. The instructor and lab assistants circulate in the room to assist the students. Homework is returned almost daily to keep the class moving and quizzes are given every two weeks to keep students progress monitored. The results of the class are generally favorable; however some students seem to have great difficulty in visualizing. All students who have not had a high school drafting experience are required to take the course. It can be taken prior to or concurrent with ENGR 1560. Recently, a trial of having incoming students take the class during the summer session before the typical fall semester beginning worked very well. This aided the transition from high school to the university, aided the students with adapting to university life, and facilitated the early faculty-student contact. This concept will be pursued in future years.

Conclusions

The overall goals of the integrated freshman-engineering program are to improve student retention while equipping the student with necessary skills to become a capable engineering student. The Engineering Deans' office supervises the program and maintains assessment and student related enrolment data. Based on this data and personal observations of the faculty the following conclusions are presented.

1. Retention of freshman engineering students to the sophomore year has improved from about 60% to 85%.
2. The number of students working in study groups in the Engineering Program has significantly increased.
3. Students' computer skills have significantly improved.
4. Students' spend much of their available social time with other engineering students rather than going back to their high school friends.

5. More students are seeking and obtaining engineering internship and coop assignments.
6. The students seem to be far more loyal to the Engineering Programs and are proud of their school and program. As they get to the sophomore and higher level in the programs they are excellent ambassadors for the programs and it would be extremely difficult to get them to change majors or transfer to another school. They have been transformed to a loyal engineering student and much of their out of school life revolves around the people they have met here.

The freshman engineering program at Youngstown State University is thought to be very successful. It has improved retention and improved the attitude and soft skills of many of the engineering students. However, this would not be possible without the efforts of faculty members who have the correct personality and teaching methods that work with freshmen engineering students and an administration that strongly supports the program. With these critical components in place freshman engineering programs like the one described in this work are a significant part of a successful engineering program.

Bibliography

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