A Comprehensive and Culminating Thermodynamics Lab Competition

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Introduction

Lab components to engineering courses are valuable for providing students with hands-on experiences, demonstrating principles learned during lecture and developing basic experimental and measurement skills. Depending on the target learning outcomes, students in a lab class may take part in a variety of experiences including demonstrations, "cookbook" type experiments, guided inquiry exercises, and independent/design projects (Edwards & Recktenwald, 2010; Prince & Felder, 2006; Prince & Felder 2007). Typically the lab component runs concurrently with lectures throughout the semester, allowing the lab material to coincide with lecture material. As the semester nears completion student anxiety typically increases and it is common for instructors to spend the final lecture reviewing material rather than squeezing in one more topic. This allows students to revisit material learned, spot gaps in their knowledge, ask any lingering questions, and works to quell the building anxiety.

It was with this mentality that the following lab experience, nicknamed the Labstravaganza, was created for a standard thermodynamics course. As a way to review material learned throughout the lab component different elements from many of the individual labs were integrated into a comprehensive competition amongst student groups. The goal of this was to revisit the material without relying on lecture or testing and finish up the lab component with an academically rigorous yet spirited experience. The competition was based upon four challenges which incorporated energy and entropy balances, specific heat, the incompressible model, ideal gas laws, psychrometrics, thermocouple construction, unit conversions and required students to use their engineering judgment to make choices and predict outcomes. Surveys were used to assess student attitudes towards the exercise and possible improvements are discussed.

Competition Description

In preparation for the competition lab tables were spread out to the far corners of the room so that students would be less tempted to eaves-drop or interfere with other groups. Each table started out with all of the necessary materials that would or could be used throughout the competition. A list of these materials can be found in the Appendix. Teams of 3-4 students were created by drawing names from a hat and students were advised on the following rules:

- no cell phones, computers, or internet in any capacity
- textbook and teammates are your only reference materials
- if something is unclear ask for clarification
- any answer submitted is considered a final answer and cannot be changed
- no spying on other teams or purposely disrupting/interfering with them
- each team member must understand how conclusions were reached and be able to explain the process

- answers must be neat, easy to follow, and include units where appropriate

A lifeline was also available to the teams in the form of a single yes/no question asked of the instructor. Any clarifying questions were not considered as use of their lifeline. At the conclusion of each challenge the instructor judged the answers turned in and awarded a few extra credit points to the team who did the best. To ensure that all team members were participating, a member of the winning team was randomly selected to explain part of the team's answer. If it was clear that the team member did not know how or why an answer was arrived at the team would forfeit the extra credit points. The different challenges were presented to the students as follows:

Unit Conversion Challenge
A common parameter in fluid mechanics is the Reynolds number which represents a ratio of inertial to viscous forces and is defined as:

$$\mathrm{Re} = \frac{\rho V d}{\mu}$$

In the equation ρ represents fluid density, V is fluid velocity, d is a characteristic length (i.e. diameter for pipe flows) and μ represents the fluid viscosity. Determine the Reynolds number in the simplest units for the following **air** flow characteristics: (there is a 10 minute time limit for this challenge)

$V = 16{,}300$ in/hr $d = 8 \times 10^{-8}$ kJ·s^2/lb·cm $\mu = 3.74 \times 10^{-7}$ lbf·s/ft^2 $T = 45^{o}$F
$P_{gage} = 4$ Btu/ft^3 (gage Pressure)

Hot Can Challenge
In this challenge an aluminum can with a small amount of water in it will be placed on a hot plate. The water will be heated up to its boiling point and allowed to boil for a few moments so that steam is exiting the mouth of the can. The can will then be quickly flipped over so that the mouth is pointing towards the ground and partially submersed into a bucket of water at room temperature. Providing details and reasoning predict the outcome of this event (a P-ν diagram would be good to include). There is a 10 minute time limit for this challenge.

Upon receiving all the team's answers the process was demonstrated to the class. When a soda can with a small amount of boiling water is turned upside down and placed into cooler water there is a large decrease in pressure which causes the can to suddenly implode.

Heat Capacity and Humidity Challenge
On your table there are three different materials in a pot of boiling water: brass, aluminum and acrylic. The mass of each material is listed on a sheet on your table and their specific heats are:

$C_{brass} = 0.35$ kJ/kg·K
$C_{aluminum} = 0.83$ kJ/kg·K
$C_{acrylic} = 0.48$ kJ/kg·K

Also on your table is an insulated vessel with 500 mL of water inside and temperature and humidity sensors. Your goal is to add one of the different materials into the vessel with the goal of maximizing the dew point temperature inside. Providing details and reasoning, predict the final dew point temperature. After turning in your prediction place the hot material into the water, wait a couple minutes while swirling the water around then determine the actual dew point temperature. There is a 25 minute time limit for this challenge.

Entropy Challenge

On your table you will find a pressurized vessel with a valve on it and an unpressurized vessel (Volume = 26.65 in^3) fitted with a thermocouple and flare fitting. Your goal in this lab is to maximize the total entropy within both vessels while bringing them into equilibrium. The vessels cannot be moved from their space, get wet, or have a heat source applied to them. Calculate the final entropy and the change in entropy for the system and provide your calculations and results to the instructor. Also provide the details and reasoning behind your method. There is a 50 minute time limit for this challenge.

Results

Following the competition a survey was administered to get feedback from the students on this experience. The first part of the survey had students rate certain aspects of the experience on a Likert scale and the results of this are shown in Table 1. It is seen that students responded very positively to the exercise and its use as a last day lab experience.

Statement rated from 1-5 (1=strongly disagree, 5= strongly agree)	**average**
The Labstravaganza helped to strengthen my understanding of material presented in this course.	3.7
The Labstravaganza is useful as a cumulative review of material.	4.1
I was challenged at the appropriate level by this exercise.	4.2
Working as part of a team of students enhanced my learning.	4.3
Working as part of a team enhanced my enjoyment.	4.4
The Labstravaganza is a good way to wrap up the lab.	4.5

Table 1. Labstravaganza survey results

When asked what they liked most about this exercise the students enjoyed: fun, friendly, while competitive, tied everything together and covered lots of material, working in teams, the open-ended nature, extra credit and applying what they learned. When asked how this exercise could be improved the students commented that they would have liked more time or less problems, more lifeline questions for the instructor, more extra credit plus food and more explosions.

Due to the overall positive response from the students it seems that using a competition such as this is a great way to wrap up the lab component of a course. In the future more time should be allowed for the challenges, perhaps an extra 30% than suggested above, while incorporating less problems. In fact only the Hot Can Challenge had all teams submit an answer within the allotted time. With some creative thinking it may be possible to cover as many topics with fewer challenges. Alternatively, an instructor could review how the class performed on different labs earlier in the semester and use this as guidance in coming up with challenges that would incorporate only material that was initially struggled with. Incorporating the student suggestion of allowing more questions of the instructor could also work in reducing the time required to complete any challenge, though this must be balanced with a desire to force the students to figure things out as a team.

Finally, on the Entropy Challenge students seemed to not think very creatively. Despite understanding causes of entropy generation such as friction, heat transfer, and sudden processes they did little to incorporate these thoughts into how they connected the different vessels. It was common to see the groups cut a short piece of copper tubing and add flare fittings to attach the vessels and then simply open the valve. Each table had 25 feet of copper tubing at their disposal plus a propane torch allowing much greater increases of entropy to be generated as the vessels were brought into equilibrium. In the future students should be prodded and encouraged to think critically about causes of entropy generation and creatively on how to incorporate them via the materials they have at their disposal for this challenge.

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Appendix

Materials provided to the students included:

- boiling water with samples of brass, aluminum and acrylic
- thermocouple wire
- wire stripper
- thermocouple connector
- small screwdriver
- thermocouple reader
- relative humidity sensor
- insulated 64 oz. plastic mug with lid
- 26.65 in^3 pressurized air cylinder (50 psi) fitted with ball valve
- empty 26.65 in^3 air cylinder fitted with thermocouple and flared fitting inlet
- 25 ft. of copper tubing (1/4 in. ID)
- tools for making flared tubing connection
    - 45^o flaring block
    - tube cutter
    - ¼ in. swaging punch
    - hammer
    - flare nuts
- tools for soldering
    - propane canister and torch tip
    - flame striker
    - flux and flux brush
    - emery cloth
    - heat proof pad
    - vise
    - pliers
- eye protection

Intelligent Control on the S12 Microcontroller Using Fuzzy Logic Instructions

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Introduction

Intelligent Control is a modern phrase that implies using creative algorithms in computer control applications to address problems in unusual, or "intelligent," ways. One tool that is used to implement Intelligent Control is Fuzzy Logic, a scheme by which computer applications can make decisions on imprecise, incomplete, or "fuzzy" information. This approach to Intelligent Control has seen application in various commercial products, from home appliances to sophisticated system designs. The value of using Fuzzy Logic in such applications depends on the situation. Using Fuzzy Logic to detect and control the "darkness" of a piece of toast in a toaster seems to be a force-fit application, but in more complex situations, Fuzzy Logic allows implementation of non-linear control without complicated mathematical support.

The Freescale S12 microcontroller includes specific instructions in its instruction set to support Fuzzy Logic applications. The presence of these four instructions as primitive operations in the S12 makes that microcontroller unique, and especially well-suited to Intelligent Control applications. This paper details those instructions in the S12's instruction set that implement Fuzzy Logic operations, and provides some applications in which the S12's Fuzzy Logic capabilities are used.

During Spring semester, 2010, a Design Workshop course was offered in which students used the S12 microcontroller to implement applications of Intelligent Control. Based on the experience of teaching that workshop, a similar Design Workshop course is scheduled for Fall semester, 2010. This paper will include some results from the design projects conducted during the Spring workshop as examples of Intelligent Control applications using Fuzzy Logic.

The Freescale S12 processor is probably the most popular general-purpose 16-bit microcontroller currently on the market. It is used as the focus for microprocessor/microcontroller courses in many Electrical or Computer Engineering programs across the country. However, the four instructions in the instruction set that implement Fuzzy Logic primitives are often omitted from discussion because their use requires an understanding that exceeds normal microcontroller applications. This paper tries to remove the mystery surrounding the Fuzzy Logic capabilities of the S12 microcontroller, and demonstrates how they can be used for Intelligent Control.

Overview of the Fuzzy Logic Instructions

The S12 microcontroller includes four primitive instructions in its instruction set specifically intended to support Fuzzy Logic operations. These are MEM, REV, REVW, and WAV, and they are introduced briefly below. Following sections of this paper will discuss the instructions in more detail.

The MEM (membership) instruction performs the first step in Fuzzy Logic operations known as fuzzification of the external crisp input values. This produces a set of fuzzy input variables that are later combined to produce fuzzy output values.

The REV and REVW (rule evaluation and weighted rule evaluation) instructions perform the meat of the fuzzy calculations, using the fuzzy input variables produced by MEM and generating fuzzy output values.

The WAV (weighted average) instruction performs the final step of Fuzzy Logic operations known as defuzzification. It takes the fuzzy output variables and transforms them into crisp system outputs that can then be used in traditional processing.

These three steps, fuzzification, rule evaluation, and defuzzification, form a brief outline of any Fuzzy Logic application, and each step is implemented by a primitive instruction in the S12 microcontroller's instruction set.

MEM Instruction

The MEM (membership) instruction takes crisp input values received from transducers or other devices and generates fuzzy input variables that represent the extent to which the crisp input values belong to certain fuzzy categories, or labels. The crisp input can be fully a member of a certain category, partially a member of that category, or not a member at all. To be specific, imagine a system that controls the water temperature in a shower for people of various ages.

Labels are implemented via trapezoidal membership functions, as depicted in Figure 1. This figure shows five labels for water temperature, each with an associated trapezoidal membership function, to take an input water temperature from a sensor and categorize the temperature as cold, cool, warm, hot, or scalding. It also shows a second set of trapezoidal membership functions that depict three labels, young, adult, and senior, based on the age of the shower user. In each case, the crisp input, (water temperature or age) is represented by a one-byte number in the range 0 to 255 on the horizontal axis, and the resulting fuzzy values are also represented by one-byte numbers in the range 0 to 255 on the vertical axis.

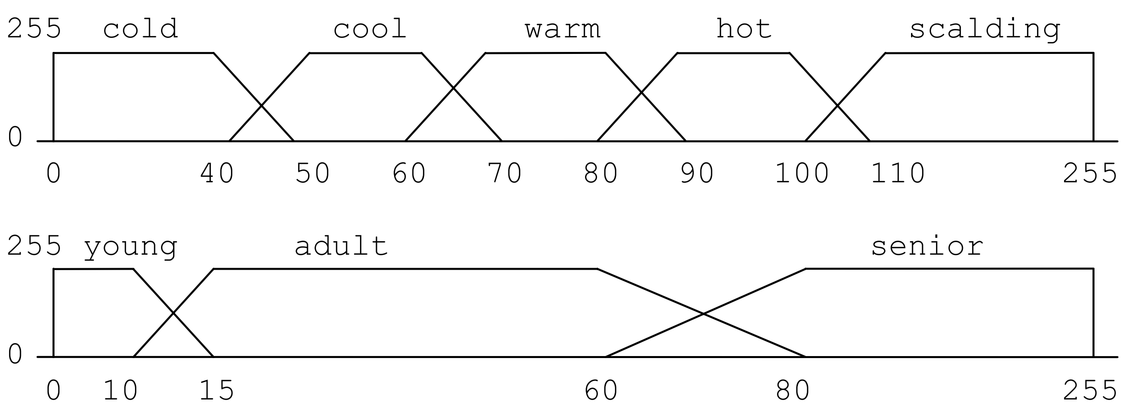

Figure 1. Membership functions that fuzzify two crisp input values, water temperature and age, and produce eight fuzzy input values, cold, cool, warm, hot, scalding, young, adult, and senior.

To use the MEM instruction, the trapezoidal membership functions must be described in the microcontroller. This is accomplished via a data structure that records four numbers for each trapezoid: left x-axis intercept, right x-axis intercept, left slope, and right slope (negated). Thus, the "cool" trapezoid in Figure 1 would be described with the data structure 40, 70, 25, 25 in the S12's memory. Infinite slopes are represented by a special-case slope value of 0. The four values for each trapezoid are stored sequentially in memory.

Before executing MEM, three registers in the S12 CPU must be initialized. Register A holds the crisp value being fuzzified. Register X holds the address of the first byte of the trapezoidal function being evaluated. Register Y holds the address in memory where the resulting fuzzy input value is to be stored. MEM is executed once for each trapezoid in the set of membership functions. In this example, eight separated MEM instructions must be executed, five with register A holding the crisp water temperature, and three with register A holding the crisp age of the shower user.

The result of executing MEM for each of the trapezoids is a list in memory of fuzzy input values representing the extent to which each crisp input is a member of the associated fuzzy category identified by each trapezoid. These fuzzy input values are then used in the next step of the processing.

REV and REVW Instructions

The REV and REVW (rule evaluation and weighted rule evaluation) implement the meat of the Fuzzy Logic processing. Through these instructions, fuzzy inputs produced by MEM are combined using a set of rules to produce fuzzy outputs. The rules are a collection of statements that describe the fuzzy output based on characteristics of the fuzzy inputs. In the example discussed here, the single fuzzy output describes how to change the shower water temperature, given the fuzzy inputs that describe the characteristics of the current measured temperature and the age of the shower user.

Figure 2 shows a typical set of rules that might be used in this shower temperature control example. In the table, the action required to adjust the water temperature is identified for each of the possible categories of water temperature and age of the shower user. Entries in the table mean the following: ↑↑ = raise temperature quickly, ↑ = raise temperature slowly, ↔ = leave temperature unchanged, ↓ = lower temperature slowly, and ↓↓ = lower temperature quickly.

	cold	cool	warm	hot	scalding
young	↑↑	↑	↔	↓	↓↓
adult	↑↑	↑↑	↑	↔	↓↓
senior	↑↑	↑	↔	↓↓	↓↓

Figure 2. Rules used by REV and REVW to generate fuzzy outputs from fuzzy inputs

To use the REV and REVW instructions, the list of rules shown in Figure 2 must be stored in the S12 memory in another data structure. Each box in Figure 2 is represented with a list of bytes that record the statement “If the water temperature is (…) AND the showerer is (…) THEN adjust the water temperature in this way (…)” where each of the (…) represents a fuzzy input produced by MEM or a fuzzy output generated by the REV or REVW instructions. Thus, a sample rule would be “If the water temperature is cool AND the showerer is young THEN raise the temperature slowly.”

The difference between REV and REVW is that REV allocates the same “weight” to each rule, meaning that each rule has equal impact on the resulting fuzzy output. By contrast, REVW allows the programmer to assign weights to the various rules so that some rules have more impact on the fuzzy output result than others. The data structures in memory for REV and REVW differ in order to accommodate this weighting feature. In order to avoid confusion, suffice it to say that the data structure specifying the list of rules identifies, for each rule, the fuzzy inputs that are combined with the AND operator, and identifies the fuzzy output that is produced by that rule. Rules are stored consecutively in memory, and are separated by special “marker” values stored between the rules in the data structure. Results of the rules are combined with the OR operator to determine the final value of the fuzzy outputs. In this example, there are five fuzzy outputs: raise the temperature quickly, raise the temperature slowly, leave the temperature unchanged, lower the temperature slowly, and lower the temperature quickly.

Numerically, the AND operator in Fuzzy Logic is implemented as an arithmetic minimum operator, so that the AND of two fuzzy inputs is just the minimum value of the two fuzzy values. The OR operator in Fuzzy Logic is implemented as an arithmetic maximum operator, so that when rule results are combined by ORing them, the fuzzy output value is just the maximum value produced by each of the rules being combined.

The result of rule evaluation is a set of fuzzy output values indicating the extent to which each of the output actions should be taken. Thus, in this example, five numbers are produced in the range 0 to 255, one for each of the five actions that should be taken on adjusting the water temperature. This form of the result is not particularly useful for the system that actually must control the water temperature. Thus, there is one more step in the process.

WAV Instruction

The WAV (weighted average) instruction takes the fuzzy outputs produced by REV or REVW and combines them to produce a crisp output value that can then be used in further traditional processing. This is accomplished by assigning a set of ideal values, known as “singletons,” to each of the fuzzy outputs, and then performing a weighted average calculation using the fuzzy outputs as “weights” to condition the singleton values associated with each fuzzy output. This calculation is much the same as a “center of mass” calculation in a mechanical system. The resulting number is a value somewhere within the limits established by the specified singleton values, determined by the fuzzy outputs that specify the extent to which the output should represent each of the fuzzy output labels.

In this example, if the fuzzy outputs say that the water temperature should be raised slowly to a large degree, left unchanged to a small degree, and lowered not at all, the resulting value after WAV will be a value between the singleton values for raise slowly and leave unchanged, shaded toward the raise slowly singleton according to the weights identified in the fuzzy output variables.

Example Applications

Students in the Electrical and Computer Engineering Design Workshop course during Spring semester, 2010, used the S10 microcontroller and its Fuzzy Logic instructions to implement various applications of Intelligent Control. Some of these student projects are described here.

In the "Intelligent Greenhouse" project, students designed a system that controls the environment of growing plants. The system measures temperature and humidity in a greenhouse atmosphere and uses those values as crisp inputs to the system. Employing Fuzzy Logic, the system generates signals to control heat and ventilation of the greenhouse to optimize conditions for plant growth. The results of this project were hard to demonstrate, but plants did grow, so something must have been right.

In the "Color Recognition for Tracking Robots" project, students designed a typical line-following robot, but added a twist. The color of the line being tracked controlled the speed of the robot. A green line indicated full speed. A blue line slowed the robot, and a red line caused the robot to stop. Filtered sensors were used to detect the color of the line, and Fuzzy Logic was used to combine the crisp sensor outputs and to generate the control signal to specify robot speed. This project worked well, after some difficulty in properly sensing the different colors.

The "Path Tracking" project was also based on a line-following robot, but in this case the line sometimes included alternate paths which could be selected by the robot, based on the surrounding environment and the intended destination. The robot used infrared sensors to detect the line, and ultrasonic sensors to detect surrounding obstacles. By combining the line-tracking sensor information with information about surrounding obstacles, the robot was able to make intelligent decisions when faced with a bifurcation in the path it was following.

Two projects attempted to use spoken commands to control a system. One project included a multi-color light display, and the user could light one or more colors of lights by speaking the color. Colors could be brightened or darkened by speaking "more" or "less" as well. This project did not function well. The second voice-control project did better, using spoken commands to control the speed and direction of a motor. The S12 processor does not have any special support for signal processing, so these projects attempted to just capture the frequency pattern of spoken input and analyzed that pattern to determine appropriate actions.

A final project equipped a motorcycle helmet with ultrasonic sensors to detect surrounding obstacles. A "threat level" indication was provided for the helmet wearer to indicate the presence and direction of detected obstacles. Intelligent Control attempted to analyze the threat situation and report the severity of the threat via lights in the peripheral vision of the user.

Student reactions to using Fuzzy Logic to implement control systems for their projects ranged widely. Some students appreciated the opportunity to implement a control scheme using a state-of-the-art technique, and eagerly dove into their projects. Other students were not convinced that the use of Fuzzy Logic in their projects justified the added complexity in their software required to support that approach. It is true that with the level of complexity addressed here in these student projects, the full benefit available through the power of Fuzzy Logic systems is not realized. In more complicated cases, however, Fuzzy Logic can be used effectively to implement cleanly a control system that otherwise would require many levels of mathematical modeling and simulation.

Summary

Intelligent Control applications were successfully implemented by students in the Design Workshop Class during Spring semester, 2010, using the Fuzzy Logic capabilities of the S12 microcontroller. No conclusion is drawn here that Fuzzy Logic is the best, or even an appropriate vehicle for solving these problems, but the availability of Fuzzy Logic support instructions in the S12's instruction set makes the approach at least viable. Experience with these primitive applications of intelligent control using Fuzzy Logic demonstrated the processing power that is available through special features of today's systems. That experience may encourage instructors in microprocessor classes using the S12 processor to address the capabilities available through the Fuzzy Logic instructions in its instruction set.

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Biography

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A COST-EFFECTIVE ANTENNA POSITIONING SYSTEM FOR MODERN RADIO-FREQUENCY (RF) AND MICROWAVE ANTENNA MEASUREMENTS

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INTRODUCTION

Recently, the microwave test equipment in the Electrical and Computer Engineering Department (ECE) at North Dakota State University (NDSU) was significantly upgraded. A new Agilent E5071C 8.5 GHz ENA series network analyzer and an anechoic chamber were two major pieces added to the lab. This upgrade required the development of an antenna measurement system (AMS) that could be used to measure the far-field behavior (i.e., field patterns) of an antenna. To develop an AMS a team consisting of ECE seniors was assembled. This team designed an AMS system that uses LabView to interface with the Agilent network analyzer and a structure that rotates the antenna in both the E- and H-planes. The computer running LabView interfaces with the network analyzer using the Ethernet and interfaces with the rotating structure using an infrared (IR) port. By correlating the S_{12} data from a network analyzer to the angle of rotation of the structure, a complete far-field pattern of the antenna can be measured. This paper will summarize the design and operation of the AMS along with the total cost. The cost of the AMS is about 10% of the cost of commercially available systems, thus making the system attractive to programs with a limited budget.

MOTIVATION FOR AN ANTENNA MEASUREMENT SYSTEM

Wireless communications is being studied extensively and has attracted the attention of many researchers throughout the world. A major component in all wireless systems is the antenna. These antennas mainly consist of three-dimensional antennas (Balanis, 2005) and planar antennas (Waterhouse, 2007). Therefore, when a novel antenna is developed, a system of testing the performance of this antenna is required. One method of testing a newly developed antenna is to use an AMS.

An AMS measures two main properties of an antenna: radiation pattern and input impedance. By measuring the radiation pattern of an antenna, a designer is able to determine the performance of the antenna in the space surrounding the antenna (this space is usually air). From this information, the direction the antenna is radiating the most power can be determined as well as how much power is actually radiated by the antenna (i.e., gain) and how much is being lost in the material used to construct the antenna. The AMS can also be used to measure the input impedance of the antenna. If done correctly, this measurement results in a value representing the input impedance of the isolated antenna element and does not include the influence of the antenna feeding network. This value is useful for proper design of efficient power delivery to the antenna by a transmitter or efficient power delivery by the antenna to a receiver.

TOPOLOGY OF THE ANTENNA MEASUREMENT SYSTEM

The AMS consists of three major components: 1) antenna positioner, 2) network analyzer and 3) computer. The topology of the entire system is shown in Fig. 1. The following sections describe the operation of each major component.

Antenna Positioner

The antenna positioner rotates the antenna under test 180 degrees in both the x-z and y-z planes. Photographs of the antenna positioner are shown in Fig. 2. The step size of the positioner is defined by the user on the computer using the LabView software. Two servo motors control the antenna positioner. One servo motor rotates the antenna mast from 0 to 180 degrees (illustrated in Fig. 2 by the white arrows) at defined step sizes and the second servo rotates the plate at the top of the antenna mast from 0 degrees to 90 degrees in one step. In summary, the motions of the antenna positioner during a measurement are as follows: 1) the bottom servo rotates the mast from 0 degrees to 180 degrees at step sizes defined by the user; 2) when the mast is rotated to 180 degrees, the second servo rotates the antenna plate at the top of the mast 90 degrees in one step; 3) then the servo at the bottom of the mast rotates the mast back from 180 degrees to 0 degrees at the step sizes defined by the user. It should also be noted that the user can define a specific time delay between each step taken by the servo motor. This allows the mast to settle before measurements are taken by the network analyzer.

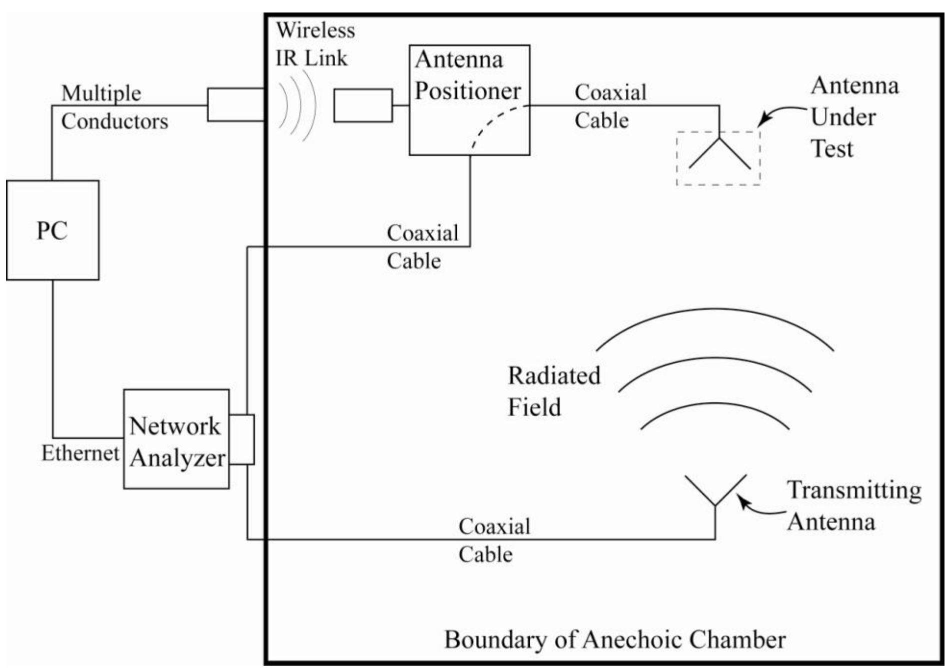

Fig. 1. The topology of the antenna measurement system.

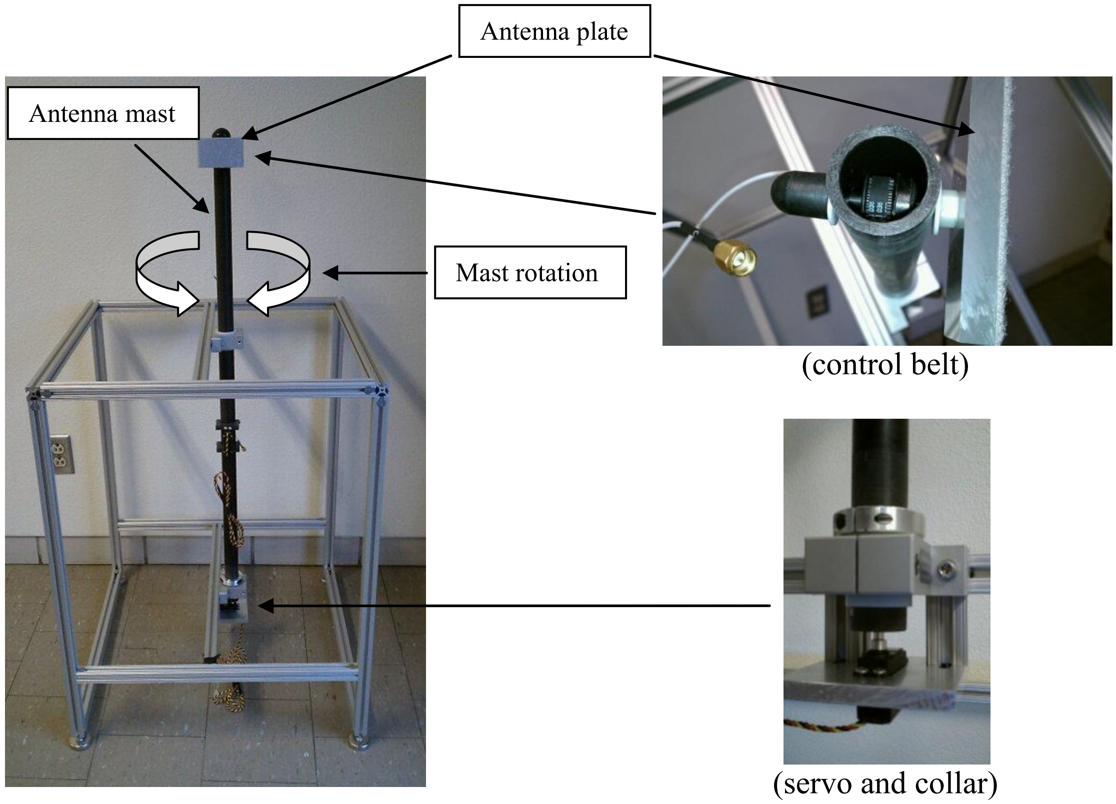

Fig. 2. Antenna positioner.

Network Analyzer

The network analyzer is the piece of equipment that takes the actual field measurements. This is done by attaching an antenna to port 1 and the antenna under test (AUT) to port 2 (as shown in Fig. 1), both with coaxial cables, and placing both antennas in an anechoic chamber. An image of the network analyzer and the anechoic chamber is shown in Figs. 3 and 4, respectively. The network analyzer provides measurement results in the form of the scattering matrix. These measurements determine how well the AUT is receiving power and how well the two antennas are linked in the chamber. The measurements on how well the antennas are linked provide the necessary information about the antenna as to how well the AUT is radiating into the region around itself.

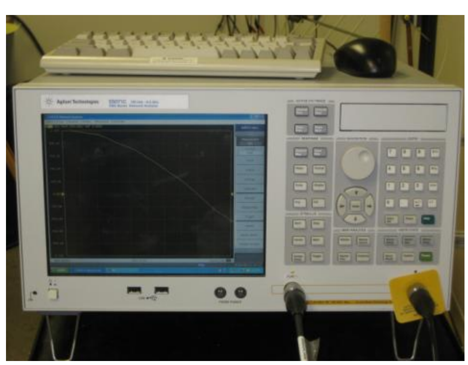

Fig. 3. Agilent Technologies network analyzer.

Fig. 4. Anechoic chamber.

Computer

For correct operation of the system, it is essential that the PC must manage the timing and information between the network analyzer and the antenna positioner. The PC is connected to the network analyzer though the Ethernet port and connected to the antenna positioner through an infrared (IR) port. An image of the IR port and controlling circuitry is shown in Figs. 5 – 7 (schematics for these boards are shown in the Appendix). The PC controls the system with a single user interface written in LabView. A screen-shot of the LabView interface is shown in Fig. 8.

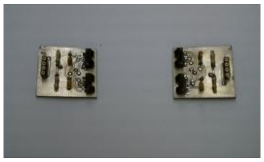

Fig. 5. IR boards used to communicate between the PC and the antenna positioner

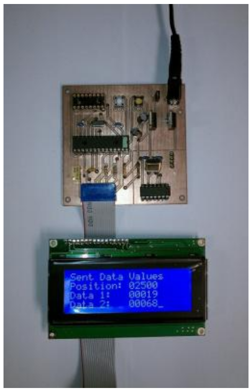

Fig. 6. PC board used to send data from the PC to the antenna positioner to control the servos.

Fig. 7. PC board used on the antenna positioner
to receive data from the PC to control the servos.

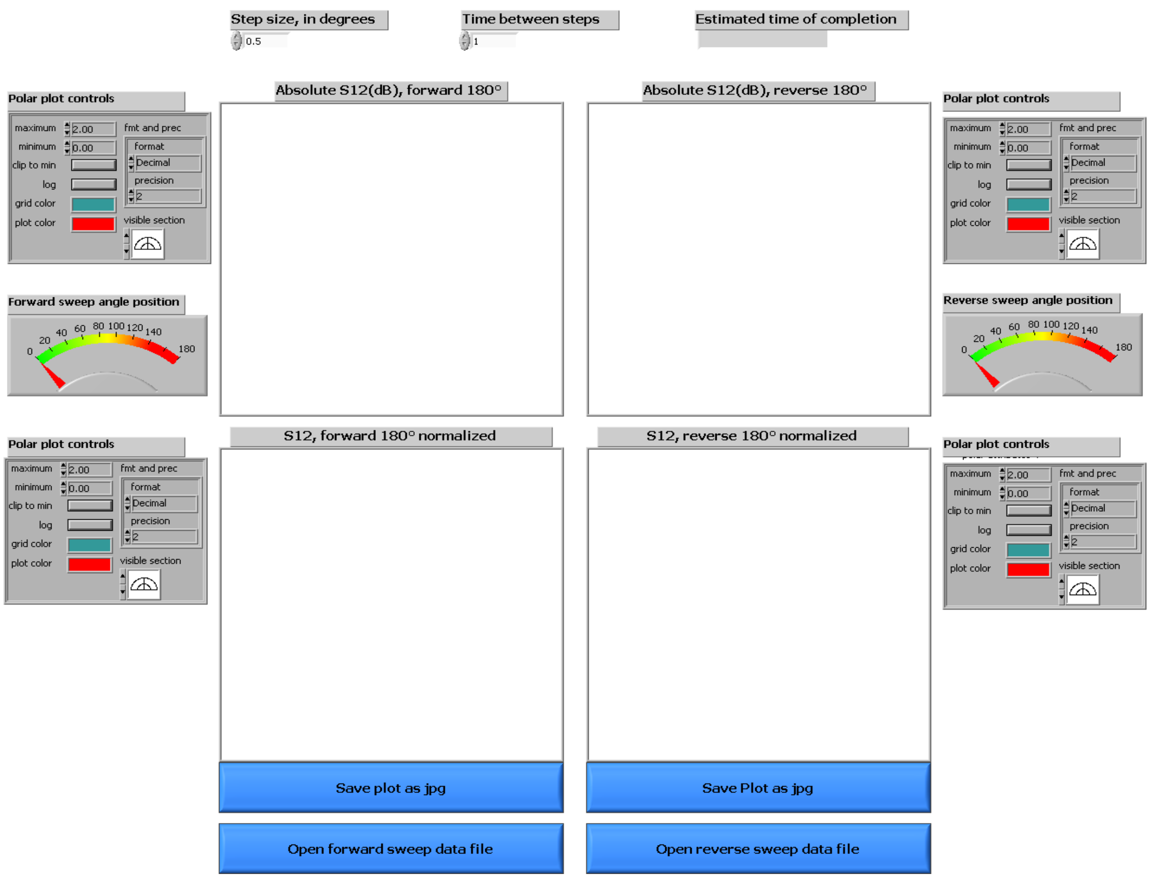

Fig. 8. LabView Interface.

DESCRIPTION OF THE ANTENNA MEASUREMENT SYSTEM

When a measurement is underway, the following sequence of events occurs:

1) When the system is setup and initialized (i.e., angle = 0 degrees), the PC records the first values from the network analyzer.
2) When this value is recorded the PC communicates with the antenna positioner and rotates the mast from 0 degrees to $0 + \Delta$ degrees where Δ is the user-defined angle step size in LabView.
3) After a short wait time, the new value measured by the network analyzer is recorded by the PC and stored in a manner related to the angle of the mast (i.e., each measurement corresponds to an angle of the antenna positioner).
4) After this value is recorded by the PC, the PC rotates the antenna positioner to $0 + 2\Delta$ degrees.
5) The PC then waits a short time and records the new measurement in the same manner as in step 3).
6) Steps 4) and 5) are repeated until the antenna positioner reaches a mast angle of 180 degrees. At that point the antenna plate rotates 90 degrees and the measurement process is repeated from 180 degrees back down to 0 degrees.
7) The result from this measurement is a matrix that contains measurement values from the network analyzer and corresponding antenna positioner angles.
8) LabView draws a polar plot of the measurement values and corresponding angles.

COST

The AMS system developed at NDSU has shown to be a reliable and accurate system. The budget for the entire project was $750. This low cost places the AMS system in reach of many smaller ECE programs.

CONCLUSION

A simple cost-effective antenna measurement system has been presented. The topology of the system has been summarized and details of the three main components have been summarized. Furthermore, a detailed sequence of events involved with a typical measurement has been offered. This was then followed by a total cost summary of $750 which makes this system affordable for many smaller ECE programs.

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Waterhouse, R. (Ed.), (2007). *Printed Antennas for Wireless Communications,* Hoboken, NJ: John wiley and Sons.

BIOGRAPHICAL INFORMATION

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MICHAEL R. WEISZ is a research engineer apprentice at the Center for Nanoscale and Engineering (CNSE) at NDSU. He graduated with his B.S. degree in Electrical Engineering at NDSU in May of 2010.

JEDIDIAH A. MEYER graduated with his B.S. degree in Electrical Engineering at NDSU in May of 2010.

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BENJAMIN D. BRAATEN is an Assistant Professor of Electrical and Computer Engineering at NDSU. He earned the B.S. in Electrical Engineering and the M.S. and Ph.D. degrees in Electrical and Computer Engineering, all from NDSU. He conducted post-doctoral research at South Dakota School of Mines and Technology.

DAVID A. ROGERS is a Professor of Electrical and Computer Engineering at NDSU. He earned the B.S.E.E. and Ph.D. (E.E.) degrees from the University of Washington, the M.S.E.E. from Illinois Institute of Technology, and the M. Div. (Ministry) degree from Trinity Evangelical Divinity School.

APPENDIX

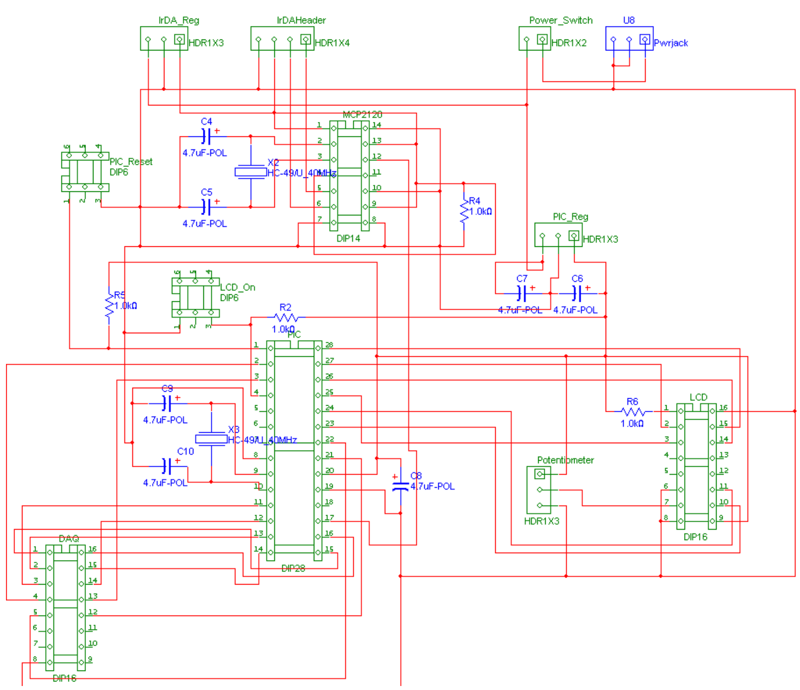

Fig. 9. Transmitter schematic.

Fig. 9 is an image of the Transmitter schematic. This circuit contains the following components:

- (2) LED indicators
- (7) 4.77µF capacitors
- (4) 1kΩ resistors
- (2) push button
- (1) MC33063A voltage regulator
- (1) MCP2120 IrDA driver
- (1) 10kΩ TrimPot
- (1) 100kΩ TrimPot
- (1) PIC18F242-I
- (2) 40MHz Crystals

This circuit contains a PIC that sends data to a MCP2120, which is the IrDA encoder/decoder. The MCP2120 then sends the data to the IrDA transceiver. There is a 1x4 header that connects to a 4 conductor ribbon cable from the IrDA PCB. There is also a 2x8 header that connects to a 16 conductor ribbon that runs to a backlit LCD screen. The various capacitors and resistors are used to reduce noise throughout the circuit. The two push buttons are to reset various devices.

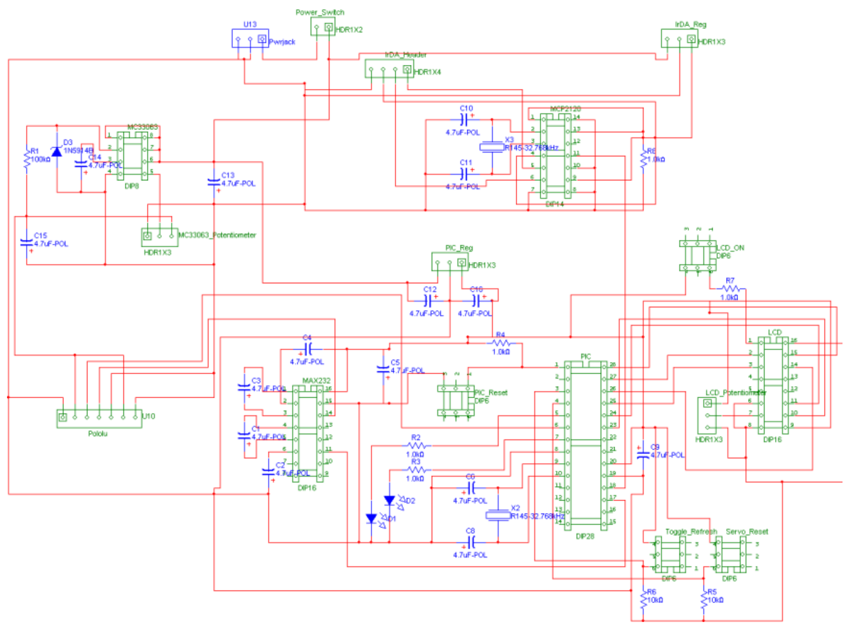

Fig. 10. Receiver schematic.

Fig. 10 is an image of the schematic for the Receiver PCB. This circuit contains:

- (2) LED indicators
- (14) 4.77µF capacitors
- (4) 1kΩ resistors
- (2) 10kΩ resistors
- (1) 100kΩ resistor
- (4) push button
- (1) MC33063A voltage regulator
- (1) MCP2120 IrDA driver
- (1) 10kΩ TrimPot
- (1) 100kΩ TrimPot
- (1) Pololu Micro-Controler SSC03A
- (1) MAX232A RS-232 driver
- (1) PIC18F242-I
- (2) 32.768kHz Crystals

This circuit contains a PIC that sends data to a MCP2120, which is the IrDA encoder/decoder. The MCP2120 then sends the data to the IrDA transceiver. There is a 1x4 header that connects to a 4 conductor ribbon cable from the IrDA PCB. There is also a 2x8 header that connects to a 16 conductor ribbon that runs to a backlit LCD screen. The various capacitors and resistors are to reduce noise throughout the circuit. The MAX232 is used to convert from UART to RS232 for the Pololu Micro-Controller. The four push buttons are used to reset various devices, and the MC33080 is for power regulation.

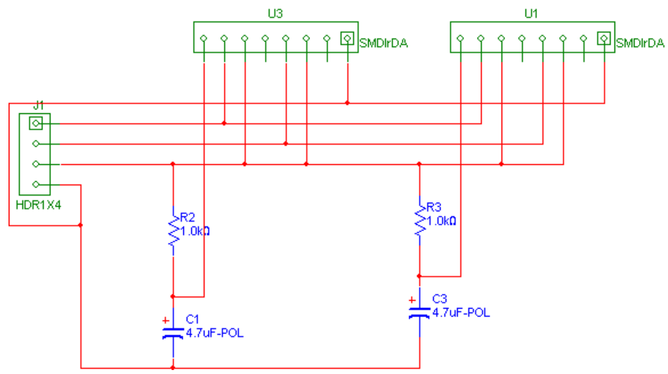

Fig. 11. IR board schematic.

Fig. 11 is an image of the schematic for the IR circuit. This board contains the following components:

- (2) 1kΩ resistors
- (2) 4.7µF capacitors
- (2) TFDU4101 Vishay Infrared Transceivers
- (1) 4 pin header to connect to transmitter or receiver

This circuit connects two IrDA transceivers in parallel to increase our transmission range. The 1x4 header connects by a 4 conductor ribbon cable to either the transmitter or receiver. The resistors and capacitors in the circuit are there to reduce noise throughout the circuit.

Addressing Intellectual Property (IP) and Student Needs in Industry Collaborative Student Projects

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Engineering and Technology/Patent Law Offices P.C.
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Abstract: Many engineering programs are encouraging collaborative student projects with industry sponsors. These joint or sponsored projects can benefit both students and sponsors providing real world experience for the students and low cost research or development opportunities for the sponsor. However, both sides must enter into these arrangements with open eyes and realistic expectations. This paper will explore the balance of interests among (i) students' career advancement, (ii) non-disclosure obligations, (iii) intellectual property (IP) rights, and (iv) project funding.

Introduction: The Electrical and Computer Engineering and Technology department at Minnesota State University, Mankato has approximately 25 electrical and computer engineering students graduate each year. The department is fortunate to be supported by a very active Industrial Advisory Board (IAB). This board meets at least twice a year and has in the past been involved in reviewing student senior design projects. As a result of IAB member interest and involvement with local industry and inventors, the Fall 2009 and Spring 2010 senior design experiences were truly collaborative and real world experiences. The first project consisted of a rework of an existing commercially available product. The second design effort consisted of taking a concept that was undergoing patent protection and creating hardware to support demonstration of the proof of concept. Both experiences were incredibly positive for the students and sponsors but also provided challenges that others following this path should be aware of.

Design experience 1. The Fall 2009 senior design experience truly began during the summer of 2009 with the course instructor meeting with the president of the company with the product needing redesign. The product is a very successful commercial product in which the company is planning to move from a dated input method into something that is more user-friendly. Further, the project was to explore the possibility of adding additional data storage and analysis to provide the company with a recurring income stream. The project provided many lessons learned for course instructor, the project sponsor and also the students. These will be described in general terms because currently the project is still under a nondisclosure agreement.

Positives associated with this project:

- Students were able to visit the production location.
- Students were able to see current products and move a current product into the lab for redesign.
- Students were able to use the current product as a test-bed.
- Students had to work with existing portions of current product which forced them to work

with real-world constraints

Design Experience 1 Implementation: The students were divided into teams of three or four. Each team was assigned a portion of the project and in some cases teams had overlapping or parallel responsibilities. One of the challenges associated with this is that some teams had more of a hardware focus while others had more of a software focus. Efforts in senior design are always expended to make sure students have a balanced hardware and software experience as part of their final design experience. Because this design needed to be completed in one semester students chose to use many off-the-shelf components and became in many cases systems integrators.

Challenges that occurred with this project:

- The students have a limited ability to discuss the project with others because of nondisclosure agreements required by industry sponsor.
- Time dependency created significant challenges in a one credit class to complete this effort within 15 weeks.
- The end result really has become a proof of concept rather than something that can be easily manufactured.
- Students because of the very rapid need to get this done in many cases did not have as holistic experience as with other projects.
- Dependencies of one group on the deliverable of another group became a challenge. Timeline slipping for one group and their deliverables created significant of issues with others resulting in finger pointing.
- How does the sponsoring company move forward with lessons learned?

Design experience 2: The second design experience occurred as a result of the discussion with one of our IAB board members who was working with a firefighter seeking a patent for his invention. As a starting point the firefighter came and presented his system concept to the senior design course during the second class meeting in the Spring 2010 semester. During the remainder of the week the students in the class were required to submit brief project proposals of what they would like to do for their final semester project in the senior design course to the course instructor. Based on the information provided by our potential sponsor two groups decided to undertake designs to support his product development. In both cases these teams had three members and in both cases the teams elected to take portions of the project that covered both hardware and software concepts. The nondisclosure agreement (NDA) was prepared and provided students for their examination and acceptance. Students who elected to work on this project had to complete and abide by the nondisclosure agreement. This agreement was iterated upon multiple times to make sure that students had the ability to discuss the project with potential employers and yet the provisions of the agreement would protect the inventor from inappropriate disclosures. Key provision of a sample agreement can be found at the end of this paper.

Students working on this project provided regular updates to the project sponsor showing both successes and challenges. Expenses for this project unlike those for other senior design projects were covered by the inventor. The course instructor however discussed with students the need to be charging only for successes and not imposing the cost of learning on the inventor. Students commenting on the differences in the both real world experiences pointed at the advantages of looking at a project in which they as a team were responsible for all aspects rather than depending upon other teams to meet other design requirements.

Issues to be resolved before design efforts start:

- All involved must have a clear understanding of the NDA and what it requires and what limitations it imposes. It is recommended that as we did, the author be available to discuss the implications of the NDA with students.
- It is critical when efforts like this occur in a one semester course that groundwork for this occur before the semester starts.
- The scope of each team's assignment and the required design interfaces between teams should be carefully matched to team size so that each team can produce a useful prototype independent of the progress of other teams.

Concluding thoughts:
The current course configuration for senior design at Minnesota State University Mankato provides students one course credit for each semester of effort in their senior design course. Most students are completing 15 credits of coursework during both semesters in their senior year. Additionally, most students are working part time to fund their education and in the Spring semester most students further increase their workload by seeking fulltime employment.

The positives associated with industry sponsorship are great! Comments from students working on the projects point to the positive experience of working on a project that really can make a difference. The students realized that their efforts supported increasing corporate viability of a small company with their first semester effort and developed the prototype for a new system in the second system effort that could be the basis or helping or protecting others. The students' efforts were further validated when the prototype from the second semester effort won the grand prize award at the 2010 Minnesota Inventors Congress.

Questions that still exist: What happens at the end of the semester – what should really happen? Students want/need to move on but small companies still need help moving forward. In the case of the second design system the Inventors Congress provided public exposure and opportunities for this inventor to continue moving forward. In the case of the other system the course instructor is still working with the company trying to find cost-effective engineering talent to move their product line forward.

Lessons learned:

- As has been found in the past, student teams of greater than three reduced the learning experience and were much harder to coordinate and grade.
- Student teams that depend upon others result in significant finger-pointing.
- Faculty engagement with industry sponsored projects significantly increases the faculty workload.
- Students engage and expend significantly more effort on projects with external sponsorship.
- Industry expectations must be clearly managed with it being clearly understood that the output of student projects is best viewed as proof of concept.

- Students in a senior design course are not well-equipped to create true manufacturing prototypes.
- Students need to have an understanding of intellectual property and appropriate documentation before entering into industry sponsored projects.
- Students’ willingness to complete documentation with industry sponsored projects is better than with faculty directed and created projects.

Appendix A

Selected Provisions of a **Nondisclosure Agreement suitable for industry-student collaboration effort**

These provisions are between students or faculty members ("PARTICIPANT") in an identified course during a specified semester and the industry sponsor ("SPONSOR"). The key provisions addresses issues relating to (1) proprietary information, (2) ownership of inventions, and (3) non-competition.

1. Proprietary Information

a. Restrictions on Proprietary Information

I agree that, during the COURSE and after, I will hold the Proprietary Information of the SPONSOR in strict confidence and will neither use the information nor disclose it to anyone, except to the extent necessary to carry out my responsibilities as a PARTICIPANT of the COURSE or as specifically authorized in writing by the SPONSOR.

I understand that "Proprietary Information" means all information pertaining in any manner to the business of the SPONSOR or its affiliates, consultants, or business associates, unless:

i. the information is or becomes publicly known through lawful means;
ii. the information was part of my general knowledge prior to the COURSE; or
iii. the information is disclosed to me without restriction by a third party who rightfully possesses the information and did not learn of it from the SPONSOR.

This definition includes, but is not limited to, (A) schematics, techniques, development tools, processes, computer printouts, computer programs, design drawings and manuals, electronic codes, formulas and improvements; (B) information about costs, profits, markets, sales, customers, and bids; and (C) plans for business, marketing, future development and new product concepts.

b. Permitted Disclosures

SPONSOR authorizes limited disclosures of certain Proprietary Information as follows:

i. For the purposes of a job interview for employment, PARTICIPANT may discuss technical information about the sub-system to which PARTICIPANT was primarily assigned, and its input signals and output signals, only to the extent it does not suggest or reveal the overall operation of the system as a whole; PARTICIPANT may not discuss or mention any information about the other sub-systems to which the PARTICIPANT was not primarily assigned.

ii. In the event that PARTICIPANT desires to disclose more than permitted in clause 1(b)(i), PARTICIPANT may request permission from SPONSOR in writing (including by e-mail) at least 10 business days before any disclosure to permit SPONSOR a reasonable opportunity to file a patent application to preserve SPONSOR's rights to seek foreign patent protection. **The written request must fully describe, in <u>text and/or drawings, the entire subject matter</u> that PARTICIPANT seeks permission to disclose.** SPONSOR will not unreasonably deny permission to disclose limited amounts of technical information, but permission may not be granted for disclosure of marketing or end-use application information. Where possible, SPONSOR may grant written permission to PARTICIPANT in less than 10 business days upon request.

2. Inventions

a. Assignment of Inventions

At or before the end of the COURSE, I agree to assign to the SPONSOR, without further consideration, my entire right, title, and interest (throughout the United States and in all foreign countries), free and clear of all liens and encumbrances, in and to all Inventions. Notwithstanding the foregoing, the SPONSOR may, in its discretion, agree to provide consideration for certain Inventions through a written agreement between the SPONSOR and the undersigned which specifically provides for such consideration; in all other cases, no consideration shall be paid. The Inventions shall be the sole property of the SPONSOR, whether or not copyrightable or patentable. In addition, I agree to maintain adequate and current written records on the development of all Inventions, which shall also remain the sole property of the SPONSOR. I understand that "Inventions" means all ideas, processes, inventions, technology, designs, formulas, discoveries, patents, copyrights, and trademarks, and all improvements, rights, and claims related to the foregoing, that are conceived, developed, or reduced to practice by me alone or with others during and for the COURSE. The foregoing shall not apply to an invention that the PARTICIPANT developed entirely on his or her own time without using the SPONSOR's equipment, supplies, facilities, or trade secret information.

3. Non-Compete

PARTICIPANT agrees not to engage in any activity that is competitive with any activity of SPONSOR during the course of their relationship and for a period of 12 months after termination of the Agreement. For purposes of this paragraph, competitive activity encompasses forming or making plans to form a business entity that a reasonable person participating in the COURSE would believe may be deemed to be competitive with any business of SPONSOR. This does not prevent PARTICIPANT from seeking or obtaining employment or other forms of business relationships with a competitor after termination of the COURSE so long as such competitor was in existence prior to the termination of the COURSE and PARTICIPANT was in no way involved with the organization or formation of such competitor.

Biographies

William B. Hudson Dr. Hudson has been teaching senior design at Minnesota State University for 8 years. Prior to joining the faculty at Minnesota State Dr. Hudson held faculty positions at Kansas State University and New Mexico State University and industry positions at Lindsay Manufacturing, Sprint as well as serving as a consultant.

Craige O. Thompson, JD, EE, PE. Mr. Thompson directs Thompson Patent Law Offices PC, a patent boutique law firm that provides experienced counsel on offensive and defensive patent matters. Previously, Mr. Thompson practiced law at Fish & Richardson for 7 years, after a 10 year career as a design engineer with Plexus Corp.

MASTER OF ENGINEERING
A ROAD TO PROFESSIONAL DEVELOPMENT

Stanley G. Burns
Associate Dean and Jack Rowe Professor of Electrical and Computer Engineering
University of Minnesota Duluth Swenson College of Science and Engineering

INTRODUCTION

The University of Minnesota Duluth offers Bachelor of Science degrees in Chemical, Civil, Electrical and Computer, Industrial, and Mechanical Engineering with a combined enrollment approaching 1000 students. In addition, Master of Science degrees in Electrical and Computer Engineering, Engineering Management, and a Master of Environmental Health and Safety program are also offered. To respond to our constituencies, the increasing regional need for professional development opportunities for engineer practitioners, and recognizing that there are potential changes in obtaining licensure requirements, UMD now offers a Professional Master of Engineering degree. The Professional Master Of Engineering degree emphasizes the practice of engineering in either the private or public sector. This new degree program, approved at the December 2009 Board of Regents Meeting, focuses on developing competencies in the areas of engineering design, problem solving, and practice beyond what can be achieved in earning a Bachelor of Science degree in a given engineering discipline.

An **MEng** graduate student is expected to have a focus and degree designation in one of the core UMD disciplines of Chemical Engineering, Civil Engineering, Electrical and Computer Engineering, Industrial Engineering, or Mechanical Engineering.

This paper provides some background in the development and implementation of this degree program and its expected impact on regional engineering education.

JUSTIFICATION

We are basically responding to a key portion of the UMD Mission Statement which reads, *"UMD serves northern Minnesota, the state, and the nation as a medium-sized comprehensive university dedicated to excellence in all of its programs and operations. As a university community in which knowledge is sought as well as taught, its faculty recognizes the importance of scholarship and service, the intrinsic value of research, and the significance of a primary commitment to quality instruction……."* Our constituencies in the region also includes the Iron Range public and private sector employers. Our engineering graduates, public and private sector employers, and the professional societies have asked for expanded graduate engineering professional development opportunities.

A flexible, primarily coursework, **MEng** degree does:

- Provide an opportunity for student and engineering alumni professional development
- Address regional private and public sector needs for a graduate level technically-trained workforce
- Strengthen the regional economic base and attractiveness as a place to live and work for engineering professionals
- Offer post-baccalaureate engineering education opportunities to engineers employed on the Minnesota Iron "Range"
- Provide expanded opportunities for faculty in Chemical Engineering, Civil Engineering, Electrical and Computer Engineering, Industrial Engineering and Mechanical Engineering to engage in applied research and development activities with the private and public sectors
- Enhance UMD engineering faculty career development and retention.
- Expand opportunities for external research funding from the private and public sectors.

EXTERNAL FORCES

Another major driver in offering an MEng degree is recognizing that there are changes looming on the horizon with respect to professional engineering licensure and also related to this issue is the amount of mathematics, science, and discipline-specific technical courses that can be accommodated in a standard 4-year, 128-130 semester credit undergraduate engineering program. Stated in a National Academy of Engineering report [1], *"It is evident that the exploding body of science and engineering knowledge cannot be accommodated within the context of the traditional four year baccalaureate degree".*

The National Council of Examiners for Engineering and Surveying (NCEES), the National body responsible for the FE and PE examinations, have promulgated the following change in the "Model Law" when working with individual State engineering licensing boards [2]. The change states,

> *"… that to sit for the PE exam a person must have either an MS from an EAC/ABET accredited program or equivalent, and 3 or more years of experience OR a BS from an EAC/ABET accredited program or equivalent, an additional 30 credit hours of acceptable coursework from approved course providers and 4 or more years of experience."*

The "Model Law" becomes effective in year 2020. Other requirements remain unchanged.

The Professional Societies have a mixed response to this NCEES "Model Law". By far, the American Society of Civil Engineers (ASCE) is the strongest professional society supporting this "Model Law". According to PS 465(Policy Statement 465)[3],

> *"…the ASCE Book of Knowledge (BOK) will be fulfilled by means of formal education and experience—that is, a bachelor's degree plus a master's degree, or approximately 30 semester credits, and experience. Two common fulfillment paths were developed—one involving an accredited bachelor's degree in civil engineering followed by a master's degree, or approximately 30 semester credits of acceptable graduate-level or upper-level undergraduate courses, and the other*

using an appropriate bachelor's degree followed by an accredited master's degree."

The official position of ASME is the one the ASME Board adopted April 24-25, 2008[4],

"ASME General Position Statement on Mandatory Educational Requirements for Engineering Licensure," which expresses ASME's opposition to Master's or Equivalent. The position statement has been endorsed by eight other engineering organizations since its release: AIChE, ASHRAE, IESNA, IIE, ISA, SME, SNAME and TMS.

The official position of the IEEE states,

"IEEE-USA neither supports nor opposes the National Council of Examiners for Engineering and Surveying (NCEES) decision to recommend that engineers who have successfully completed accredited baccalaureate-degree educational programs be required to take 30 additional hours of engineering education to become licensed, beginning in 2020. IEEE-USA recommends that NCEES work with ABET and concerned professional societies to ensure that the proposed additional education requirement is better defined, and to develop a clearly articulated process by which state licensing boards can ensure that individual applicants for licensure have met the requirement. Such actions will better serve the career needs of electrical engineers and the public need for an adequate supply of licensed professional engineers. IEEE-USA"

David L. Whitman, Ph.D., P.E., NCEES President, presented an overview of the current status of the "Model Law" at the ASEE Engineering Deans Institute, April 2010[6] . He is aware of the mixed responses and additional discussion is scheduled for the August NCEES meeting.

Even though the National professional societies provide a mixed message, we expect a significant number of graduates in the new UMD Civil Engineering program will want to pursue this BS + 30 option leading to eventual licensure. Career opportunities are severely limited for BS graduates who do not pass the Fundamentals of Engineering exam as the initial step leading to Professional Engineering licensure and it appears that licensure will require some type of a BS + 30 . In a sense, we are being proactive in the development and offering of the **MEng** degree in response to these potential changes.

THE PROGRAM

Virtually all of the ASEE North Midwest Section member universities offer a variety of Master of Engineering, or similar degree monikers, with a focus on engineering or a specific discipline within engineering. In general, these programs focus on a strong emphasis towards the practice of engineering in industry, business, or government. In addition, these programs:

- Cater to a regional constituency
- Cater to place and time bound students
- Include minimal project or research components

- Have different admission requirements than a Master of Science degree program. Typically this includes undergraduate GPAs in the 2.5 to 3.0/4.0 range and consideration of post-baccalaureate professional experience
- Require a minimum of 30 post-baccalaureate semester credits

and are often, but not always, considered as a terminal degree, not directed toward continuation in a Ph. D. program.

The focus and content of the UMD **MEng** program is congruent with these characteristics. The requirements are similar to many other programs.

The UMD **MEng** degree program is primarily a coursework degree program, often referred to as a Plan C at the UMTC, with a minimum of three credits and a maximum of six credits allocated to a design project to be arranged between the Departmental Advisor and student. The 30 credits require a minimum of 14 credits at 5XXX or higher, and a cap of 6 credits on 4XXX courses. There is no requirement for a final exam above and beyond what is required in individual courses. Deviations from Table 1 must be agreed upon by the Departmental Advisor and student. The resultant Program of Study must then be approved by the Department, the SCSE **MEng** Director of Graduate Studies and forwarded to the UMD Office of Graduate Education for final approval.

Many classes are conveniently offered in the late afternoon or evening and many courses are offered by ITV or enhanced face-to-face at the Mesabi Range Community and Technical College in Virginia, MN as part of the Iron Range Graduate Engineering Education Program(7).

Course Requirements	Semester Credits	Course Level
Major Plan Department: ChE, CE, ECE, ME (within MIE), IE (within MIE)	12 Minimum	5XXX or 8XXX***, Selected 4XXX courses*
Engineering Course Project within the Major Plan Department: ChE, CE, ECE, ME (within MIE), IE (within MIE)	3 to 6	5XXX to be arranged by the Departmental Advisor and student.
Other Engineering****	6 to 9	Selected 4XXX; 5XXX, 8XXX
Non Engineering**	3 Minimum	Graduate Courses-Approved Lists
TOTAL APPROVED CREDITS	30 Minimum	

TABLE 1 Master of Engineering Program

** Identical/similar courses taken as part of an undergraduate degree either at UMD or at another institution can not be repeated or applied as part of the* **MEng** *program. The Departmental Advisor and the SCSE Director of Graduate Studies will work with the student on this issue when setting up the Program of Study.*

*** Non-engineering courses would consist of courses approved for graduate credit by the Departments of Computer Science, Mathematics and Statistics, Physics, Chemistry, Geological Sciences, or Biology. Identical/similar courses taken as part of an undergraduate degree either at UMD or at another institution can not be repeated or applied as part of the* **MEng** *program.*

The Departmental Advisor and the SCSE Director of Graduate Studies will work with the student on this issue when setting up the Program of Study.
**** In consultation with their Departmental Advisor, students may choose to include one or more 8XXX courses in their Program of Study. It should be noted that even though there are no requirements for 8XXX courses,* **MEng** *students who meet the course prerequisites for 8xxx courses in Electrical and Computer Engineering, Engineering Management, Geologic Sciences, and Computer Science will be encouraged to include these courses in their degree program.*
***** Courses selected in collaboration with the Departmental Advisor.*

All **MEng** Graduate Students will have a Departmental Advisor. Non-faculty, including members of the industrial community, are invited to collaborate and work with the student and Departmental Advisor.

Any project report or presentation requirement within the 3-6 credits of the engineering course project are at the option of the Departmental Advisor and Department.

Admission requires that an applicant has:

- Completed an undergraduate degree in an engineering program, or upon approval by the SCSE **MEng** Director of Graduate Studies, in a related discipline, e.g., computer science, physics, etc.
- Earned an undergraduate grade point average (GPA) of 3.00 (on a 4.0 scale) for admission. This preferred performance minimum of a 3.0*/4.0 GPA must be from an ABET accredited program or equivalent.
- Provided two letters of recommendation-academic and/or professional references

** Industrial experience and professional licensure will be considered for applicants with a grade point less than the preferred minimum*

In addition:

- For international applicants whose native language is not English, a TOEFL score preferred performance minimum is 213 on the computer based test.
- The GRE score is recommended but not required

SUMMARY

The University of Minnesota Duluth Swenson College of Science and Engineering (SCSE) now offers a **Professional Master Of Engineering** degree The **MEng** addresses regional private and public sector needs as well as responds to external forces in the engineering profession. This degree program is designed to provide a strong emphasis toward the practice of engineering by focusing on the development of competencies in the areas of engineering design, problem solving, and practice beyond what can be achieved in earning a Bachelor of Science degree in a given discipline. An **MEng** graduate is required to specify a degree designation in one of the core UMD disciplines: Chemical Engineering, Civil Engineering, Electrical and Computer Engineering, Industrial Engineering, or Mechanical Engineering.

Additional information is available at http://www.d.umn.edu/scse/degrees/MEng/index.html

ACKNOWLEDGEMENTS

The University of Minnesota Duluth Swenson College of Science and Engineering would like to thank:

- Iron Range Resources (IRR) Higher Education Committee for financial support.
- Northeast Higher Education District (NHED) for the support and collaboration necessary to use Mesabi Range Community and Technical College facilities.
- The following regional professional societies for their encouragement, efforts and support:
  - The American Society of Civil Engineers (ASCE)-Duluth Section 3
  - Institute of Electrical and electronics Engineers (IEEE)-Arrowhead Section
  - Duluth Engineers Club
  - Minnesota Society of Professional Engineers-Arrowhead Chapter

REFERENCES

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2. *Section 130.10.C.c, page 12* of NCEES Model Law." National Council of Examiners for Engineering and Surveying
3. Civil Engineering Body of Knowledge for the 21st Century Preparing the Civil Engineer for the Future Second Edition Copyright © 2008 by the American Society of Civil Engineers
4. http://www.licensingthatworks.org//FAQs.cfm
5. http://www.ieeeusa.org/policy/positions/LicensureEducation1109.pdf
6. http://www.asee.org/conferences/edi/2010/upload/Whitman.pdf
7. IRR Higher Education Committee (multiple meetings 2009 and 2010)

STANLEY G. BURNS

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The Itasca Community College Engineering – Condensed Scheduling Effects on Persistence and Time to Graduation

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Itasca Community College Engineering

Abstract

Groups within and outside engineering education are interested in student success rates and time to graduation for engineering students in order to meet the nation's need for new engineering graduates. In 2002 Itasca Community College's Engineering program changed from a traditional 16 week semester to a "block scheduling" format with classes taught "one-at-a-time" in 4 weeks and then in the Spring of 2005 to a "two-at-a-time" in 8 weeks. This scheduling method is successful in providing students the ability to navigate through the pre-calculus and calculus sequences at different paces than in a traditional schedule yet have the ability to complete their engineering degree in four years. Students who have started their engineering education at Itasca in the block scheduling format average 8.7 semesters to completion of their bachelor's degree in engineering with graduation rates higher than many comparable to institutions across the nation at 54%

Introduction

Throughout the nation there are many efforts underway to increase student success rates and reduce time to graduation for engineering students in order to meet the nation's needs for engineering. Itasca's part of this effort led to utilizing block scheduling to increase student success rates and reduce time to graduation regardless of starting math course. For a majority of engineering programs, the calculus math sequence is the key factor in the time to graduation due to the prerequisites required for engineering and physics courses. For a student to complete their engineering degree in four years, they need to start in calculus 1 in the fall of their first year and successfully complete all of their math and other STEM courses on the first attempt and in a specified order.

This study analyzes the impact of condensed scheduling on graduation rate and time to graduation in Itasca Community College's engineering program. The study looks at two groups at Itasca:

- 4-Week Block Group – Students who started in the Fall of 2002 and Fall of 2003 and had a majority of their STEM classes taught in a 4-week block format
- 8-Week Block Group – Students who started in the Fall of 2004 and Fall of 2005 and had a majority of their STEM classes taught in a 8-week block format

Background

Itasca Community college (ICC) is a small (1000 FYE), two-year college located in Grand Rapids, Minnesota about 80 miles northwest of Duluth, Minnesota. It was founded in 1922 and has held accreditation with the North Central Association Higher Learning Commission since the mid 1970's. ICC primarily serves students located in the northern third of the state. ICC is a member of the Minnesota State Colleges and Universities system (MnSCU) as well as a member of the Northeast Minnesota Higher Education District (NHED). The college offers a number of two year transfer and terminal programs. The college is exceptionally known (regionally and nationally) for its associate of science engineering transfer program.

The ICC engineering program is an open admissions program with approximately 1/3 of the student body ready to start their math sequence with calculus 1, 1/3 with pre-calculus, and 1/3 at a math course below pre-calculus. The program's faculty consists of 6 engineering/physics instructors, 2 math instructors, and 1.5 chemistry instructors. The program has grown from 10 students in 1993 to 150 students in 2010 (Ulseth 2004).

Students who complete ICC's engineering program then transfer to 4-year institutions across the nation to complete their STEM degree. A majority of the students transfer to the regional institutions with engineering programs with which Itasca has strong partnerships and articulation agreements:

- Bemidji State University
- Michigan Technological University
- Minnesota State University, Mankato – Main Campus
- Minnesota State University, Mankato – Iron Range Engineering Campus
- North Dakota State University
- University of Minnesota – Duluth
- University of Minnesota - Twin Cities
- University of North Dakota
- St. Cloud State University

ICC Engineering's Condensed Course Model

The majority of classes at ICC are the traditional 16-week semester courses, while classes in ICC's engineering program (engineering, math, chemistry, and physics courses) are currently delivered in a "two classes at a time" 8-week block format with two eight week blocks per semester. Students generally take two engineering, math, or science classes per block while completing one or two semester long general education courses. Each block class is scheduled for 2 hours per day, 5 days a week with flexibility for the instructor to provide "float" or non-contact days to allow for student work days or engineering program events. This scheduling format has the following attributes:

- Focus on two engineering, math, or science courses at a time
- Flexible two hour class setting to create an interactive and student-led learning environment
- Ability to complete more than one math or physics course in a semester

The ability to take more than one math or physics course in a semester provides students with the ability to "catch up" to their peers in their STEM courses. Traditionally a student who tests into a pre-calculus course is a semester, if not a year, behind in the four year curriculum due to the math prerequisite requirements for first and second year physics and engineering courses; most importantly with the calculus 1 prerequisite. There are a multitude of scenarios for math course sequences for a student based on a student's starting math course, performance in a particular course and potential scheduling issues such as full courses, which can cause a delay in the completion of a STEM degree in four years.

Prior to the 8-week block format students learned in a 4-week block format with one STEM class at a time with a total of 9 STEM courses in a year. The class schedule changed to an 8-week format in 2005 to address potential concerns with scheduling, illness issues, and classroom utilization.

	Math Courses by Semester					
Starting Math Course	Fall 1st Year	Spring 1st Year	Fall 2nd Year	Spring 2nd Year	Fall 3rd Year	Spring 3rd Year
Calculus 1	Calculus 1	Calculus 2	Multi-Variable Calculus	Differential Equations		
Pre-Calculus	Pre-Calculus	Calculus 1	Calculus 2	Multi-Variable Calculus	Differential Equations	
Calculus 1 - with Calculus 1 repeated	Calculus 1	Calculus 1	Calculus 2	Multi-Variable Calculus	Differential Equations	
Intermediate Algebra	Intermediate Algebra	Pre-Calculus	Calculus 1	Calculus 2	Multi-Variable Calculus	Differential Equations

Table 1: Sample Math Course Sequences in Traditional Semester Model

	Math Courses by Semester							
	Fall 1st Year		Spring 1st Year		Fall 2nd Year		Spring 2nd Year	
Starting Math Course	**1st 8 Week Block**	**2nd 8 Week Block**	**1st 8 Week Block**	**2nd 8 Week Block**	**1st 8 Week Block**	**2nd 8 Week Block**	**1st 8 Week Block**	**2nd 8 Week Block**
Calculus 1		Calculus 1	Calculus 2		Multi-Variable Calculus		Differential Equations	
Pre-Calculus	Pre-Calculus		Calculus 1	Calculus 2	Multi-Variable Calculus		Differential Equations	
Calculus 1 - with Calculus 1 repeated		Calculus 1	Calculus 1	Calculus 2	Multi-Variable Calculus		Differential Equations	
Intermediate Algebra	Intermediate Algebra	Pre-Calculus	Calculus 1	Calculus 2	Multi-Variable Calculus		Differential Equations	

Table 2: Sample Math Course Sequences in ICC Engineering's 8 Week Block Format

Tables 1 and 2 show the impact that block scheduling has on the ability for students to stay on a path to graduating in four years regardless of starting math class or any need to repeat a class. The scheduling itself only allows for the opportunity for students to stay on a four year track. The impact was similar in the 4-week block format. The next question is how students perform in terms of graduation rate and semesters to completion of their four year engineering degree given the condensed course models.

Data

All students who started ICC's Introduction to Engineering courses from the Fall 2002 to present date have been tracked to evaluate their success in the condensed course format. For the 241 students who started at Itasca in the Fall of 2002 through Fall of 2005 the following data was collected:

- Starting Math Course
- Successful Completion of Calculus 1
- Successful Completion of Physics 1
- Transfer Institution
- Degree Obtained at Transfer Institution
- Total Semesters for Completion of Bachelor's Degree in Engineering

The data was collected through transcript reviews and follow-up contacts with each of the students. The data was then compiled to evaluate:

- Graduation rates overall
- Graduation rates based upon starting math course
- Graduation rates for students who started Physics 1
- Graduation rates based upon starting math course grade
- Average semesters to graduation

Results

					Number of Semesters to Graduation		
Starting Academic Year	# of Students Starting Intro to Engineering	STEM Degrees	% Completion of STEM Bachelors Degree	Start Physics 1 & Completion of Degree	Calculus 1 as 1st Math Course	Pre-Calc or Int. Algebra as 1st Math Course	Regardless of 1st Math Course
2002	60	39	65%	80%	8.5	8.9	8.7
2003	39	25	64%	78%	8.8	8.7	8.7
2004	75	34	45%	68%	8.9	9.2	9.0
2005	67	33	49%	77%	8.5	8.6	8.5
Overall	241	131	54%	75%	8.7	8.9	8.7

Table 3: Results of the ICC Engineering Block Schedule

The results show that the ICC engineering block model is a success. The overall average degree completion rate of 54% is higher than the degree completion rates found in other national studies:

- 40.8% degree completion in engineering/engineering technologies for students entering STEM field in 1995-96 as of 2001 in Engineering (Chen 2009)
- 45% and 49% 6 year graduation rates for male and female students, respectively, starting for Southeastern University and College Coalition for Engineering Education (SUCCEED) Institutions (SUCCEED institutions award over 1/12 of all U.S. engineering degrees) (Borrego, Padilla, Zhang, Ohland, & Anderson, 2005)
- 38% in 6 year graduation rate in STEM for students starting in Fall 1993 in the Center for Institutional Data Exchange and Analysis (C-IDEA) study (Tan, 2002)
- 21% 4 year STEM graduation rate for students starting in Fall 2005 at Wright State University (Klingbeil 2010)

In comparison to these national studies, the ICC engineering program model is more successful in producing students who complete their Bachelor's degree in engineering. ICC's success is despite an open admissions policy with a majority of the students below calculus 1 ready in math preparation and other factors that would classify them as "at-risk" students. In addition, the students must then transfer after their two years at Itasca and deal with the issues associated with transferring to a new institution.

In addition to the higher success rate, the students are completing their degrees in a shorter amount of time. Itasca students average 8.7 semesters to completion of their STEM degree regardless of starting math course and Itasca's open admission policy. The data also shows there is no significant difference in average semesters to completion between students with calculus 1 as their first math course and those with a lower starting math course. Figure one compares the 4, 5, and 6 year graduation rates for the Fall 2002 class at Itasca with the Fall 1996 class at the SUCCEED institutions (Borrego, Padilla, Zhang, Ohland, & Anderson, 2005).

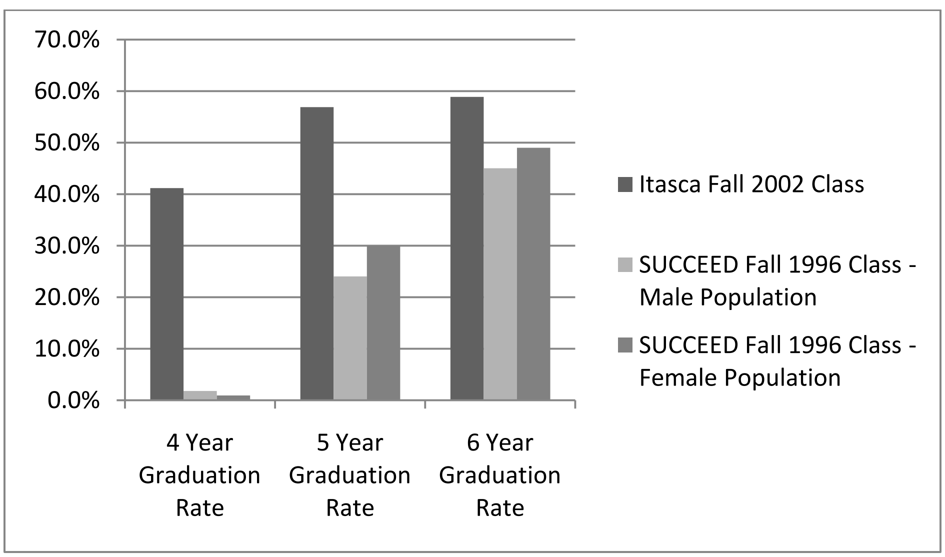

Figure 1: Comparison of 4, 5, & 6 Year Graduation Rates of Itasca and SUCCEED Students

As shown in Figure 1, the success of the Itasca model in providing a pathway for the students to complete their degree in 4 years is evident in comparison to the SUCCEED institutions.

In addition to the condensed class schedule at Itasca, other key attributes of the ICC engineering program that contribute to the student success are:

- Student centered learning environment
- A very strong and vibrant faculty and student learning community

Another noteworthy finding is the decrease in degree completion rate as ICC's engineering program transitioned from a 4-week to an 8-week condensed course model. Possible reasons for this decrease are:

- Decreased sense of focus on learning with multiple courses being taken at one time
- Reduced sense of a small cohort for each class

Future Work

Although the findings from this study are encouraging for the condensed block formatting at Itasca, there is still some additional work needed:

- Study of comparison groups at Itasca's partner 4 year institutions
- Study of ICC students prior to the condensed block format
- Investigation into combining a more progressive model for math education, such as the Wright State University model, into ICC's condensed class format
- Investigation to effect of student learning in small cohorts
- Continued investigation into more data on national averages for time to completion of degree

Conclusion

The condensed course format of Itasca Community College's engineering program has been very successful with high student graduation rates (54%) for students achieving a bachelor's of science in engineering in a short time frame (8.7 semester average) despite the students starting with a wide spectrum of math placements and then transferring to other institutions to complete their degree. This model is transferable to other institutions and can serve to increase the number of students finishing an engineering degree. The model can be fully adopted or could be used for select courses, such as math, and still function within a traditional 16 week class format The potential for the ICC two year engineering model to transform engineering education is significant due to the fact that 42.0 % of degrees granted in engineering/engineering technologies are for students who started a 2-year public institution according to the July 2009 US Department of Education report "Students Who Study Science, Technology, Engineering, and Mathematics (STEM) in Postsecondary Education" (Chen 2009)

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TENURE: OBSERVATIONS AND CONSEQUENCES

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INTRODUCTION

Tenure for college and university faculty members at small to mid-size institutions has long been a topic that has been hotly debated. Traditionally these institutions had mainly a teaching focus. In the early years tenure might have been awarded after a probationary period of five or six years and announced simply by a letter in the mail. However, since faculty abilities and interests vary widely, it was not uncommon for some faculty who were moderately or heavily involved in teaching to also produce some significant research results. Natural curiosity, student interests, capstone projects, or monetary necessity might have been the driving motivations. Many faculty members and administrators at such institutions were aware of the advantages of producing research results simply by observing the work of their peers at larger, research-oriented universities. As the years went by, the standards of these institutions were admired and gradually were put in place, at least partially, at the mid-size institutions. This might have been done simply in the name of "progress." It might also have been done to enhance the careers of faculty at the smaller institutions and to increase their mobility. Research accomplishments and notoriety also improved the prestige of an institution. This, it seems, has also led to public recognition or acceptance of the importance of faculty research as a measure of institutional quality, especially by students and parents involved in the choice of an institution for undergraduate studies. At the same, in the United States, many applicants are available for each faculty opening. These factors have come together to increase expectations for faculty performance and the development of elaborate criteria for choosing an applicant and for the subsequent award of tenure. Measured in terms of teaching, research, and service, these expectations are rapidly becoming common throughout the educational world. These standards determine the working environment and even the lifestyle of college and university faculty members today.

There are some very important issues regarding tenure which really should be subjects of separate studies. The first is whether or not we should have tenure in our institutions at all. The second is the issue of the relationship between tenure and diversity in faculty hiring and retention. Both of these topics are worthy of extensive study and discussion, but we will reserve this for another occasion.

STANDARDS FOR TENURE

Tenure means different things to different institutions and faculty depending on their mission and history. If we model tenure in three institutional dimensions--type, location, and age—we witness a wide range of perspectives. Fundamentally, tenure can be viewed as a license to teach at a particular institution. Without tenure, the instructor's time at the institution is limited.

Tenure is rooted in the belief in academic freedom. The instructor worthy of tenure will be protected from prejudice through a guarantee of job security. The professor's academic and professional standing including professional integrity merits tenure.

For some institutions, especially in prior decades, achievement of tenure occurred through adequate performance of assigned teaching duties and was indicated to the instructor without the necessity for any formal application. At the other extreme, the modern research university has a comprehensive standard of intellectual production stretching from research through teaching to service.

INSTITUTIONAL PROCEDURES

Today evaluation for tenure might involve processing through three or more administrative levels and two or more faculty levels. Ideally these two lines of evaluation would be independent, allowing for a variety of viewpoints to be considered. Administratively, the unit chair evaluates the candidate, perhaps using some faculty input, and then forwards a recommendation regarding promotion or tenure to the dean (or director). The unit chair and the dean must be cognizant of unit, college (or school), and institutional promotion and tenure regulations and make recommendations that are consistent. Faculty committees at the unit, college, and institutional levels will bring a variety of perspectives, but all must be aware of expectations from different entities. Finally, the university provost (or academic vice president, chancellor) receives the administrative and faculty recommendations and makes the final decision. In the final analysis, the provost decides whether or not the candidate represents the type of faculty member who will serve the long-term needs of the institution.

A typical probationary period for tenure and promotion is six years. For subsequent promotion there is disagreement. Five years is a commonly considered minimum, but 10 years wouldn't be unusual. For tenure, the institution usually has standards for teaching effectiveness, research productivity (stable external funding, consistent publication record), and service (to the institution, to the profession, and to the community). Problems come when the various administrators and faculty committees have different interpretations of the standards set in institutional regulations.

CANDIDATE PERSPECTIVE

Several things might contribute to a lack of interest in an academic career: the long probationary period, low salary, high workload, and financial insecurities of an academic institution. On the other hand, some might choose such a career anyway, perhaps for the following reasons: (1) the chance to participate in a research community or a community devoted to learning,

(2) appropriate intellectual gifts for such work, which makes such a career actually a liberating experience, (3) the college or university environment being the best opportunity for using one's education, (4) the prestige of a university position, and (5) the opportunity to serve students.

Even though we might agree that an academic position is desirable, earning the Ph.D. degree doesn't guarantee a job offer. So, anyone interested in an academic position is risking perhaps three or more years of life beyond the bachelor's degree. Some fields might require work experience in the profession or post-doctoral studies. If the position is obtained, tenure will be either earned or denied. So, conceivably after about 10 years of study and work the individual might have failed in the pursuit of an academic career and some major or minor career change could be necessary. A negative aspect of pursuing a Ph.D. is that, if a teaching position is not available, having the Ph.D. degree might in some cases reduce employment opportunities. In the case of a traditional engineering position, the candidate might be viewed as being overqualified or too expensive.

THE CANDIDATE: TENURE REALITIES

Here we take the liberty of offering some advice to the tenure candidate. The suggestions below emphasize the candidate's perspective while providing useful information for evaluators. Policy variations from one institution to another can be significant. The comments presented below are general observations about the process that won't fit everyone's situation.

1. **Application for Tenure**. It is important for the department chair, department promotion, tenure, and evaluation (PTE) committee, and the dean to closely follow the candidate's career progress. Correspondingly, the candidate benefits if the unit and the college have carefully and thoughtfully written PTE documents that measure up to current institutional standards. Some institutions require an early review (third or fourth year) that should be taken very seriously. There could be an informal conversation with the chair, dean, and provost two years ahead of the planned tenure application. This should certainly happen at least with the unit chair. Some institutions require candidates to include external review letters in their dossiers. The candidate should carefully follow the institutional guidelines as to format and content of the dossier or application. Hopefully, portfolios used by successful candidates will be available for inspection by current candidates.

2. **Position Description**. Each candidate usually has an individual appointment letter and/or job description that should be consulted along with the PTE documents of the individual's department and college. The candidate should do quality work in quantity that is roughly equivalent to the job description (for example, research, teaching, and service percentages of 40, 40, and 20, respectively). The candidate should strive to perform at an excellent level in all three areas. Under no circumstances should research be neglected.

3. **Evaluation by Peers and Administrators**. We suggest that candidates not apply for early tenure or promotion unless they are clearly outstanding. At every level of evaluation almost everyone compares current candidates with those people she/he considers to be at about the same point in their career. A marginal evaluation at a lower level might not mean that the candidate will be denied tenure/promotion at the provost level.

4. **Research**. Candidates should develop their own research programs. It should be recognizable as a research effort at the candidate's current institution. The candidate should continue doing some publishing in their original area of expertise even if they are forging ahead in a new research area at their current institution. Journal publications still are the key factor (for some institutions, one [good] or two [better] per year). Most evaluators still don't appreciate the value of an acceptance of a paper at a prestigious conference. The "bar" is moving higher. There are some senior faculty members that suggest that we evaluate not only the quality of the journals in which we publish, but also the impact of the publications and the number of citations. As is discussed below, external funding really helps. It is growing in importance and might be a requirement at some institutions.

5. **Grants and Contracts**. A significant factor in promoting research productivity is the candidate's ability to attract research support through grants and contracts and, correspondingly, to support research assistants (RA's). Without RA's, young faculty in search of tenure will have their chances of publishing limited. Faculty at mid-size institutions typically will be assigned few or no RA's (or even teaching assistants) as compared to faculty at large research universities. This problem is partially addressed by the National Science Foundation's Experimental Program to Stimulate Competitive Research (EPSCoR). This leads to the issue of "stimulus" or "start-up" packages. In some institutions, and in some high-demand areas (chemical engineering, for example), these packages can amount to several hundred thousand dollars or more. In a non-EPSCOR state, smaller institutions are at a disadvantage. Hopefully NSF and other government agencies will develop programs that address this issue (start-up packages) in lieu of or in addition to the programs they already have in place to help the most talented young faculty.

6. **Teaching**. Candidates should include at least two peer reviews of teaching in their portfolios. They should report on advising effectiveness (prospective students, undergraduate and graduate students, and student organizations) along with teaching effectiveness. The tenure process is ultimately for the benefit of our students since faculty research adds to the quality and prestige of the institution. Students' careers will be significantly impacted by the public's perception of the institution.

7. **Service**. Aside from institutional expectations, the candidate should be involved in at least one professional society. To serve at the national committee level is a worthy goal. This brings recognition to the candidate's institution.

8. **Collegiality**. Tenure itself is no guarantee of long-term career security. Conflicts with administrators or colleagues might lead to a future resignation. To survive or thrive, the candidate must be gifted with intelligence, energy, an excellent work ethic, and the people skills required to be effective with students, faculty colleagues, and administrators. Some today refer to these people skills with the term collegiality (American Association of University Professors [AAUP], 1999; Connell & Savage, 2001). In recent years there has been some effort to include collegiality in institutional promotion and tenure documents, although this has not achieved the status traditionally given to research, teaching, and service. Although the AAUP (1999) is troubled by the effort to include collegiality as a part of the faculty evaluation process, the courts

(Connell & Savage, 2001) have consistently upheld the right of an institution to use collegiality as a significant factor in the evaluation process. The candidate should be aware of this since many administrators have been through situations in which lack of collegiality by certain faculty members was detrimental to unit productivity.

THE CANDIDATE: MAINTAINING MOBILITY

The candidate should not limit himself/herself to fulfilling the minimum criteria for tenure (or promotion), but should always try to go beyond this. The main reason is mobility: with the minimum, one can only move laterally, or downward, not upward. Institutions usually recognize tenure from other institutions when they are "higher" in prestige or reputation. But there are many circumstances in which a relatively young and brilliant faculty member wants to move to another place which has higher standards. That will not be possible unless he/she has exceeded the requirements of the current institution. This would also be true in the case of someone wishing to be an administrator.

FACULTY COMMITTEES AND ADMINISTRATORS: TENURE DECISIONS

Members of faculty promotion and tenure committees and unit administrators have the difficult task of evaluating the performance of the tenure-track faculty member and predicting the candidate's long-term success at the institution. The tenure process is based on an underlying assumption that the behaviors learned during graduate studies and continued and improved during the tenure process will lead to a lifetime of scholarly work that will bring benefits to the institution and her students. From the perspective of the institution and its constituency, tenure involves something like a 25- to 40-year commitment. If you set an average salary for engineering faculty at one hundred thousand dollars plus overhead, that is a commitment of about five million dollars or more by the institution and its constituency. Often the constituency is the State, and it is the taxpayers' money, so that cannot be taken lightly.

The advice to the candidate given above reflects the expectations commonly held by faculty promotion and tenure committee members and unit administrators. Correspondingly, evaluators have the obligation to do a fair and balanced evaluation of each candidate in each area of performance mentioned or hinted at in the above list.

A difficulty with earlier reviews (or even annual reviews), which in many institutions are mandatory, is that candidates generally don't like criticism. The candidate's response might be essentially defensive. The review then produces few useful results for the candidate's career and might even generate a lawsuit against the institution or its administrators. This points out how important it is to clearly inform prospective faculty members about the nature of the institutional evaluation process. This should also be part of new faculty orientation. At some institutions this is dealt with through faculty mentoring programs.

A joint project of the American Council on Education (ACE), the American Association of University Professors, and United Educators Insurance Risk Retention Group produced the document *Good Practice in Tenure Evaluation: Advice for Tenured Faculty, Department Chairs, and Academic Administrators* (2000). This report has four main sections. Chapter 1 calls for developing and maintain clear standards and procedures for tenure evaluation. Chapters 2 and 3 call for consistency and candor in tenure decisions and evaluation. A final chapter deals with the difficult task of caring for unsuccessful candidates. The summary at the beginning of the report is must reading for all involved, and the entire report should be helpful to anyone who is concerned about the legal aspects of the tenure evaluation process.

A practical concern suggested by the ACE document is the importance of faculty and administrators being well versed in existing and approved institutional policies or regulations concerning the tenure process. Since faculty committee membership is subject to a continuing rotation, it is important that senior faculty members of such committees make an extra effort to provide what we might call an institutional memory of how tenure evaluation has and does occur. The evaluation process will change over the years, but this change should be gradual enough so that the results in the short term don't indicate inconsistency. Administrators are perhaps in a better position to encourage consistency since usually they hold their posts much longer than do faculty members of tenure committees.

The ACE document further encourages those involved in evaluations to provide clear explanations of tenure requirements and correspondingly clear advice about how to meet tenure requirements. For example, a given academic unit might have a very specific requirement understood within the unit but not specified in the unit regulation. Such a situation could easily lead to confusion and possibly to legal problems for the institution.

SPECIAL PROBLEMS

Given the tenure picture described thus far, we must also admit that there are valuable faculty colleagues that don't measure up to the standards we have suggested. This might be true early in their careers, at mid career, or in their final years. The common model at a research university is that the standards established during the tenure period continue throughout the faculty member's career. Some institutions might find it difficult to hire and maintain on staff such model faculty. In some units there have been informal arrangements among collegial faculty members to hire and maintain faculty with a variety of gifts. Gifted teachers would be used as teachers. Great researchers would be given reduced teaching loads. Those with gifts of service would focus on service. All faculty members contribute to carrying the workload in the department to the best of their abilities. However, as institutional standards develop, at many institutions it has gradually become difficult to deal with the unit workload in this manner. This could be viewed as an erosion of unit autonomy. Some institutions have what are essentially per-faculty production quotas that work in favor of building units where the expectation is that each faculty member will be equally productive in all areas. Some units have dealt with this, if budgets allow, by hiring faculty with specific titles such as senior lecturer or professor of practice. These categories of faculty are outside of the tenure track. This development suggests that in future decades we can expect that faculty members who have essentially a teaching-only role will not have tenure.

A related situation exists for an institution that either is not strong in research or is committed only to teaching. A compromise should exist to save those exceptional teachers who are not that enthused (or stimulated) about research. Such institutions might give tenure to outstanding teachers or they might award long-term contracts (five years or more) in the categories mentioned earlier: senior lecturer or professor of practice.

CONCLUSION

There is much uncertainty for the person who desires an academic career. As noted above, progress towards tenure might involve an investment of a significant portion of an individual's life, and might, for one reason or another, lead to having to make a second career choice. For the successful candidate, we must assume that a great deal of pride and satisfaction comes with the award of tenure and having a lifetime career as a professor.

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A METRIC FOR ASSESSMENT OF ABET ACCREDITATION OUTCOME 3B – DESIGNING EXPERIMENTS AND ANALYZING THE RESULTS

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South Dakota State University

Introduction

The Accreditation Board for Engineering and Technology, Inc. (ABET) requires evaluation of program outcomes (POs) as part of the undergraduate engineering curricula accreditation process. Assessment under this criterion is one or more processes that identify, collect, and prepare data to evaluate the achievement of program outcomes. The Department of Civil and Environmental Engineering at South Dakota State University (SDSU) chose to use program outcomes originally established, known as the "a" through "k" outcomes. Evaluation of outcome "b", "a graduating student should have an ability to design and conduct experiments, as well as to analyze and interpret data" was accomplished using a well-designed rubric, as is the subject of this paper. The rubric was established and administered in CEE-346L, Geotechnical Engineering Laboratory. The means of assessment was a particular laboratory experiment, One Dimensional Consolidation Test. The rubric consisted of several indicators in each of the categories: "1" – Below Expectation, "2" – Meets Expectation, and "3" – Exceeds Expectations, with a desired metric threshold score of 2 or greater. The rubric was applied to the entire class for the selected laboratory exercise during the years of 2007, 2009, and 2010. The class average was used as assessment relative to the threshold score. Data collected to date indicates the threshold score is being met; however evaluation of the metric has promulgated minor adjustments in selected areas of the curriculum to improve scores. This paper outlines the details of the assessment process, metric results, and changes to the curriculum.

Accreditation Framework

The ABET program outcomes (POs) are statements that describe what students are both expected to know and to apply at the time of graduation. This achievement indicates that the student is equipped to attain the program educational objectives. POs are measured and assessed routinely through national, university, department, and curriculum level assessment processes. The POs themselves are evaluated and updated periodically to maintain their ties to both the department's mission and program educational objectives (PEOs). The assessment and evaluation process for the program outcomes follows a continuous improvement process. The first step is to establish program outcomes that are tied directly to the program educational objectives. The program outcomes were adopted from the ABET Engineering Criteria 2000. The POs were reviewed by the faculty in the Department of Civil and Environmental Engineering (CEE) at SDSU as well as the department's advisory board before being adopted by the program. SDSU's Civil Engineering program outcomes "a" through "k" are adopted from

ABET criterion three. During the Fall semester of 2008, the CEE department faculty established the following formal methodology for reviewing and revising program outcomes. In general terms, the following outlines the Program Outcome Assessment Process (SDSU, 2009):

1. A metric or metrics will be established for a PO.
2. A threshold value will be established for each metric.
3. The value of the metric will be determined for an evaluation cycle and compared to the threshold value. Typically, the value will be determined and evaluated annually based on a 2-year moving average value of the metric.
4. For the first evaluation cycle:
    a. If the value of the metric exceeds the threshold value, then no action is necessary,
    b. If the value of the metric is less than the threshold value, then the variance is noted and possible causes for the variance will be discuss and reported by the department faculty, but no additional action is required at this time.
5. For the second evaluation cycle:
    a. For those metrics that previously exceeded the established threshold from 4a:
        i. If the value of the metric again exceeds the threshold value, then no action is necessary,
        ii. If the value of the metric is now less than the established threshold, then same response as 4b above.
    b. For those metrics that previously were less than the established threshold from 4b:
        i. If the metric now exceeds the threshold value, then no action is required,
        ii. If the value of the metric again is less than the established metric value, then the situation is considered to be a concern. The departmental faculty will at this time develop potential corrective action(s) that will be agreed upon by consensus.
6. For subsequent evaluation cycles:
    a. If the value of the metric exceeds the established threshold value, then no action is necessary,
    b. If the value of the metric exceeds the threshold value for three consecutive evaluations, the department will consider increasing the threshold value.

Evaluation Metric for ABET Program Outcome 3b

The CEE departmental faculty has established evaluation metrics for the assessment of the achievement of the outcomes for each of the eleven POs. These metrics include survey results, laboratory rubrics, class assignments, interviews, and results from the Fundamentals of Engineering (FE) examination. A critical threshold value for each metric has been established that is realistic and attainable, yet ambitious enough to result in continuous improvement. Evaluation of ABET PO 3b, the subject of this paper, "a graduating student should have an ability to design and conduct experiments, as well as to analyze and interpret data" was accomplished using a well-designed rubric.

Rubrics are scoring tools that are generally considered subjective assessments. A set of criteria and/or standards are created to assess a student's performance relative to some educational outcome. The unique feature of a rubric is that it allows for standardized evaluation of each student to specified criteria, making grading more transparent and objective. A well-designed rubric allows instructors to assess complex criteria and identify areas of instruction that may require revision to achieve the desired outcome.

The literature is sparse on assessing PO 3b directly in civil engineering; therefore the literature was searched in constructing the rubric from other engineering disciplines. Felder and Brent (2003) discuss instructional techniques in meeting evaluation criteria for the various POs. The Engineering Education Assessment Methodologies and Curricula Innovation Website (2007) also discusses some strategies for PO assessment, but in a broad, general sense. McCreanor (2001) discusses assessing POs from an Industrial, Electrical, and Biomedical Engineering perspective. Winncy et al (2005) discusses meeting PO 3b from a Mechanical and Aeronautical Engineering perspective. Review of the literature revealed the following common features of rubrics: each focus on a stated objective (evaluating a minimum performance level), each use a range of evaluative scores to rate performance, and each contain a list of specific performance indicators arranged in levels that characterize the degree to which a standard has been met.

Information gleaned from the literature was coupled with the CEE department's needs relative to our continuous improvement model established for ABET accreditation to produce an evaluation rubric. Table 1 presents the various scoring areas of the rubric. Note that reporting is not explicitly part of the Criteria 3b, but was included in the rubric none-the-less.

The final important step was to select a laboratory exercise that would allow assessment of the various areas of the rubric. The One Dimensional Consolidation Test laboratory exercise in CEE 346L – Geotechnical Engineering Laboratory was chosen for the rubric. The laboratory exercise was initially evaluated to have the expectation elements outlined in Table 1. The consolidation test is used to evaluate the load deformation properties of fine-grained soils. When an area of soil is loaded vertically the compression of the underlying soil near the center of the loaded area can be assumed to occur in only the vertical direction, that is, one-dimensionally. This one-dimensional nature of soil settlement can be simulated in a laboratory test device called a consolidometer. Using this device, one can obtain a relationship between load and deformation for a soil. Analysis of the results ultimately allows the calculation or estimation of the settlement under induced loads such as a building or other large structure.

A cutoff score of 2 (meets expectations) was established after the rubric was initially developed. The rubric was then applied to the entire class of multiple laboratory sections for the selected laboratory exercise. The class average was used as assessment relative to the cutoff score. The rubric was originally developed to be administered every other academic year. However, during SDSU's on-site evaluation by ABET for reaccreditation in 2009, the ABET program evaluator encouraged the CEE department to administer the rubric yearly.

Table 1. Rubric Scoring Criteria

	Level 1 *Below Expectations*	Level 2 *Meets Expectations*	Level 3 *Exceeds Expectations*
Expectations Characterized By	Uses unsafe and/or risky procedures	Observes occasional unsafe laboratory procedures	Observes established laboratory safety plan and procedures
	Does not develop a systematic plan of data gathering; experimental data collection is disorganized and incomplete	Development of experimental plan does not recognize entire scope of the laboratory exercise, therefore data gathering is overly simplistic (not all parameters affecting the results are	Formulates an experimental plan of data gathering to attain the stated laboratory objectives (develops a plan, tests a model, checks performance of equipment)
	Data are poorly documented	Not all data collected is thoroughly documented, units may be missing, or some measurements are not recorded	Carefully documents data collected
	Does not follow experimental procedure	Experimental procedures are mostly followed, but occasional oversight leads to loss of experimental efficiency or loss of some data	Develops and implements logical experimental procedures
	Cannot select the appropriate equipment and instrumentation	Needs some guidance in selecting appropriate equipment and instrumentation	Independently selects the appropriate equipment and instrumentation to perform the experiment
	Does not operate instrumentation and process equipment, does so incorrectly or requires frequent supervision	Needs some guidance in operation of instruments and equipment	Independently operate instruments and equipment to obtain the data
	Makes no attempt to relate data to theory	Needs some guidance in applying appropriate theory to data, may occasionally misinterpret physical significance of theory or variable involved and may make errors in conversions	Independently analyzes and interprets data using appropriate theory
	Is unaware of measurement error	Is aware of measurement error but does not systematically account for it or does so at a minimal level	Systematically accounts for measurement error and incorporates error into analysis and interpretation
	Seeks no additional information for experiments other than what is provided by instructor	Seeks reference material from a few sources - mainly from the textbook or the instructor	Independently seeks additional reference material and properly references sources to substantiate analysis
	Reporting • Reporting methods are poorly organized, illogical and incomplete • Uses unconvincing language • Devoid of engaging points of view • Uses inappropriate word choices for the purpose • Consistently uses inappropriate grammar structure and has frequent misspellings	Reporting • Reporting methods are mostly organized with areas that are incomplete • Uses language that mostly supports means and methods • Occasionally makes engaging points of view • Mostly uses appropriate word choices for the purpose • Occasionally uses incorrect grammar structure and/or misspellings	Reporting • Reporting methods are well organized, logical and complete • Uses convincing language • Makes engaging points of view • Uses appropriate word choices for the purpose • Consistently uses appropriate grammar structure and is free of misspellings
	Evaluative score of 1	Evaluative score of 2	Evaluative score of 3

It should be emphasized that the rubric was used to evaluate the department's program outcomes, not the course outcomes in the particular course where the rubric was administered. The scoring/grades that students received were assigned relative to course outcomes. Therefore, when the rubric was applied, the laboratory assignments were graded twice for each evaluation. As such, students were not aware of the assessment relative to the department's program outcome 3b. This was by design so as not to bias student's effort and work for the particular laboratory assignment.

Results

The constructed rubric was initiated in the 2006-2007 academic year. Laboratory data collection by students was performed in the laboratory on March 14 and 15, 2007 (multiple laboratory sections). Laboratory data analysis was subsequently performed by the students in the laboratory March 21 and 22, 2007. The students' reports were submitted for grade one week later. Thirty three laboratory reports were evaluated with a resulting average score of 2.0 and a standard deviation of 0.9. Therefore, the program outcome for 2007 was achieved and a baseline for future evaluation was established. Although the cutoff was met, the class average was exactly at the cutoff score and enhancements were qualitatively deemed advisable to address the level 1 performer. Therefore, selected technical aspects of the lecture materials were enhanced to address areas of the rubric that were scored lower than desired. The technical content of the lecture materials are beyond the scope of this paper.

The rubric was re-administered in the 2008-2009 and 2009-2010 academic years. Laboratory data collection by the students was performed in the laboratory March 24, 25, and 26 in 2009 and March 23, 24, and 25 in 2010 (multiple laboratory sections). Laboratory data analysis was performed by the students the following week and handed in for grade one week later similar to the prior year. Fifty one and 33 laboratory reports were evaluated for the progressive academic years, respectively, resulting in an average score of 2.5 with a standard deviation of 0.4 for the 2008-2009 academic year and an average of 2.3 and a standard deviation of 0.6 for the 2009-2010 academic year. Given the averages increased and the standard deviations decreased over the baseline, the implemented improvements were achieved in evaluated student performance. Most notable was the improvement in the range of student performance; there were fewer students that performed at Level 1. The program outcome was considered achieved and no changes were made to the lecture materials.

Conclusions

A well established evaluation metric, a rubric in this case, can be used to both evaluate and enhance Program Outcomes in an ABET accreditation process. Based on the experience from the process outlined in this paper, the following conclusions are offered:

- Evaluation metrics should be conceived based on the continuous improvement process of: desired outcome → devise metrics → establish threshold and actions → first evaluation cycle and actions, if necessary → subsequent evaluation cycles and actions, if necessary.

- Evaluation metrics can take on many forms, choose the appropriate metric to measure the desired outcome.
- The rubric used to assess ABET criteria 3b allowed for evaluation relative to meeting the desired outcomes, but also allowed to review curriculum in addressing specific areas of concern.
- Stated outcomes are easily assessed by rubric scoring.

References

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