Pendulum Experiments for a Vibration Laboratory

Frank M. Kelso, Ph.D.
Mechanical Engineering Department
University of Minnesota

Abstract
An introductory course in vibration engineering naturally begins with the basic "building block" concepts on which a deeper understanding is built. The study of single degree of freedom lumped parameter systems lays the conceptual groundwork needed for studying the behavior of multi-degree of freedom or continuous systems. The simplest single degree of freedom vibratory system is of course the pendulum. Pendulum problems illustrate basic vibration theory very nicely, providing a simple and intuitive illustration of the building block concepts: lumped parameter models, simple harmonic motion, natural frequency, damped and undamped systems, free and forced response. Constructing these simple pendulum arrangements in a "testbed" environment and measuring the actual natural frequency provides a useful vehicle for extending theory into actual practice. This paper examines one particular pendulum problem and its implementation and use in a laboratory setting.

Background

The vibration lab is intended to provide students with an introduction to the *theory* of mechanical vibrations, and the *practice* of identifying and measuring vibrations in actual systems.

Vibration *theory* covered in this lab begins with the basic lumped parameters used to model simple mechanical systems: mass, damping, and structural stiffness. These building blocks are used to construct single degree of freedom (SDOF) analytical models of mechanical systems, which may then be used to predict vibration characteristics such as natural frequency.

Vibration *practice* in the laboratory involves instrumenting an actual system and determining actual vibration characteristics (e.g. natural frequency.) In addition to learning how to use transducers and data acquisition systems to collect and analyze vibration data, the student will (1) gain experience and confidence in the use of simple models, and (more importantly) (2) gain experience in discovering the source and magnitude of discrepancies between ideal analytical models and actual physical systems.

Students spend a great deal of time developing and using analytical models during the course of their undergraduate curriculum. A lab class can provide a valuable reminder of the limitations and approximations inherent in these analytical models.

Illustrative Example

A typical textbook problem taken from Steidel [1] is shown in Figure 1 below:

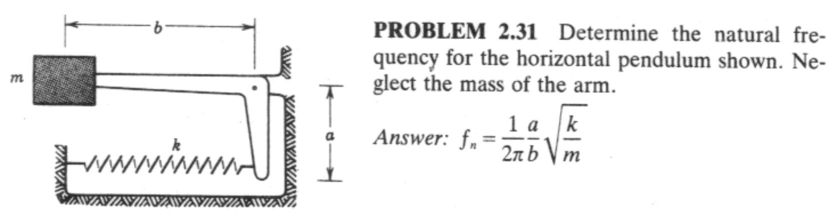
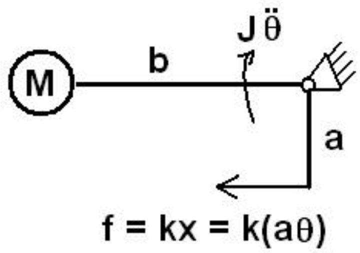


Figure 1: Problem 2.31 from Steidel

Solving this textbook problem provides an excellent application of vibration fundamentals. The student constructs a free body diagram of a lumped parameter model of this system (Figure 2 below), then performs a torque balance to develop the system model:



$$J\ddot{\theta}+Ka^2\theta=0$$

$$Mb^2\ddot{\theta}+Ka^2\theta=0$$

Figure 2: Free Body Diagram

This model can then be used to calculate the (ideal) natural frequency of the system:

$$w_n^2=\frac{a^2}{b^2}\times\frac{K}{M} \quad rad^2/sec^2 \qquad (1)$$

This simple analytical model is based on the assumption that (1) friction is insignificant, and (2) distributed quantities such as mass and compliance may be treated as lumped parameters. Theory can be connected to the real world using a physical implementation of this SDOF pendulum.

Pendulum Construction

The pendulum of Figures 1 and 2 is constructed from a (modified) 12-inch steel utility square (Figure 3 below).

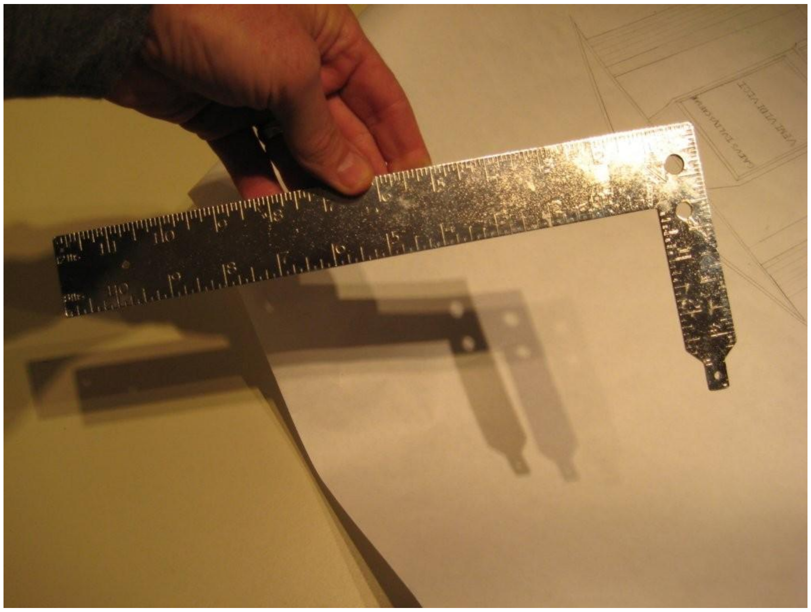


Figure 3: Utility Square (Customized)

An adjustable weight is mounted on the top of the square, and its horizontal position can be adjusted by sliding it into place and locking it down with a set screw. The adjustable weight assembly is shown below in Figure 4. The top of the weight assembly is drilled and tapped to accommodate an accelerometer.

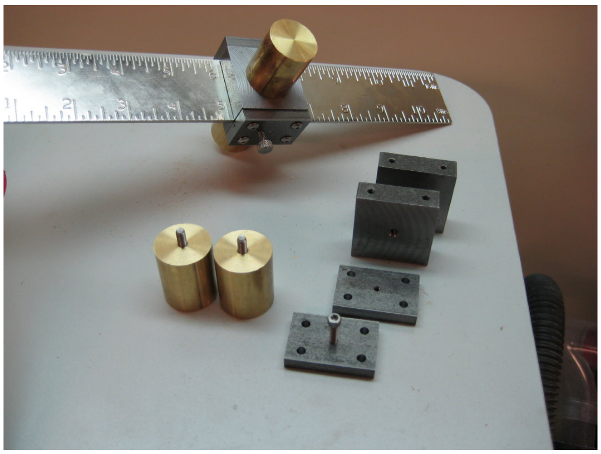


Figure 4: Adjustable Weight Assembly

A hole to receive the axle is shown at the junction of the long and short legs of the L-Square (Figure 3), and a hole to accommodate spring(s) is shown at the tapered end of the short leg. A photo of the pendulum and its support plate is shown in Figure 5 below.

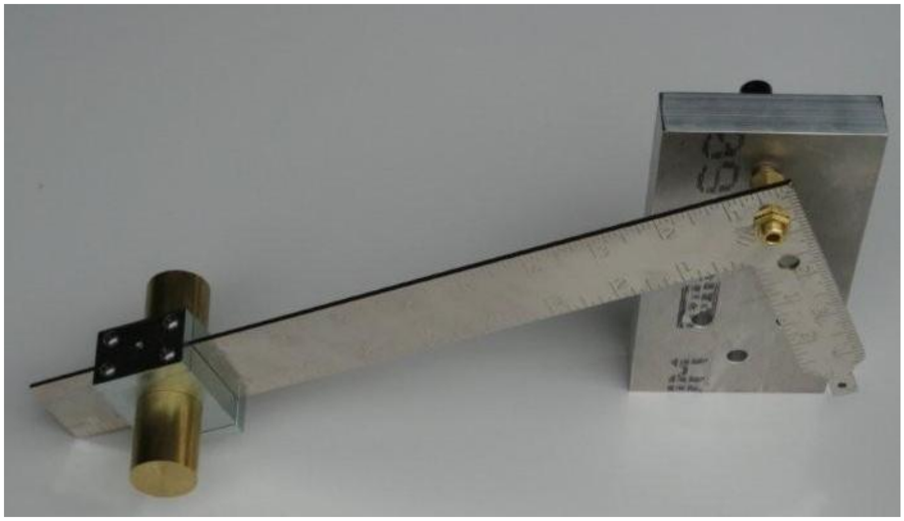


Figure 5: Physical Pendulum, Axle and Support Plate

The support plate serves two purposes. First, it supports the axle on which the pendulum oscillates (Figure 5, Figure 6B). Second, it allows a potentiometer to be attached to the pendulum axle for measuring and recording angular position. This is shown in Figure 6A below.

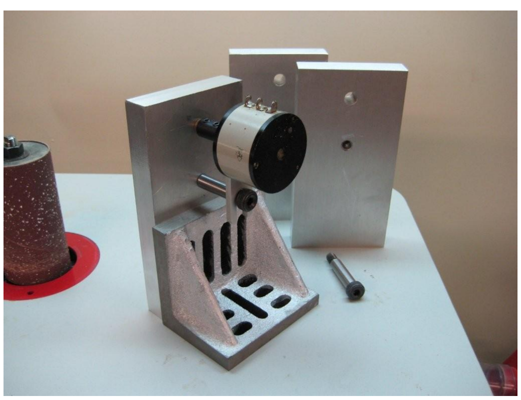


Figure 6A: Mounting the Potentiometer

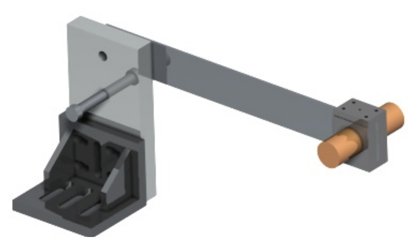


Figure 6B: Supporting the Pendulum Axle

The support plate assembly is fixed to ground by providing it with T-bolts which attach to a T-Slot baseplate, shown in Figure 7 below. The aluminum baseplate supplies a reaction mass to the oscillating pendulum.

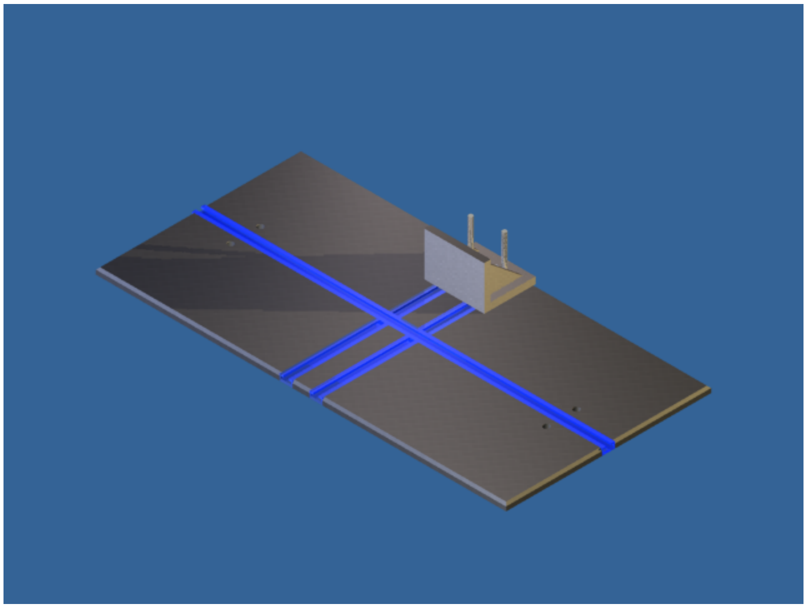


Figure 7: T-Slot Base Plate (Rendering)

Adding mill feet to the angle bracket allows the pendulum to be positioned along the double T-Track arrangement, as shown in Figure 7. Once positioned with the pendulum centered over the central T-Slot, the pendulum assembly is locked in place using T-bolts and cam clamps. The single T-Track down the center is used to accommodate a similar adjustable bracket and spring. The spring is attached to the short leg of the pendulum and tensioned by sliding the spring bracket along the single track and clamping it in place. Once the long leg of the pendulum is lifted parallel to the surface of the baseplate, the spring is clamped in place and the pendulum is free to oscillate about its static equilibrium position.

Given an initial displacement, the pendulum will oscillate at its natural frequency. The potentiometer will record the angular position as a function of time, and both the damping ratio ζ and the damped natural frequency ω_D may be calculated from the data.

Theory and Practice

There are always discrepancies between idealized analytical models and actual physical systems, and engineering students must learn to reconcile these discrepancies. On paper the natural frequency of the pendulum system shown in Figure 1 is calculated as 36 rad/sec (5.7 Hz). In fact, the measured frequency is 33.4 rad/sec (5.3 Hz). The student is therefore faced with important questions that don't typically come up in a textbook problem but do typically come up in engineering practice: questions such as:

- Is the discrepancy significant?
- Can it be accounted for by the simplifying assumptions that were made in the calculation?
- Can it be accounted for in the measurement of the system parameters (K and M, as well as lengths a and b)? Would an uncertainty analysis be helpful at this point? (yes!)
- How accurate is the lumped parameter idealization of a distributed system?
- Is friction significant or may it be neglected (undamped versus damped natural frequency)?
- Where could error enter in to the measurement process?
- Where could error enter in to the data reduction process?

All of these questions prompt students to reflect more deeply on the analytical model as well as the measurement process and its limitations. This is the value of a laboratory associated with a lecture-type class: it keeps the theory grounded in reality.

Example: Rethinking the Model

In reviewing the development of equation (1), most students immediately identified the assumption of a massless L-Square as a simplification they could easily eliminate. Several proposals were put forward for determining the rotary inertia of the L-Square and its effect on the natural frequency. The rotary inertia of this "massless" component could be determined:

- analytically - by hand
- analytically - using a computer
- experimentally

The hand calculation of an ideal L-shape is very straightforward, but once again an idealization creeps in. The actual shape of the pendulum is a *modified* L, with drilled holes and tapered edges. Accounting for these modifications becomes tedious - much more suited to computer calculation.

Using standard engineering software such as Pro/Engineer®, SolidWorks® or Inventor®, students can draft the L-Square and then list its properties, as shown in Figure 8 below. (This was in fact a post-lab exercise.)

The rotary inertia of the pendulum could also be determined experimentally using a trifilar suspension to measure the inertia. Trifilar suspensions were covered in an earlier lab, and dovetailed nicely with the current lab. By happy coincidence this earlier lab included measuring the rotary inertia of the L-Square. The experimental results were corroborated by the computer model and the result used to correct the estimate of the (ideal) natural frequency.

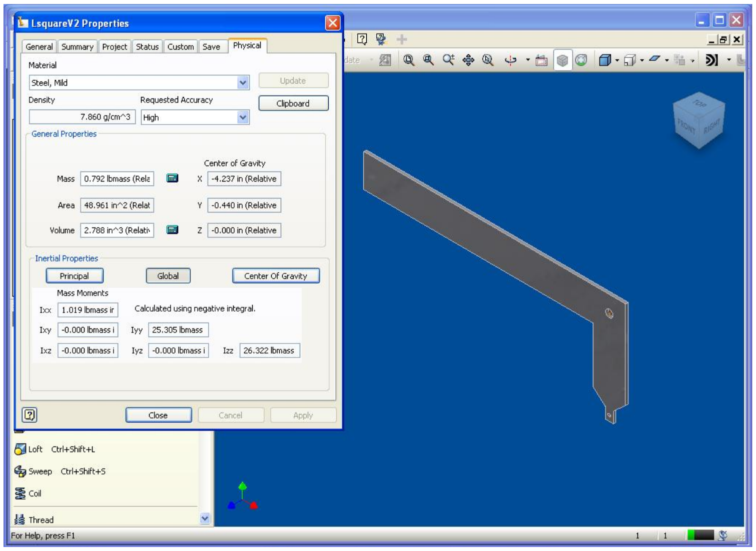


Figure 8: Rotary Inertia of the the "Massless" L-Square

Conclusion

The textbook problem in Figure 1 provided an excellent exercise for learning and reinforcing basic vibration concepts: simple harmonic motion, natural frequency, construction and use of lumped parameter system models. Connecting the textbook problem to an actual physical system raised many interesting and practical questions. These questions in turn motivated further investigation and a deeper understanding of vibration theory.

The T-Slot baseplate and fixturing facilitates the development and use of other single degree of freedom pendulum geometries. Sample problems (again taken from [1]) and future pendula are shown in the Figure 9 below.

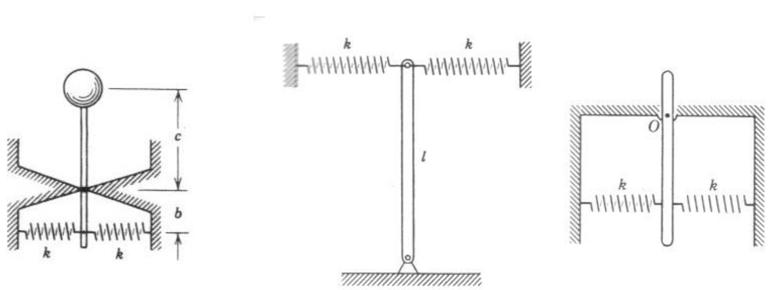


Figure 9: Other Pendulum Geometries (ref. [1])

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Dynamic Signal Analyzer Developed With LabVIEW-RF Tools

Srinivasulu Sykam, Gale Allen
Department of Electrical and Computer Engineering and Technology
Minnesota State University, Mankato

Introduction

Signal distortion consists of changes in the original amplitude, frequency, or phase of a signal. Some of the functions of a Dynamic Signal Analyzer were implemented in a LabVIEW program which controls a NI Signal Analyzer.

Laboratory Equipment

Two sets of National Instruments LabVIEW-controlled RF systems are shown in Figure 1.

Figure.1. Two NI RF Systems

Each system has a signal generator (Figure 2) and a signal analyzer (Figure 3) and a second digitizer. These are housed in the NI PXI-1045 chassis.

Figure 2. NI PXI-5671 2.7 GHz RF Vector Signal Generator with Digital Upconversion

Figure 3. NI PXI-5661 2.7 GHz RF Vector Signal Analyzer with Digital Downconversion

Dynamic Signal Analyzer
The main function of Dynamic signal analyzer is to transform the data from time domain to frequency domain. Frequency domain conversion cannot be done on continuous signals since they are not sampled and digitized. The block diagram of the DSA is shown below in Figure 4.

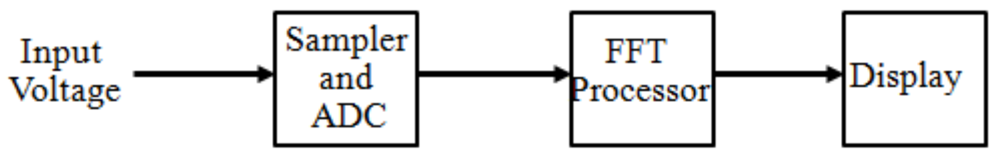

Figure.4. Block Diagram of Dynamic Signal Analyzer

In general the goal was to add features and capabilities to the existing NI Advanced Harmonic Signal Analyzer program as provided by National Instruments.

Initial Work
The initial work involved determining the features to be developed and included in the final design. The measurement capabilities of Distortion Analyzer, Agilent 35670A, were studied and considered for inclusion in the LabVIEW-based design. Some of the capabilities were provided by National Instruments in the Advanced Harmonic Signal Analyzer demonstration program. The features of the Agilent equipment and the demonstration program are included in Table 1 below along with a plan for including selected features.

Added Features
Within the time period available for this project only few of the features (mentioned as DEVELOPED in Table.1) could be added. In Table 1,

- DEVELOPED: the features which were added to the new design,
- YES: the feature is already present and
- FUTURE: the feature that can be added in the future.

Existing Measurements in Agilent 35670A	Existing Measurements in the NI Advanced Harmonic	Measurements Developed/Improved

	Analyzer Measurement.vi	
Frequency domain	NO	FUTURE
Frequency response		
Power spectrum	NO	FUTURE
Frequency spectrum		
Coherence		FUTURE
Cross spectrum	NO	FUTURE
Power spectral density	NO	DEVELOPED
Time domain		FUTURE
Time waveform		
Auto-correlation	NO	DEVELOPED
Cross-correlation	NO	DEVELOPED
Orbit diagram	NO	FUTURE
Amplitude domain	NO	FUTURE
Cumulative distribution function (CDF)	NO	FUTURE
Histogram	NO	DEVELOPED
PDF	NO	FUTURE

Table.1. Project Plan and Prospects

Stage 1: In this stage, the NI Single Tone Generation vi was removed from within the NI demo vi. The output from this program was applied as input to the remaining Advanced Harmonic Signal Analyzer vi.

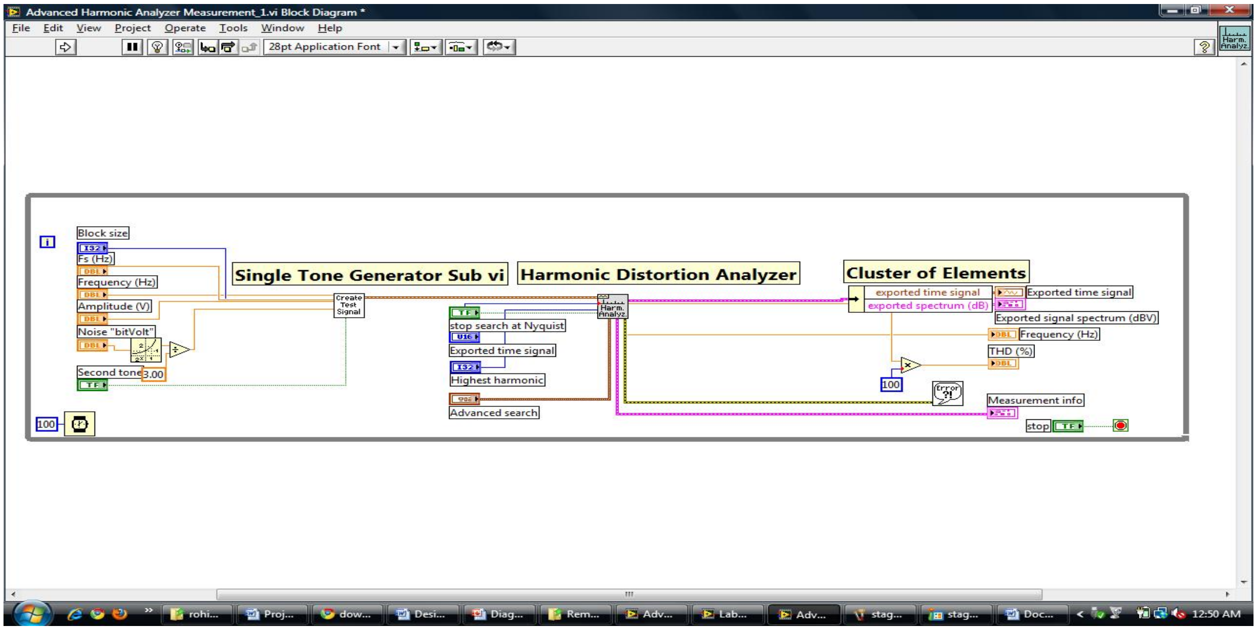

Figure.5. Advanced Harmonic Signal Analyzer

Stage 2: In this stage Signal Tone Generator blocks have been replaced with NI_RFSA blocks to collect input signal from external source and implementation of Dynamic Signal Analyzer. Single Tone Generator was able to generate a single tone but the input signal was generated internally. This program was not able to collect the signal generated by an external source. In this project, RFSA down converter (NI-PXI-5600) was used as the signal source. To collect this external signal generated on to the PC and further processing, the Single Tone block has been replaced with the RFSA blocks.

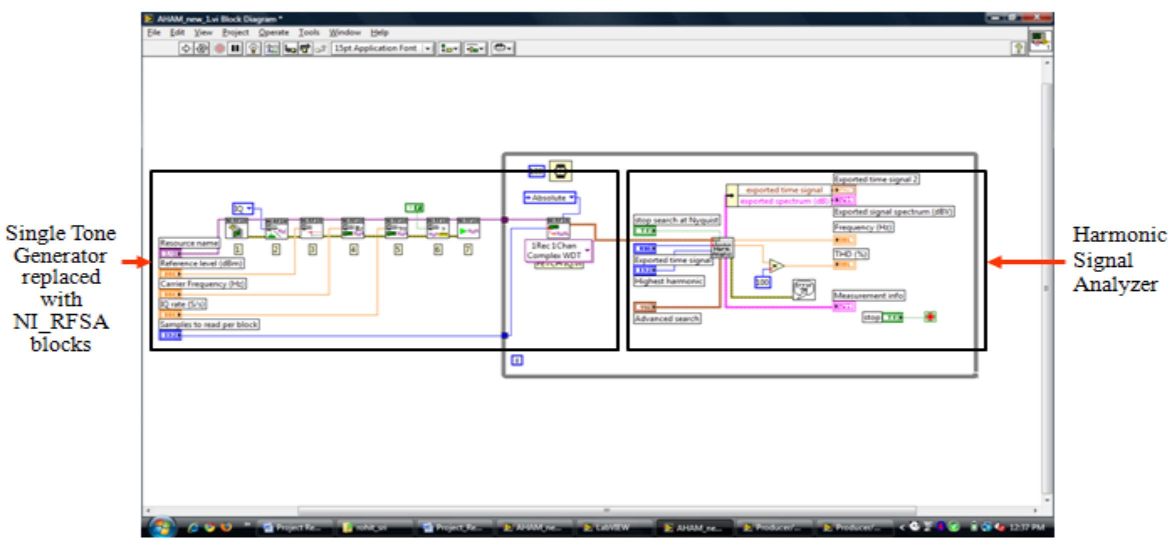

Figure.6. Advenced Harmonic Signal Analyzer with NI_RFSA blocks

Fundamental frequency is the lowest frequency in the harmonic series. Any device producing a fundamental frequency also produces harmonic frequencies that are multiples of fundamental frequency. All the harmonic frequencies are lower in level compared to the fundamental frequency. While measuring Total Harmonic Distortion of an amplifier, the extent of distortion is the measure of the level of harmonics at the input to the level of harmonics at the output.

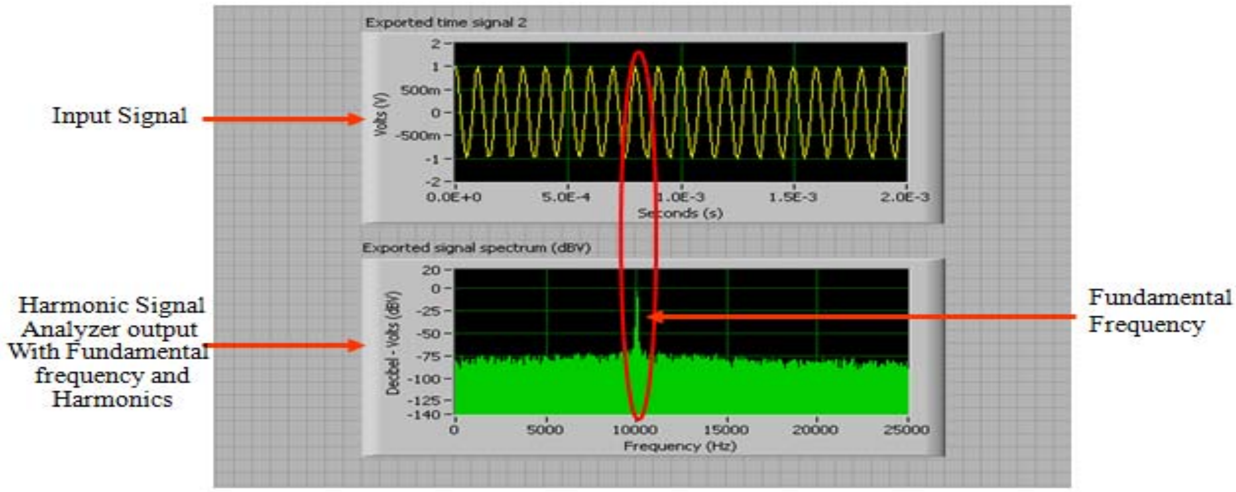

Figure.7. Output of the Harmonic Signal Analyzer with RFSA input

Stage 3: In this stage, different features were developed and added to the Dynamic Signal Analyzer vi. NI_RFSA blocks take the signal from any signal generator and processes through different stages of signal acquisition and signal processing. Output of NI_RFSA blocks is given to the Harmonic Distortion Analyzer which performs the harmonic analysis on the signal and Total Harmonic Distortion of the signal is determined.

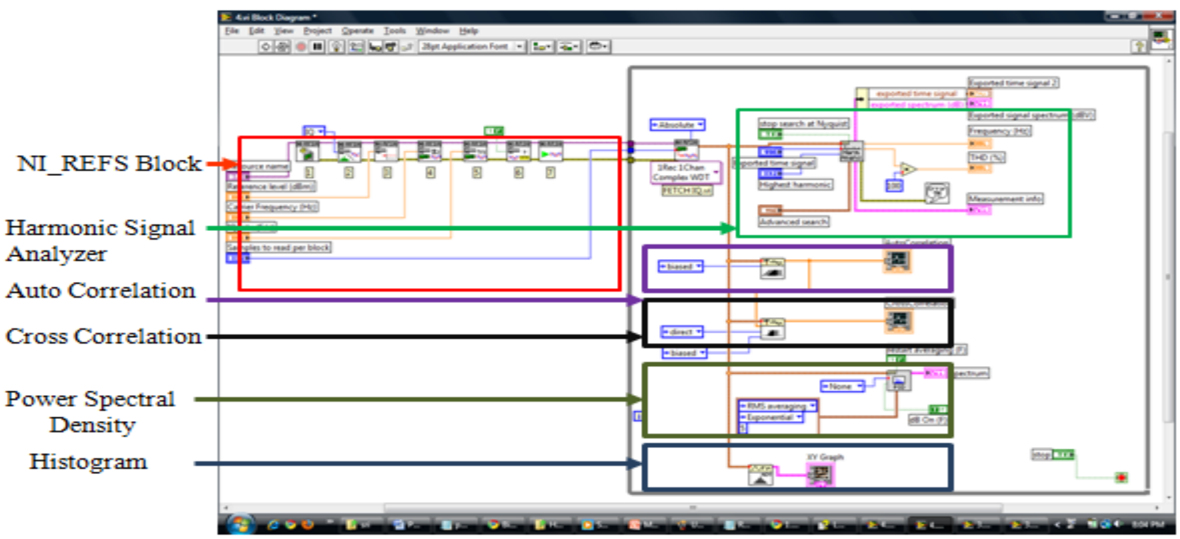

Figure.8. Final View of the Project

Below figure shows the expected outputs for the features added.

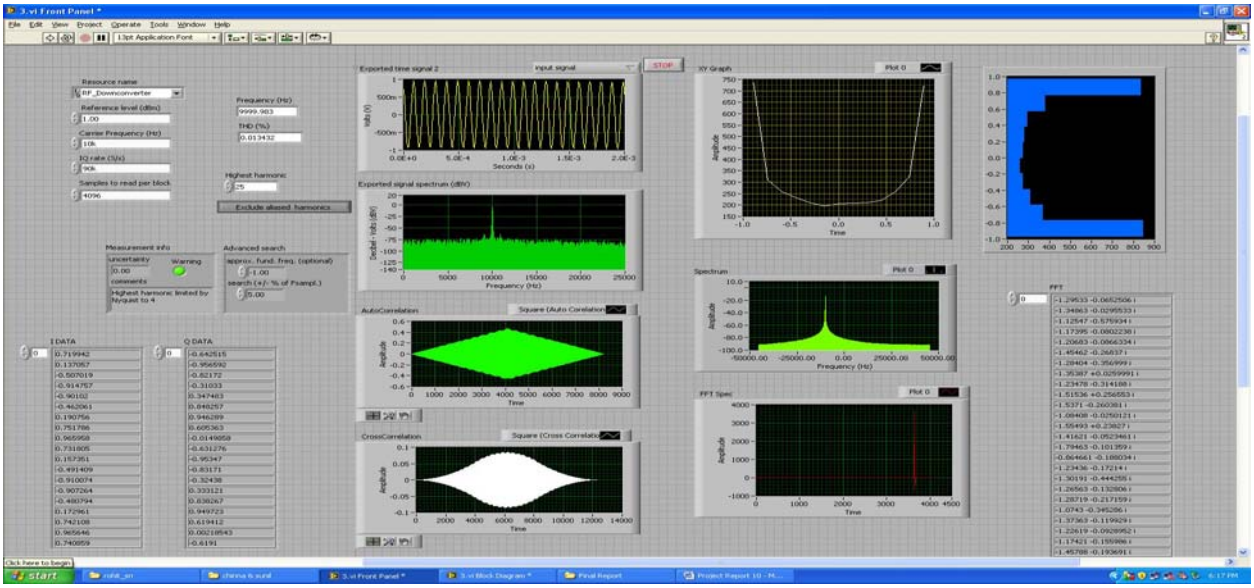

Figure.9. Final Output

Conclusion

To conclude on the whole, general purpose Dynamic Signal Analyzer vi which can take signal from an external signal device has been developed and has been successfully implemented using LabVIEW. The future developments that can be done on this design have been mentioned in Table.1.

The authors would like to thank Dr. William Hudson, ECET Department Chair, for his efforts to help improve the communications laboratory and for his ongoing encouragement and support of students and faculty. Also the staff of National Instruments provided valuable guidance on operation of the RF instruments and LabVIEW programming.

- Minnesota Center for Excellence in Engineering & Manufacturing and National Instruments for supporting acquisition of the NI RF equipment.

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Enhancing the Design Experience by Developing Projects for Special Needs Children

Daryl L. Logan, Laurie Geyer, and Ann Terrill

University of Wisconsin-Platteville, Platteville, WI 53818, Logan@uwplatt.edu/ Occupational Therapist and Physical Therapist School District of Platteville, Platteville, WI 53818

ABSTRACT

This paper describes how projects for special needs children enhance the design experience while providing a valued service to the special needs children. Teams of students in the Mechanical Systems Design course at the University of Wisconsin-Platteville (UWP) worked closely with the occupational and physical therapists from the Platteville K-12 school system to design various adaptive devices for children with special needs. Seventeen adaptive devices were designed and built in the past two semesters. This paper includes descriptions of three of these: a redesign of a bicycle for a child with cerebral palsy, a learning center for a child with spina bifida, and a visual light activity box for a child recovering from pilocystic astrocytoma brain tumors. The learning center project was a continuation of a similar project from the previous semester. Some of the specific benefits of these projects to the children include: building of self esteem and confidence, providing an improved learning environment, and redeveloping of motor skills. A formal design process as described in this paper was used to determine the final design for each team. A prototype was then built and the projects were presented to an audience of parents and friends of the special needs students, the therapists and the course instructor. The prototypes shown in this paper have been successfully used by the children at school for the past semester.

INTRODUCTION (DEFINING THE PROJECTS)

This paper describes three special needs projects that students designed and built this past semester at UWP. These projects demonstrate the design process and how they have enhanced the design experience. Initial discussion took place between the occupational and physical therapists and the instructor of the Mechanical Systems Design course to create a need for projects that could be designed and built in one semester for special needs children in the school system. The projects were then presented by the therapists to the students with explanations of the children's disabilities. These adaptive-type devices would have to motivate the children to use the devices and benefit the children by enhancing their self confidence. Upon use of the devices, the children should also improve in the following typical ways: improving motor skills and self-esteem for the child with cerebral palsy, assisting in placement of learning materials for the child with spina bifida, and recovering lost motor skills for the child recovering from brain tumor surgery.

METHOD OF SOLUTION – FORMAL DESIGN PROCESS

Teams composed of four to six students were created to match up their interests as best possible. The student individual teams then met with the special needs child, along with the therapists and classroom instructor. At this meeting, the special needs children, with insight provide by the therapists, demonstrated their abilities and needs.

Need Statement or Problem Definition

Based on a standard design process, a formal need statement was developed by each team. The need statements for the projects described in this paper were as follows:

- There is a need to redesign and modify a bicycle adaptable to a child with cerebral palsy so the child can participate with other bicycle riders.
- There is a need to design and build a learning center to allow a student with spina bifida to participate in the classroom learning experience.
- There is a need for a device to stimulate a student's eye-hand coordination to regain their normal use of upper body motion skills.

A Gantt chart was then created to assist in planning and scheduling of the project.

Background Information

Based on the defined need and information gathered during the initial visit with the special needs child, the teams then obtained background information on the particular disability of the child and began searching for existing devices that might meet the need.

Problem Constraints

Through information from their background research, from suggestions made by the therapists, and based on observed motor skill behavior and gathered physical data of the children, the teams then identified problem constraints or task specifications. Some significant constraints for the projects included:

- For the redesigned bicycle:
  The bicycle must be ergonomically designed and modified to account for the special needs of the child, including an adjustable seat with supporting back, adjustable pedals with straps, and adjustable handlebars (actually reversed from normal position) all to make sure the bicycle is safe and stable to ride.
- For the learning center:
  The learning center must have easily adjustable moving parts.
  The center must have sufficient supporting arms to hold books, notebooks, and computer.
- For the visual light activity box:
  The visual light activity box must have proper dimensions to be transportable. The orientation of the peg/light holes must be laid out to cover a sufficient area to increase the student's peripheral vision, but not be spread out too far to cause the student to over-reach.

Possible Solutions

Possible or candidate solutions were generated with each team required to generate two to three possible solution concepts. These concepts were then evaluated based on various weighted criteria in a decision matrix often including such criteria as ease of assembly, product functionality, ease of use, safety, quality, and cost. Decisions on material selection and manufacturing process, sometimes dictated by the client, also were of significant importance in the design process. These concepts were presented to the therapists. Often concepts were demonstrated using rough models of wood or cardboard or CAD animations, as appropriate. The final design decision was based on numerous iterations with input from the therapists. A typical decision matrix for the learning center is shown in Figure 1.

		Ergotron - Design 1		**Square Tube – Design 2**	
	Weight factor	Score	Value	Score	Value
Time to Produce	**0.05**	**10**	**0.5**	**5**	**0.25**
Reliability	**0.2**	**10**	**2**	**5**	**1**
Material cost	**0.1**	**8**	**0.8**	**6**	**0.6**
Manufacturing cost	**0.1**	**9**	**1**	**9**	**0.9**
Low complexity	**0.1**	**9**	**0.9**	**9**	**0.9**
Ease of Assembly	**0.05**	**10**	**0.50**	**8**	**0.4**
Ease of adjustability	**0.2**	**9**	**1.8**	**7**	**1.4**
Ease of maintenance	**0.2**	**9**	**1.8**	**9**	**1.8**
Total	**1**		**9.30**		**7.25**

Figure 1 – Typical decision matrix for learning center for special needs child

Proposed Solution

The final design concept was then selected consistent with the best scored possible solution. This solution was detailed with the aid of computer-aided software. Appropriate engineering principles and equations were included to validate the soundness of the designs. A prototype was then built by each design team. The final prototypes of the three designs described in this paper are shown in Figure 2. These prototypes, along with an oral presentation and a written engineering report were presented to the therapists. The oral presentation was also attended by the parents and relatives of the special needs child, and other interested parties from the university, including the Associate Dean, and Chair of the Mechanical Engineering Program.

(a) **(b)** **(c)**

Figure 2 – a) Child using his redesigned/modified bicycle, b) child positioned at her learning center, and c) light activity box showing arrangement of peg holes

ENHANCEMENT OF DESIGN EXPERIENCE

From these projects for special needs children, we observe how the design experience for the students has been enhanced as follows:

- Solve real life problems with a sponsor or client.
- Introduce, interact, and serve students with special needs.
- Design unique and challenging projects for special needs.
- Provide a needed device at an affordable price.
- Increase student's enthusiasm.
- Enhance team working skills.
- Enhance communication skills.

It is emphasized that the same design process is used for special needs devices as with developing products used by the general public. Projects incorporate design considerations, such as scheduling, project management, and team working skills, working within interdisciplinary settings, working with vendors and creating a bill of materials, safety, ergonomics, aesthetics, societal concerns, liability, and cost.

CHALLENGES AND RECOMMENDATIONS

Some challenges working with special needs projects include:

- Expectations that a working useful device will be created that is aesthetically pleasing;
- Variability of degree of difficulty in projects;
- That the device will be built and delivered at the assigned end of semester time;
- Follow-up logistics to observe if the actual criteria have been met;
- Lack of assurance to modify or have continuity to improve on a project from one semester to another to meet client recommendations, (In the case of the learning center, numerous changes were made by encouraging feedback to suggest improvements from one semester to the next. These changes resulted in an excellent professional functioning working solution for the high school student using the learning

center. Fortunately, the course has been taught in continuous semesters and by the same instructor for the past two years to make this possible.)

Recommendations include ways to ensure follow-up of the projects to observe if they are meeting the needs of the special needs children and continuity in course teaching and its requirements so that improvements can be made to previous projects as necessary.

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BIOGRAPHY

DARYL LOGAN is a Professor of Mechanical Engineering at the University of Wisconsin-Platteville. He received his B.S., M.S., and PhD degrees from the University of Illinois-Chicago. Dr. Logan’s teaching interests include solid mechanics, mechanisms and machines, mechanical systems, and finite element method.

LAURIE GEYER is the Occupational Therapist at the School District of Platteville. She received her B.S. degree from the University of Wisconsin-Madison. Some of her specialty areas include pediatrics, sensory integration, and vision therapy.

ANN TERRILL is the Physical Therapist at the School District of Platteville. She received her B.S. degree from the University of Wisconsin-Madison. Some of her specialty areas include pediatrics, developmental skill acquisition, sensory motor processing, and ocular motor control as related to skill development.

Dance + Engineering: A Collaboration for Freshmen Engineering Design Students

AnnMarie Thomas[1], Amy Miller[2], Heather Spicuzza[2]
University of St. Thomas, Saint Paul, MN[1]/ The Ordway Center for the Performing Arts, St. Paul, MN[2]

ABSTRACT
This paper examines a collaboration between the freshmen-level engineering graphics and design class at the University of St. Thomas (UST), dance students at Macalester College and the University of St. Thomas, Ordway Center for the Performing Arts, and Diavolo Dance Theater. Traditionally, students in ENGR171 completed a design project for a fictitious client. Through this collaboration, however, the students were given a real client, a more open-ended initial design brief, and a strict timeline. The engineering students participated in a movement workshop to familiarize themselves with some of the methods the dancers would be using. Additionally, they met with their clients to establish user needs and engineering specifications for the project. Students' designs were then commented on, via the internet, by dancers, set designers, potential users of the set piece, and potential manufacturers of the set piece. The students' deliverables included written descriptions of their designs, CAD models, and oral presentations. This paper will address some of the strengths and weaknesses of this collaborative project, as well as lessons learned that can be applied to future collaborative projects.

INTRODUCTION
Engineering Graphics and Design (ENGR171) is a four-credit required course in the Mechanical Engineering major. It is typically taken during fall or spring semester of the freshman year and is usually the first or second course the student takes in the engineering department. The other engineering course that electrical and mechanical engineering students take during the freshman year is a one-credit Introduction to Engineering course. The following is the ENGR171 course description as written in University of St. Thomas' course catalog:

"Through a combination of lectures, hands-on computer lab time, and design projects, students will learn to read, and create, engineering drawings and use computer-aided-design (CAD) terminology and technology. Topics covered will include the engineering design process, rapid prototyping, principles of projection, and introductory methods of representation and constructive geometry."

Historically, this course has focused on drafting and CAD, (Hennessey 2002, 2005), though in the past two years, St. Thomas faculty has added an emphasis on design process, product design, and rapid prototyping. In addition to a final project in which students take apart a complex object and create, using the SolidWorks CAD program, a full packet of engineering drawings and models for the object, students must complete two design projects during the semester. In a typical semester, these projects are:

- Project 1: *"Chair Design"* Students must design a chair for a specified imaginary client that can be built using a single piece of standard plywood. After creating a CAD model of this chair, students are taught how to use a laser cutter to make scale models of the chair.
- Project 2: *"Chess Project"* Students must design a chess set for their choice of one of three possible imaginary clients (a blind individual, a child, or a beginner chess player.) They must create a list of user needs for the chess set, and then create a CAD model of a full set of chess pieces that meet these needs. Students are then given the opportunity to have one of their designed pieces 3D printed in the design lab.

The goal of these projects is to encourage students to apply a structured design process to an open-ended design challenge.

In the spring of 2009, the lead instructor for ENGR171 was approached by representatives from Ordway Center for the Performing Arts as part of their Campus Connections program. The Campus Connections program (funded by The Wallace Foundation) is a campus-wide partnership with Ordway Center designed to build bridges between the Ordway and communities of students, faculty, staff, and alumni. The program's goal is to develop effective ideas and practices to integrate arts-based methodologies into teaching practice, as well as to build current and future audiences and enhance participation in the arts. As part of this program, the Ordway was interested in exploring cross-curricular connections to the presentations within their World Music and Dance Series. Introducing the engineering students to dance through work with Los Angeles-based Diavolo Dance Theater, seemed logical because of the company's reliance on objects as central to its aesthetic, and, further, would allow for students focused in two very different disciplines (science-based and arts-based) to form a practical working relationship based on mutual creativity.

Engineering is a natural fit with a Diavolo project as their dance style is very physical and always involves the use of an object or set piece. In their artistic statement, the importance of set pieces is stressed: "Architectural structures or sculpted adaptations of everyday items - sofas, doors, stairs - provide the backdrop for dramatic and risky movement, revealing metaphors for the challenge of maintaining human relationships in modern environments" (Heim). During a collaborative planning process with team leaders from UST's Engineering Department, Macalester's Dance Department, and Ordway's Community Engagement department, a process emerged in which UST Engineering students, Macalester and UST student lead dancers, and dancers from both schools would be actively and collaboratively engaged to work with Diavolo in the creation and presentation of an original dance piece, to be performed during the Spring 2010 Macalester Dance Concert. All students would work with the Diavolo team to learn the company's specific aesthetic and would apply skills from their own disciplines to the final project. A set piece would be created and Diavolo company members would guide the Macalester and UST dancers through the process of choreographing a dance around the constructed set piece. Thus, for the Spring 2010 semester, Project 1 (the chair project described above) would be replaced with an involved project in which the students would design a set piece to be the central physical element in a dance performed during the Macalester Spring 2010 Dance Concert.

It was decided that students from ENGR171 would individually design and model (using SolidWorks), a set piece based on design requirements and feedback given to them by members of Diavolo and the student lead dancers from Macalester and UST. Members of Diavolo, the student lead dancers, and representatives of the Ordway would discuss the proposed designs and then select one to be constructed. A build team from the University of St. Thomas would then create the physical set piece based on the selected design. This set piece would then be delivered to the Ordway for the intensive rehearsals between Diavolo members and Macalester/UST dancers, during which a dance involving the set piece would be choreographed. Below, this process will be discussed in detail.

PROJECT LAUNCH

One challenge presented by this project was the timeline. Typically, the first design project for ENGR171 would be presented approximately at the end of the fifth week of the semester. However, in order to have a set piece delivered to the Ordway in time for the intensive rehearsals with Diavolo and the Macalester/UST dancers, the first project was launched at the beginning of the fourth week of the semester. On the Monday of the fourth week of the semester, Jacques Heim, Artistic Director of Diavolo, along with Garrett Wolf, veteran Diavolo company member, joined the ENGR171 students for the project launch.

During the initial launch, the Diavolo representatives showed video footage of their performances and discussed the aesthetic of Diavolo. Students were then given the following project description:

> *For this project we are partnering with Ordway Center for the Performing Arts, dancers from Macalester College and the University of St. Thomas, and Diavolo Dance Theater of Los Angeles. A group of dancers will be training with Diavolo company members in order to create and perform a piece in the style of Diavolo. That's where you come in! Diavolo dances use props and/or set pieces. Using your knowledge of the design process and SolidWorks, you are going to design a piece for the Macalester/UST dancers. To do this, we will be working with dancers from both Macalester/UST and Diavolo. One of you will have your design chosen to be built into a set piece in which a dance will be choreographed around.*
> *Your set piece must be able to be built out of one to three pieces of plywood, 8' x 4' x 1/16". Your design must not require the use of any fasteners, with the exception of fasteners made out of the plywood itself. (Note that if your design is chosen for construction, we will work with you to design supports for it which may include the use of additional wood and/or fasteners.) We will then be building 1/12 scale models using thin plywood and the UST Design Lab's laser cutter. As you work on this project, please reflect on the lectures, readings, discussions of the engineering design process that we had at the beginning of the semester!*

The requirements for the project's deliverables were also presented to the students at this time. There were two sets of deliverables for this project, as described below. Students were given a chance to ask questions of the Diavolo representatives.

The next class session consisted of a movement workshop for the engineering students led by Jacques Heim and Garrett Wolf of Diavolo. Creative thinking was emphasized throughout the workshop and students were encouraged to use trust in order to accomplish the movement exercises, which included leaping into fellow classmates' arms during the Diavolo "Superman" exercise. The engineering students were also given a short assignment to choreograph a series of movements on a folding chair, which helped them gain insight into the dancers' role of moving and choreographing on a set piece.

PROJECT DELIVERABLES

The following are the instructions that the students received for the first deliverable set. Please note: Blackboard is an online forum used by UST for class discussions and postings.

> ***Part A: Preliminary designs*** [due 10 days after the project launch]
> *Please post the following on Blackboard by noon. Note that there is a scanner available for your use in OSS 105* [engineering student lounge].
> - *A half-to-full page write-up explaining your design, and why you think it is appropriate for the Macalester and UST dancers, based on your discussions and work with Diavolo.*
> - *1-2 pages of sketches (hand drawn) showing your design in enough detail to give the viewer an idea of the finished piece. You will be receiving feedback on these drawings from the dancers and choreographers.*

The students were encouraged to be bold in their ideas, and to focus on hand sketches and written descriptions which would give the viewer a sense of what the design would look like when completed, with enough information and detail such that constructive criticism could be given. During the first few weeks of ENGR171, students are given instruction in various hand-sketching methods. The sketching part of this project is meant to encourage students to continue practicing their drawing skills. Students were able to get feedback from dancers and choreographers of Diavolo, staff members from Ordway Center for the Performing Arts, the lab and lecture instructors from ENGR171, the student lead dancers, and the shop manager from the University of St. Thomas, who would lead the build team for the set piece, using an on-line discussion board format. Samples of two of the hand-drawn sketches, minus the accompanying write-up, can be found in Figure 1.

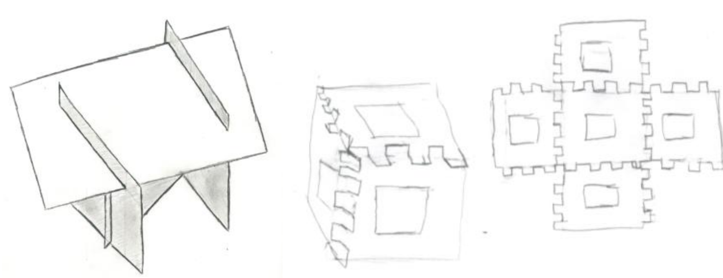

Figure 1: Samples of the initial sketch phase of the design project.
(Work by Aisha Adam and Dimitri Angelo)

Following this on-line exchange of ideas, along with accompanying discussion in the ENGR171 lecture and lab, students proceeded to Part B of the project.

> ***Part B: Presentation, models and drawings of your final design*** [due 18 days after the project launch, 8 days after the completion of Part A]
> *Create a new folder, entitled "Project 2," in your ENGR171 directory. In this directory, include:*
>
> - *SolidWorks models of each part for your final design. (Parts should be fully dimensioned for the actual size of the piece.)*
> - *An assembly file for the completed piece*
> - *(A) SolidWorks drawing file(s), saved in a .dwg format, to use as a cutting file*
>   - *8" by 4" page for each sheet of plywood that you are using*
>   - *No border or title block*
>   - *Front views only of each piece, laid out however you intend for them to be cut from the wood at 1:12 scale*
>   - *Note that this is not an engineering drawing, but rather the cutting template for the laser cutter. We will be using this file to produce your wooden model.*
> - *Please submit a packet containing the following:*
>   - *One page describing your final design. What was the idea behind it? How did your design change based on feedback? What do you think some of the challenges would be if we decided to build this full scale for the Macalester dancers?*
>   - *Printouts of the SolidWorks model (assembly) of your piece*
>   - *A printout of the SolidWorks drawing(s) described above*
>   - *An 8.5x11 inch poster designed using PowerPoint which shows:*
>   - *An assembly drawing of your design*
>   - *A short description of your design*
>   - *A title for your design*
>   - *Your name and class information (ENGR171 Spring 2010)*
>   - *Any images or sketches which you think help explain your design*
>
> *In class you will have 60 seconds to give a short presentation on your design, with the poster projected on the screen as a visual aid. The lead student dancers and Ordway staff, in addition to your classmates, will be there. The final design will be chosen after these presentations.*

Samples of student posters can be found in Figure 2. A sample of a student's SolidWorks assembly and corresponding laser cutter file can be found in Figure 3.

DESIGN SELECTION

Eighteen days after the project launch, the students gave their 60-second (single PowerPoint slide) presentations showing their designs. Samples of these slides can be found in Figure 2. In the audience for these presentations were the ENGR171 faculty and students, the student lead dancers, and representatives from Ordway Center for the Performing Arts. Representatives from Diavolo were not present due to their travel schedule. During the presentation, individuals involved in choosing the final design to be constructed for the Macalester dance took notes on which designs seemed most promising. After the mini-presentations (which took one full class period), the ENGR171 instructor met with the student dance leads and the Community Events Coordinator from the Ordway to choose the final design. Based on the results of this meeting, a short list of approximately five of the most promising designs were emailed to Jacques Heim, Artistic Director of Diavolo, who then joined the group by phone. In the course of the discussion with Jacques Heim, the final design was chosen. As will be discussed below, the group chose the final design based on a variety of factors, including how well the design would work for a group of 20 dancers.

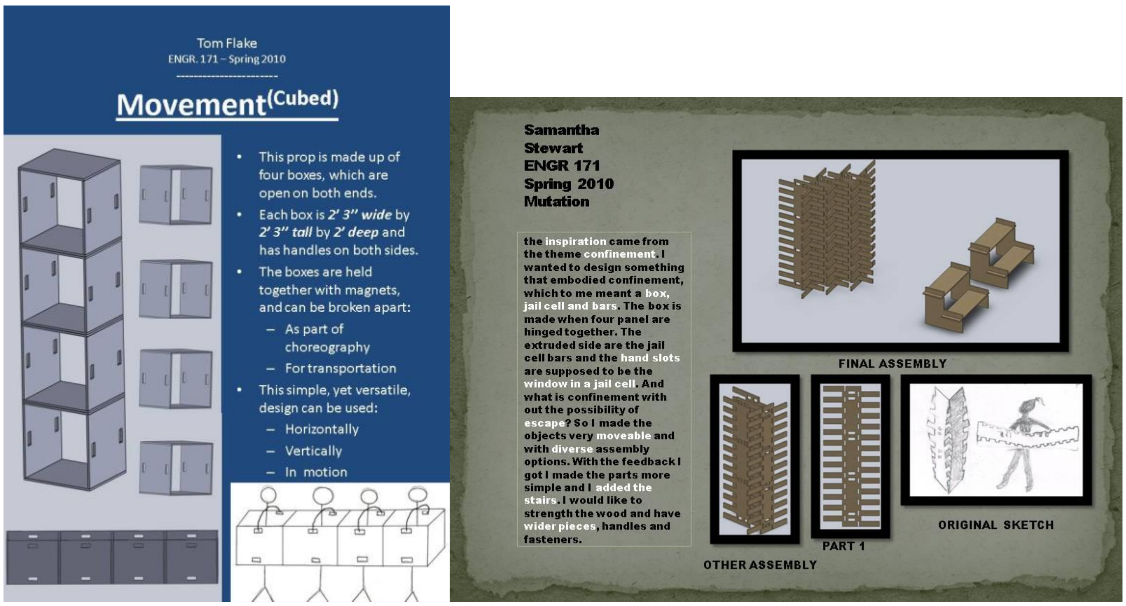

Figure 2: Samples of student slides for the 60 second project pitch presentations.
The slide on the left represents the design that was ultimately chosen for construction.
(Work by Tom Flake and Samantha Stewart)

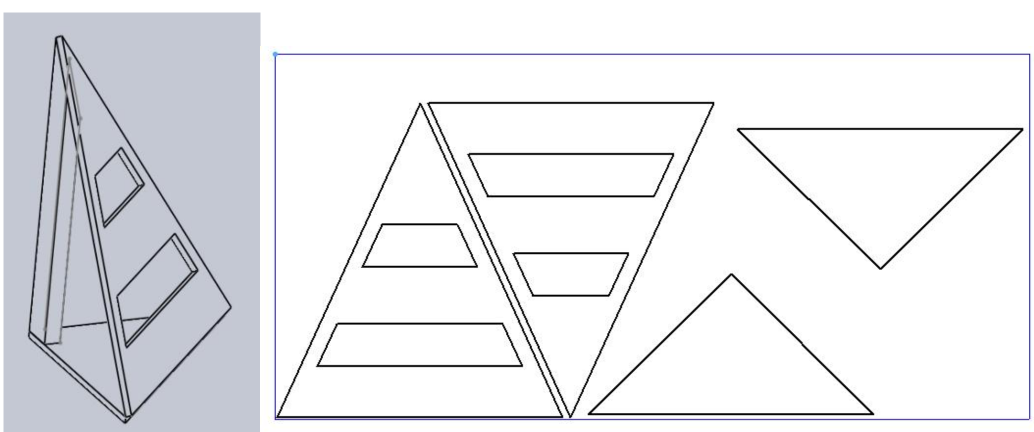

Figure 3: A sample of a student's SolidWorks assembly file and one of two corresponding laser cutting templates that are associated with this assembly. (Work by Matthew Hanson)

PROJECT BUILD

Three students who had previously taken ENGR 171were hired to work with the School of Engineering lab manager to build props based on the design provided by the student. It is important to note that the design which was built was true to the concept designed by the student, but not the physical design. One challenge of this project was that ENGR171 has no prerequisites, and thus the students did not necessarily have any experience with physics or manufacturing. The build team worked with the ENGR171 instructor as well as the student designer to revise the design to one that would be sturdy and buildable (Figure 4).

Figure 4: Undergraduate engineering students constructing the final set piece for the Macalester and UST dancers. (Photographs courtesy of John Angeli)

Figure 5: Student Tom Flake with the set piece created using his design.

While only one design was built at full scale (see Figure 5), every student who submitted a laser cutting file (as described in the instructions for Part B of the project and pictured in Figure 3) had their parts cut on a laser cutter. Some of these scale models can be seen in Figure 6. The final build involved creating two sets of the chosen design (thus using double the material limit that was specified in the instructions). This was done at the request of the Diavolo members.

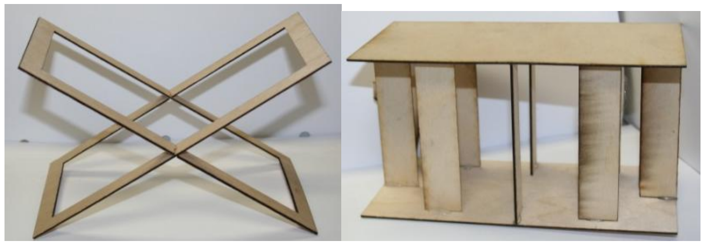

Figure 6: Scale (1/12) models of the students' models constructed using the laser cutter. (Designs by Anthony Suchla, and Stephen Bang)

SOCIAL COMPONENT

Students had the unique opportunity to attend a performance by Diavolo at Ordway Center for the Performing Arts a few weeks after the final design presentations. Prior to the show the ENGR171 students socialized with the Macalester and UST dancers, Diavolo members, and staff of the Ordway. The chance to socialize with others involved in the project strengthened the sense of community related to this project. Watching Diavolo perform with large set-pieces on stage also gave the engineering students the chance to see commissioned design works in use, giving a "real-life" factor to the project.

STUDENT FEEDBACK

As part of the Ordway's Campus Connections program, a facilitator from the Ordway ran a tuning session with the students the day after the optional visit to the Diavolo performance (approximately two weeks after the "winning" design was chosen). Each student was given a chance to verbally share their warm feedback about the project as well as their cool feedback, in the form of "I wonder…" statements. Both sets of feedback were helpful in pointing out what worked well, what could have been done differently, and further ideas for the project if done again.

In the warm feedback section of the tuning, the following were some of the aspects that the students thought were most successful about this project:

- Having the actual client (the student lead dancers, the Diavolo Artistic Director and a Diavolo company member) at the project launch meeting was very helpful.
- The online critiques of the preliminary designs were found to be helpful. At least one student discussed how this feedback led him to change his design between the initial sketch stage and the final model stage.
- The chance to build a relationship with the client was a positive experience – having the opportunity to work with an actual client who would use the design (not just a hypothetical assignment).
- The movement workshop with Diavolo was helpful. The engineering students noted that this helped them think about movement possibilities, and also that such an experience was fun since it was something that an engineering student wouldn't normally get the chance to do ("able to experience instead of just watching").
- Many students mentioned that having the chance to design something "real" as freshmen was very exciting for them. As one student said, "What was designed was actually going to be built – made it real – the design has a 'life.'"

- Competition between designers was seen by the students to be a positive aspect in that it encouraged them to produce creative, original designs.
- Learning about dance as well as working with Diavolo and learning their aesthetic style helped the students design.
- Students appreciated the chance to meet many different people from different fields.
- The project taught students about collaboration and incorporating many crucial points of view, which is important for arts-integration work

Anecdotally, students seemed much more engaged with this project than they typically have been when completing the chair project (described above) in previous semesters. Based on the warm feedback, it seems that the key factors in the students' involvement are likely the participation of a real client who was available to give students feedback, and the knowledge that their work may be turned into a physical object used by the client.

During the cool feedback portion, students were all invited to talk about things that may have been done differently. Below is a sampling of this feedback. In italics below each suggestion, we have included a response to explain the rationale behind our choice:

- I wonder if next time, there could be no material constraint – instead, have a budget to allow for more creativity?
  For this project, we constrained the materials so that the build team could begin construction of the set as soon as a design was chosen and complete it in a timely manner (the build team had only one week to build the set before intensive rehearsals for the dancers began). Additionally, as this project was done early in the semester, the engineering students had limited knowledge of SolidWorks. By constraining the project to plywood, we ensured that students would be able to create a design using simple sketching and extrude tools in SolidWorks.
- I wonder if the project could happen at a different point during the semester?
  Some students felt ill-prepared for doing a design project this early in the semester, given the limits of their SolidWorks experience. Given the deadline for delivering the set piece, we could not push this project back any further in the semester.
- I wonder if we could have more time together to talk about design, an important part of the collaboration, and to talk about the final product?
  Again, due to the need for the dancers to have the finished set piece by the middle of the semester, we were constrained to a tight timeline.
- I wonder what would happen if we worked in teams rather than individually, allowing us to exchange ideas and possibly develop more creative designs?
  This is a good point and one that we struggle with whenever we design ENGR171 projects. Since this is one of the first college classes the students take, we like them to do a mix of individual and group projects to strengthen their technical skills, as well as their teamwork abilities. The final ENGR171 project is always done in teams.

CONCLUSION

From an instructor's standpoint there were a few unique challenges and benefits that came from this project. First and foremost, when collaborating with the many partners involved in this

project, the ENGR171 instructor lost a level of control over the class project. Flexibility was key.
Because the students were freshmen, many of whom had no college-level physics classes, the students did not have the skills to do static and dynamic analysis of their designs. In some ways this project could be considered a concept design project as opposed to an engineering design project. Were this class populated with students who were further along in their engineering studies, force analysis could be added to the project. Additionally, the students' knowledge of manufacturing methods was extremely limited, so the project organizers understood that the project build crew and ENGR171 instructor would have to redesign the chosen set piece to make it buildable. For the chosen design, this was indeed the case and the edges of the box, critical for attaching the sides together, were redesigned. Figure 7 shows the boxes in their final form, being used by the student dancers.

Figure 7: Student dancers choreographing on the chosen set piece.
(Photo courtesy of Amy Miller.)

The opportunity to have first year students working with real clients added a level of excitement to this course that is absent in cases where the projects involve fictitious clients. Their attention to the project's requirements and user needs was stronger, likely owing to the fact that they were presenting their projects to the client and getting real feedback. While this particular project is unlikely to be repeated due to the unique nature of the opportunity, we will attempt to find other clients that ENGR171 students can work with in order to duplicate the success of this project.

ACKNOWLEDGEMENTS
We are grateful to the Ordway Center for the Performing Arts' Campus Connections program for offering us this opportunity. We would like to thank John Angeli, William Johnson, William Besser, and Tom McCulloch for constructing the final set pieces. The project could not have happened without Jacques Heim, Garrett Wolf, Renee Larsen and the entire Diavolo company,

Allen Moon of David Lieberman Artists' Representatives, Shelley Quiala, Wynn Fricke, Becky Heist, Susanna Hostetter, Amanda Leaveck, Sarah White, and the dancers of Macalester and University of St. Thomas. This project was funded in part by The Wallace Foundation Excellence Award grant to the Ordway.

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BIOGRAPHICAL INFORMATION

ANNMARIE POLSENBERG THOMAS is an assistant professor of Engineering at the University of St. Thomas. Her teaching and research focus on Design and K-12 Engineering Education. Prior to her appointment at UST, she was a faculty member at Art Center College of Design.

AMY MILLER is the Community Events Coordinator at Ordway Center for the Performing Arts. She coordinates events and residencies surrounding the Target World Music and Dance Series ® and the Campus Connections Program.

HEATHER SPICUZZA is the Programming Director of World Music, Dance and International Children's Festival at Ordway Center for the Performing Arts. She oversees programming of world-class artists presented in the Target World Music and Dance Series ®, Performing Arts Classrooms, and the International Children's Festival.

Bringing Engineering Concepts into the Kindergarten Classroom

Deborah Nykanen, Associate Professor, Mechanical & Civil Engineering
Minnesota State University, Mankato, MN

Ashley Rehder, Kindergarten Teacher
Hoover Elementary School, North Mankato, MN

Corresponding Author: Deborah Nykanen, deborah.nykanen@mnsu.edu, 507-389-3200

Abstract

This paper focuses on the K in the K-12 pipeline for engineering education. It will describe the experiences of the partnership of an engineering professor and elementary teacher in bringing engineering activities into a kindergarten classroom. It will discuss how the activities were adapted for the kindergarten level and will provide suggestions on how to integrate them into a school district's required curriculum. Benefits for the kindergarten teacher as well as the engineering professor will also be discussed.

1. Introduction

Kindergarten is a transitional stage in a child's life. Their young minds are soaking in new ideas and learning every day. The kindergarten curriculum not only focuses on their social and emotional development, but it also emphasizes the importance of academics such as reading, math, science and problem solving. Bringing fun, hands-on activities into the classroom that demonstrate simple engineering concepts is an excellent opportunity to introduce these students to engineering at a young age and motivate their interest in learning. There are numerous resources available for teachers through websites such as pbskids.org and www.pbs.org/teachers for engineering activities. Teachers could use these resources in the classroom on their own; however, a partnership with engineering faculty or engineering student groups make it both exciting for the kindergarten students and more feasible for the teacher to fit such activities into the curriculum.

This past year, the partnership between a kindergarten teacher and engineering professor enabled bringing hands-on activities that demonstrate basic engineering concepts into a kindergarten classroom. By combining the school district's Everyday Mathematics curriculum with real-life engineering applications, the students received a deeper understanding of how math and science can relate to their everyday lives. The activities were adapted from Public Broadcasting Service (PBS) resources at www.pbs.org/teachers and modified to be appropriately challenging for the kindergarten level and to promote student engagement. The lessons encouraged the students to explore, question, predict and test their ideas through a hands-on, interactive focus. In each session, the students were enthusiastic, interested and eager to be involved.

In this paper, we will describe the activities used, how they were adapted for the kindergarten level and discuss what we learned regarding implementation strategies. We will summarize the results from basic survey questions answered by the kindergarteners following several of the activities. Suggestions for how these activities can be integrated into a school district's required curriculum will be discussed. Benefits for the kindergartener teacher as well as the engineering professor will also be highlighted.

2. Engineering Activities

The activities were selected based on several criteria: (1) ability to demonstrate basic engineering concepts, (2) hands-on, interactive focus to engage students, and (3) fit a unit theme already being taught in the mathematics, science or reading kindergarten curriculum. The teacher rotates through different unit themes in reading, math and science throughout the school year. The activities were implemented in the spring of 2010 in a classroom of 19 kindergarten students at Hoover Elementary School in North Mankato, MN. Each activity consisted of two parts, a large group discussion or story and a small group, hands-on portion. The students performed the hands-on activity in groups of 4 – 5 students as they rotated through the afternoon math stations. The integration into the math stations format used in the kindergarten curriculum will be described further in Section 4. A description of each of the engineering activities is provided below.

2.1 Floating Objects

Unit Theme: Water (Science)

Engineering Concepts:

- Buoyancy

The whimsical Baby Einstein book entitled "What Floats?" by Julie Aigner-Clark and illustrated by Nadeem Zaidi was used to get the students thinking about things that float versus those that sink. The book ends with the line "It's curious how a ship floats by as heavy as can be, while a pebble drops with a little plop and sinks beneath the sea." After reading this book and "Curious George, The Boat Show" to the class, the engineering professor led the students in a large group discussion thinking of other objects that float or sink.

The small group activity gave the students the opportunity to play in the water and experiment with an assortment of objects. They started out with two objects that were the same size, shape and color but had significantly different weights, a golf ball and a ping pong ball. The students voted on if each ball would float or sink and then tested their hypothesis. Then, they were given a small plastic bowl, instructed to place the golf ball inside the bowl and asked if it would now float or sink. Some of the students were surprised that the golf ball that previously sank would float when the bowl and ball combination were placed in the water. They were even more surprised when they were able to load as many as 10 golf balls into the bowl before it began to sink. The students also experimented with cans of food, small wooden boards, plastic containers and rocks. The basic principles of buoyancy were explained while the students enjoyed playing with the objects in the water tub.

2.2 Levers

Unit Theme: Pan Balance (Mathematics)

Engineering Concepts:

- Simple machines
- Levers and fulcrums

Source:

- "Level Investigation" by Sid the Science Kid (http://www.pbs.org/parents/sid/activities.html?leverinvestigation)

In this activity, the small group portion was conducted first in the classroom. Following completion of the afternoon math stations, the entire class took a field trip outside to the playground for the large group part of the activity. The small group activity consisted of a crate filled with heavy books, a board 6 – 8 ft long and 12 – 16 in wide as the lever, and a small step stool placed underneath the board as the fulcrum. The large group activity required a door for demonstration purposes and a plastic spoon and several marshmallows for each student.

The small group activity was started by placing the crate filled with heavy books on the ground and giving each student the opportunity to try to lift the crate. Then the crate was placed on the end of the lever with the fulcrum positioned in the middle. Each student was again given the opportunity to push on the lever and feel how much easier it was to lift the crate. The students experimented with moving the fulcrum to different positions and the effect it had on the force required to push down on the lever and lift the crate. During the activity, the engineering professor discussed levers, fulcrums and how simple machines can be used to make tasks, such as lifting a heavy object, easier.

After each group had rotated through the lever investigation station, the class put on their coats and headed outside to the playground. On the way out, they stopped at the double doors exiting the school building and the engineering professor used the doors and a student volunteer to demonstrate a lever in action. The students saw how it is easier to open a door if you push or pull on it farther away from the hinges. This was a great opportunity to connect something they do multiple times a day to the engineering concept behind it. Outside, the students were each given a plastic spoon and several marshmallows. Using the spoon as a lever and their thumb and index finger grasping positioned on the spoon as the fulcrum, the students launched their marshmallows into the air. They experimented with how moving their fulcrum up and down the spoon handle affected how far the marshmallow was launched.

2.3 Sand Castles

Unit Theme: Ocean Animals (Reading)

Engineering Concepts:

- Cohesion and mixing materials to increase strength
- Structurally sound foundations for building

Source:

- "Day at the Beach" with Curious George (http://pbskids.org/curiousgeorge/games/day_at_beach/day_at_beach.html)

The book "Curious George Goes to the Beach" by H.A. Rey and Margaret Rey was used to introduce the Sand Castle activity. The engineering professor read the book to the class during circle time and then called on volunteers to discuss their explorations at the beach and previous experiences in building sand castles. The children were excited to talk about their experiences of playing in the sand box and at the beach.

The materials required for the small group activity included several large, shallow tubs of moist sand (approximately two students per tub) and sand shovels, cups and other molds. A large tarp spread out underneath the station area was helpful to capture the sand spillage and facilitate easy cleanup of the classroom following the activity. At the start of each small group rotation, the engineering professor used two smaller tubs, one with dry sand and the other with very wet sand, to demonstrate the importance of the right mixture of sand and water to get the proper consistency for building sand castles. Cohesion between the sand and water and how it increases the strength of the mixture was discussed.

The students used various sizes of cups and molds to build their own sand castles within the tub. As they played in the sand, the engineering professor discussed structurally sound foundations for building sand castles. Through demonstration followed by testing it on their own, the students learned about the need for a level building site and the importance of using larger molds for the bottom of their sand castle and smaller molds for the top.

2.4 Tower of Coins

Unit Theme: Money (Mathematics)

Engineering Concepts:
- Forces
- Friction
- Inertia

Source:
- "Tower of Coins" by *Zoom* (www.pbs.org/teachers/connect/resources/2692/preview/)

Most kindergartener's are already familiar with the fun science stories of The Magic School Bus by Joanna Cole. This activity was introduced by the engineering professor reading "The Magic School Bus Plays Ball" by Joanna Cole and illustrated by Bruce Degen to the class. In this story, teacher Ms. Frizzle and her class take a Magic School Bus ride into a non-friction world. Through a baseball game played on a field without friction, the story explains forces and inertia. Since the students were already familiar with the characters in the Magic School Bus series, the story provided a fun and imaginative way to introduce these engineering concepts to the class.

At first glance, the unit theme for this activity may seem disconnected to forces, friction and inertia. The students had been learning about money over the past month. This engineering activity integrated into the money theme by giving the students a fun, hands-on activity using coins. During the small group activity, each student was given a stack of 12 coins of the same size. Pennies, nickels, dimes and quarters were used for the different stacks. The students were asked to count how much money they had in their stack and as a group determine which student had the most money. They were also asked how many of their coins would they need to trade in for a $1 bill.

The small group activity was started using a ball at rest and rolling in a straight line to explain the basic concept of inertia and forces. Friction was demonstrated by the rolling ball eventually coming to a stop. A small box (filled with coins) on an inclined surface was used to further illustrate friction and its kindergarten level explanation as a “sticky” force. The engineering professor then demonstrated with one of the stacks of coins how pushing on the bottom coin slowly causes the whole stack to move together due to friction and how hitting the bottom coin quickly overcomes friction and causes just the bottom coin to shoot out and the stack to stay at rest. The students then experimented with their stack of coins. First they moved their stack of coins together by slowly pushing on the bottom coin. Then, they tried to get the bottom coin to shoot out and the rest of the coins to remain in the stack by hitting the bottom coin quickly with a flat utensil (e.g., metal spatula or butter knife). The activity took some practice for them to learn the right speed and force to use with the utensil and develop the skill to hit only the bottom coin. However, once they achieved it, they had fun with their new “magic trick”.

2.5 Wind Power Car

Unit Theme: Weather (Reading, Science)

Engineering Concepts:

- Forces, friction and inertia
- Wind power

Sources:

- “Blow It Away” by *FETCH! with Ruff Ruffman* (www.pbs.org/parents/fetch/activities/act/act-blowitaway.html)
- “Balancing Balls on Air” by *Zoom* (pbskids.org/zoom/activities/phenom/balancingballsonair.html)

We started the activity with a large group demonstration. Volunteers were called on from the class to participate in the demonstration of a ping pong ball floating in the stream of moving air from an electric blower. The volunteers tipped the blower hose at different angles and the class was amazed at how the ball remained suspended in air. During the demonstration, the engineering professor discussed forces and the power of wind with the class.

Following the demonstration, the students completed the wind power car activity in small groups. They each built a small car using a 4x6-inch index card as the car body, drinking straws for axels, and LifeSavers® mint candies as wheels with mini marshmallows as stoppers to keep the wheels from falling off. They built sails using popsicle sticks and a choice of aluminum foil, plastic bags or small paper cups and added load to their cars using string with paper clips attached to the end.

Discussion points used in conversation with the small group during the activity included kindergarten level explanations of inertia, forces, friction and wind power. Basic demonstration of the car remaining at rest until the force of the wind acts upon it, the force of the wind needing to be stronger than the friction to get the car to move, and friction resisting the motion of the car and causing it to slowly stop if the wind stops where used to illustrate these concepts. The students were asked to talk about other things that the wind moves (e.g., tree branches, ocean waves, sailboats, kites, flags). A pinwheel was used in the conclusion of the small group activity to discuss how wind power can be collected and stored using wind mills.

3. Survey Results

For the last three activities, a multiple-choice survey was handed out to the class to assess if the students enjoyed the activity and what they learned. It was challenging to design a survey that would be understandable and meaningful for the kindergarten level. In some cases, the multiple choice answer options consisted of pictures or sketches. For example, the "did you have fun today" question had choices of a happy, indifferent or sad face. In other questions, the choice of answer was a list of words that would already be familiar to kindergarteners plus the new engineering words they learned during the activity. The teacher asked students with advanced reading skills to read the question out loud to the class. The teacher then read through all the answer choices and helped the students point to each word as she read it. They were told to circle the one word that they thought was the correct answer. The process of going through the survey gave the students an opportunity to apply what they were learning in reading on sounding out words along with allowing us to assess if they could remember the new engineering words they learned in the activity. In several questions, they were asked to write down a one-word answer to a question rather than circling a multiple-choice answer. This gave them practice in matching letters with the sounds in a word and working on their writing of those letters.

Table 1. Survey Results

	Format of Choices	Correct Happy Face[1]	Partially Correct Indifferent Face[1]	Incorrect Sad Face[1] No Answer
SAND CASTLE ACTIVITY				
1. Did you have fun today building sand castles?	pictures	14	2	1
2. What happens if you mix too much water into the sand?	pictures	10		7
3. What happens if you use dry sand?	pictures	10		7
4. Which sand castle has the best foundation?	pictures	16		1
5. Which mold should you use when building the bottom of your sand castle?	pictures	13		4
6. Which mold should you use when building the top of your sand castle?	pictures	12		5
TOWER OF COINS ACTIVITY				
1. Did you have fun today playing with the tower of coins?	pictures	18		
2. Circle the two new words you learned about today in our engineering activity.	words	12	5	1
3. What stops a ball from rolling forever?	words	14		4
4. How can you make an object that is at rest start to move?	short answer	11		7
WIND POWER CAR ACTIVITY				
1. Did you have fun making a car today?	pictures	19		
2. What force was used to make the car move?	words	17		2
3. What force between the wheels and the table resisted the car moving?	words	12		7

[1]The multiple choice answer options for question 1 were a happy face, indifferent face and sad face.

The results of the surveys confirmed what we saw in the faces of the students during the activities. They were enthusiastic, interested and eager to be involved. In almost all cases, they circled the happy face as the answer for having fun in the activity. The percentage of correct answers on the questions to assess what they learned was encouraging. For the most part, the students picked up the basic engineering concepts being taught. They were learning new words such as inertia and fulcrum and retaining this knowledge. In subsequent sessions, the teacher would start by asking the class if they remembered what they learned during the last engineering activity. Not only did they remember the activity, but were also able to recall the basic concepts and new engineering words they had learned 2 – 3 weeks earlier. The retention of this knowledge was encouraging for both the teacher and the engineering professor.

4. Integration into Kindergarten Curriculum and Implementation Strategy

Kindergarten teachers are responsible for meeting the school district's educational requirements for the kindergarten level. The curriculum emphasizes the importance of academics such as reading, math, science and problem solving and also focuses on the students' social and emotional development. They are given some flexibility in trying new methods and ideas along with using the established best practices in kindergarten education. Thus, the teachers have to make conscious decisions regarding what curriculum choices and activities work well for their students while meeting the school district's educational requirements.

Hoover Elementary School is part of Independent School District (ISD) 77. The district uses *Everyday Mathematics* for its math curriculum and *2005 Macmillan-McGraw Hill Science* for science. Both of these focus on real-life problem solving and everyday experiences in their curriculum. The reading curriculum, *2006 Macmillan-McGraw Hill Treasures*, is also based on themes that are relevant to their everyday lives. The topics for the engineering activities were selected to integrate with the unit themes currently being covered in the mathematics, science and reading curriculums.

The partnership between an engineering professor and kindergarten teacher made it feasible to integrate the engineering activities into the curriculum with only a minimal interruption of the normal routine. The *Everyday Mathematics* curriculum was typically covered during the afternoon through whole-group instruction followed by small group, partner or individual activities. Stations were regularly used to give each student the opportunity to work in a variety of different groups settings while learning, applying and completing new skills. These station activities balanced teacher-directed instruction with opportunities for open-ended, hands-on explorations, long-term projects and on-going practice of skills. The students rotated through approximately four stations in small groups of 4 – 5 students with each station lasting approximately 10 minutes. The stations were based on the *Everyday Mathematics* curriculum along with integration of science, reading and problem solving.

On five occasions this past spring, an engineering activity related to the lessons or units they were focusing on was used as one of the stations. The large-group instruction time for that day was used to read a book or perform a demonstration related to the engineering concept the students would be learning about. This strategy of implementation fit the engineering activity into the normal classroom routine. Since the afternoon stations were followed by free time, it worked well to pull any extra time required for the engineering station out of the free time allotment. The students were so eager to have extra time to play with the engineering activity, that the station was also kept set-up and supervised during the remaining free time.

With each session, we learned more about how to effectively implement the activities through large group story time or demonstration followed by small group, hands-on activities. Throughout the process, we also gained experience on the logistics of implementing each activity at a kindergarten level. Field notes were kept regarding these logistics and will be used to improve future implementations. For example, the most effective group size was determined to be 3 – 4 students. When the small groups consisted of 5 students, it was significantly more challenging to keep everyone in the group paying attention to the discussion of the engineering concepts and calming taking turns with the hands-on component. We also experience some challenges in groups focusing on their current station. They were so eager to participate in the engineering activity that is was distracting them from the learning taking place at their current station. Thus, the students had the opportunity to work on their skills in patience and focusing on the task at hand while they waited their group's turn to rotate into the engineering station.

This initial experience of bringing engineering concepts into a kindergarten classroom was based on implementation in one classroom through the partnership of an engineering professor and kindergarten teacher. A broader group of students could be reached by expanding future implementations to include all kindergarten classrooms in a school or even across the district. Suggestions for this type of larger scale implementation would be to draw on the resources of college student organizations at the university such as the America Society of Mechanical Engineering (ASME), American Society of Civil Engineer (ASCE) or Society of Women Engineers (SWE). An engineering faculty member could organize and coordinate the engineering activities and draw upon these student organizations for volunteers to effectively bring the activities into multiple classrooms and multiple schools in the district. This would have the added benefit of providing an opportunity for these college students to volunteer and serve the community using their chosen major. It would give them the opportunity to share their passion for engineering and instill those concepts into future engineers.

5. Benefits for Kindergarten Teacher and Engineering Professor

Benefits for the engineering professor included both professional development and involvement in community service. The professional development plan for tenure and promotion at Minnesota State University, Mankato outlines five key areas in which faculty members are expected to grow and contribute. Community service falls within one of these areas and is recognized by the university as a valuable contribution. The engineering professor enjoyed having this opportunity to use her knowledge and training to motivate young students to consider engineering. The excitement of the kindergarten students as they worked on the various activities was rewarding and encouraging. The professor also used this experience to sharpen her skills in adapting engineering concepts to be understandable by people with various levels of background knowledge. In this case, the kindergarten students provided an extreme case in adapting concepts to basic explanations that are fun, easy to understand and connected to everyday life. Engineering concepts seen at this basic level is a valuable viewpoint to have even when developing lectures for engineering courses at the university. Furthermore, developing professional connections with elementary education is beneficial for engineering departments and universities as they focus on the K-12 pipeline for future engineering students.

Benefits for the kindergarten teacher included learning about engineering applications and how to integrate them into various areas of the kindergarten curriculum, developing collaboration with engineering faculty, and experiencing the excitement of the students as they participated in the hands-on activities. Opportunities to bring parent and professional volunteers from the community into the classroom are beneficial for both the teacher and the students. The power of collaboration through a program like this allows that partnership to extend from professor to teacher, teacher to student, student to professors alike. It creates a new community of explorers that take what they are learning in the classroom and applying it in new and challenging ways. It was exciting for the teacher to see the students work, explore, and investigate together to learn new concepts. It creates an inviting atmosphere where students, teachers, and professors are excited about what they are learning and how they are learning it.

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Biographical Information

DEBORAH NYKANEN is an Associate Professor of Civil Engineering at Minnesota State University, Mankato. She has a Ph.D. in civil engineering from the University of Minnesota. Her focus areas include water resources, hydrology and hydrometeorology. She has 10 years of academic experience and is a registered P.E. in Minnesota.

ASHLEY REHDER is starting her second year as a kindergarten teacher at Hoover Elementary School in North Mankato, Minnesota. She received her Bachelor of Science in Elementary Education from Minnesota State University, Mankato and is currently working on her Master of Science in Teaching and Learning.

Assessing the Written Communication Skills of Graduating Mechanical Engineering Students

Melanie I. Cashin and Saeed Moaveni
Minnesota State University
Mankato, MN 56001

Abstract

The Accreditation Board for Engineering and Technology (ABET) Criterion 3(g) requires engineering programs to demonstrate that their graduates have attained the ability to communicate effectively. To develop students' communication skills, the mechanical engineering program at Minnesota State University, Mankato (MSU) requires all students to take the English Composition class and one additional course in either Public Speaking, Public Speaking for Technical Professionals, or Technical Communication. In addition to standard lab and project reports, during the senior year, students are required to take the mechanical engineering seminar class and write a half-page summary discussing what they gained from listening to presenters from industry. Each week a presenter shares his or her professional experience with the seminar class and talks about career paths, ethics, continuing education, and the "dos" and "don'ts" of a professional. The summaries are read for both content and proper use of grammar and sentence structure, and points are deducted for improper use of grammar and misspelled words. The seminar class is the last opportunity to assess our students' written communication skills. In this paper we will discuss the collaboration between an English graduate student (first author) and a mechanical engineering professor (second author) to assess and improve the written communication skills of mechanical engineering students at MSU. We will present the common mistakes that are made by graduating seniors and an intervention method to correct them, as well as discuss the need for and success of the intervention.

Introduction

Over 300 colleges and universities in the United States offer bachelor's-degree programs in engineering that are accredited by the Accreditation Board for Engineering and Technology (ABET). ABET examines the credentials of the engineering program's faculty, curricular content, facilities, and admissions standards before granting accreditation [1]. In this paper, we focus on ABET Criterion 3(g), which requires engineering programs to demonstrate that their graduates have attained the ability to communicate effectively. At Minnesota State University (MSU), to develop our mechanical engineering students' communication skills, we require all students to take the following courses. The values in parentheses indicate the number of semester credits associated with each course. The course descriptions are taken from the MSU website [2].

ENG 101 (4): English Composition: *Students will practice strategies for generating and developing ideas, locating and analyzing information, analyzing audience, drafting, writing sentences and paragraphs, evaluating drafts, revising, and editing in essays of varying lengths. Students will also become experience in computer-assisted writing and research.*

and

ENG 271 (4) Technical Communication: *Introduction to learning the written and oral communication of technical information. Assignments include writing and presenting proposals, reports, and documentation. Emphasis on use of rhetorical analysis, computer applications, collaborative writing, and usability testing to complete technical communication tasks in the workplace.*

or

CMST 102 (3) Public Speaking*: A course in communication principles to develop skills in the analysis and presentation of speeches.*

or

CMST 233 (3) Public Speaking for Technical Professionals: *This course is designed to introduce and develop the skills and knowledge necessary to create and present effective public communication of technical content for a technical or general audience.*

In addition to these courses, students are required to write laboratory and design project reports in many of their mechanical engineering courses such as Introduction to Problem Solving and Design (ME 201), Engineering Analysis (ME 291), Mechanical Engineering Experimentation I (ME 336), Mechanical Engineering Experimentation II (ME 436), Mechanical Engineering Experimentation III (ME 446), Mechanical Engineering Design Project I (ME 428), and Mechanical Engineering Design Project II (438). During the senior year, students also are required to take the mechanical engineering seminar class and write a half-page summary discussing what they gained from listening to presenters from industry. Each week a presenter shares his or her professional experience with the seminar class and talks about career paths, ethics, continuing education, and the “dos” and “don’ts” of a professional. The summaries are read for both content and proper use of grammar and sentence structure, and points are deducted for improper use of grammar and misspelled words. The seminar class is the last opportunity to assess our students’ written communication skills. In the past, the mechanical engineering professor in charge of the seminar class read the summaries. However, last year, in order to have a direct assessment of students’ written communication skills, a professor of mechanical engineering collaborated with an English graduate student to study the common mistakes made by students and find ways to intervene and reduce mistakes before they graduate. In the following sections, we will discuss the class profile, typical written mistakes, the intervention method, and the results of our findings.

The Class Profile

The seminar class consisted of 31 students with the following composition: three international and 28 domestic. Eighteen of these students received A (17 domestic, 1 international), ten received B (8 domestic, 2 international), and three students received C (all domestic) grades for their efforts in the English Composition class. Moreover, eight students took the Technical Writing course, while seventeen students took the Public Speaking class, and the remaining six students took Public Speaking for Professionals. The distribution of grades for each of the mentioned classes is shown in Figure 1.

Our data shows minimal correlation between grades received in required English and communication courses (see Figure 1) and grades received for grammar and communication in the mechanical engineering seminar prior to the intervention (see Figure 3). The fact that students typically scored much higher in ENG 101, ENG 271, CMST 102, and CMST 233 than they scored on their senior seminar writings indicates a problem. Either students lost or did not use the skills they displayed in their earlier English and communication coursework, or student grades fail to reflect students' lack of grammatical correctness and clarity in these courses. We believe that an increased focus on correctness and clarity in ENG 101, ENG 271, CMST 102, and CMST 233 combined with regular interventions and reinforcement in other coursework would ensure that students continually improve their communication skills between freshman and senior year. The details of our intervention as well as a suggested system of intervention and reinforcement are discussed below.

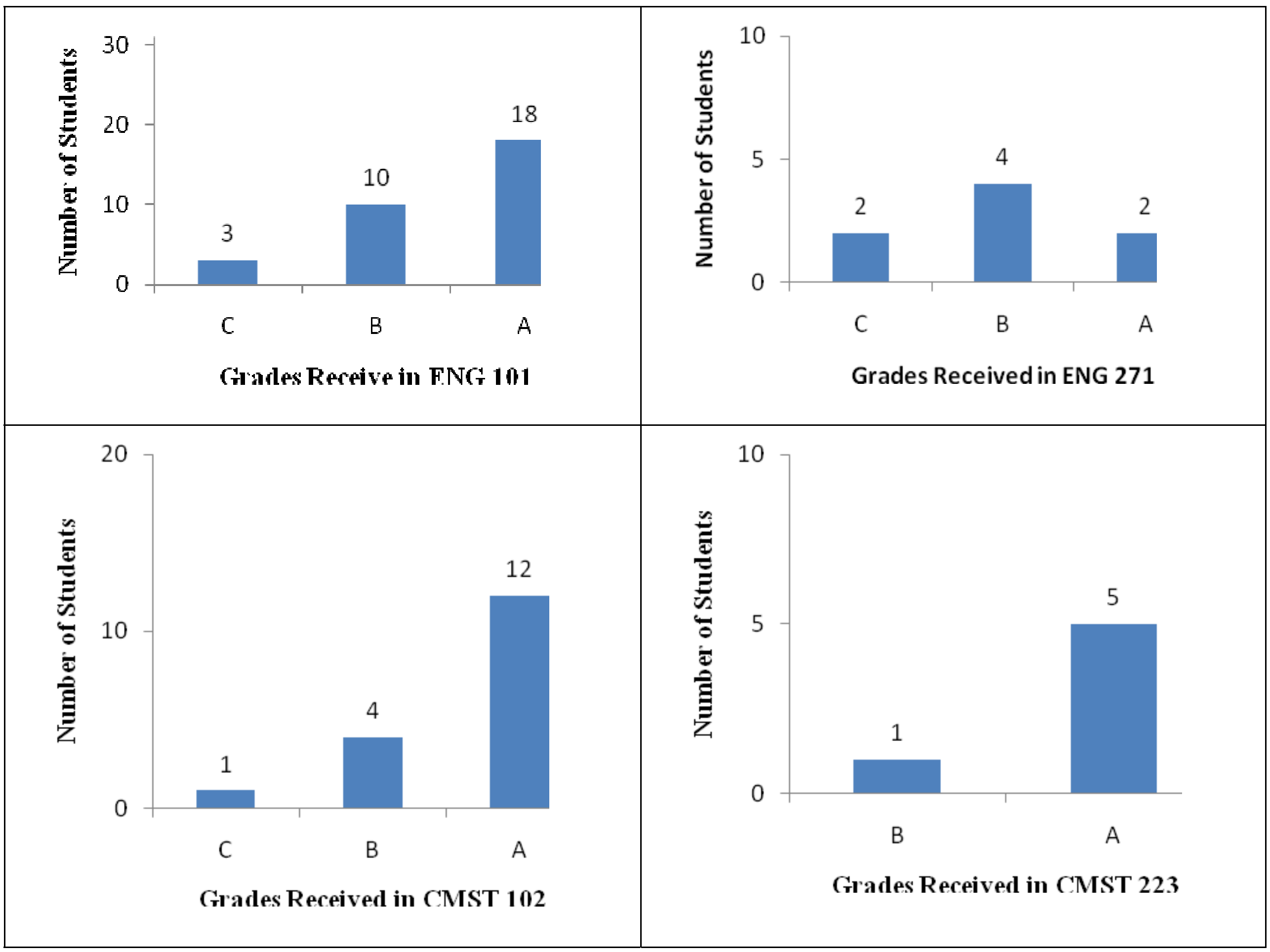

Figure 1 The grade distribution in ENG 101, ENG 271, CMST 102, and CMST 223.

Typical Written Mistakes

During the first half of the spring semester, we did not inform the students that their summaries were being examined in detail for typical mistakes. After the spring break, we intervened and informed the students about the mistakes that they commonly made.

Although students exhibited a variety of grammatical errors, as well as occasional errors of spelling or word choice, the few errors that occurred most often included improper use of or omittance of commas, improper use of semicolons, improper use of *you* in the memo format, inconsistent use of person, and unnecessarily lengthy or fragmented sentences. Students often referred to *you* in the weekly memos when the advice or information was directed at fellow classmates rather than at the reader of the memo. In addition, many students switched between using first, second, and third person pronouns to describe the same subject or object within the same paragraph or even within sentences.

Intervention

The English graduate student began reading and copyediting student papers and determined a weekly grade for each student based on the number and level of errors within the given paper. This grade was given on a ten-point scale. These marked-up papers were returned weekly to the mechanical engineering professor, who returned the papers to his students. An in-class presentation by the English graduate student was scheduled for the week following spring break. By this time, students would have received written feedback on seven individual papers. Using an experienced outside source to edit and grade student papers allowed for an unbiased assessment of student skills and a more authoritative presentation on correcting errors than if the mechanical engineering professor had undertaken this assessment and intervention on his own.

We decided that it would be most productive to focus on a few common errors that appeared in many students' papers. We chose to focus on the five mistakes listed above and created a handout that explained each error and gave an example of correct usage or tips for correcting the error. In addition, the first author used sentences taken from the last edited papers to compose a handout exhibiting these errors. The handout consisted of 11 sentences, each taken from a different student's paper. These are shown in Tables 1 and 2. During the class period, students received both the informational handout and the worksheet. Following a brief introduction and explanation of common errors and how and why to avoid them, presented by the English graduate student, students had the opportunity to ask questions about technical writing or the correct use of the English language. Finally, students were given approximately 20 minutes to correct or improve the sentences in the handout. Students were asked to volunteer their improvements. Additionally, the presenter displayed her own improvements to demonstrate the many options available for increasing sentence correctness, clarity, and conciseness.

After the presentation, student papers continued to be edited and graded as usual. We coded the above-mentioned errors for each student each week in order to track the occurrence of each error and any improvement.

Table 1 The intervention handout

Polishing Professional Writing
Second person (you): Use “you” when directly addressing the reader. In a memo, the reader is listed in the “To:” line. *Example: You will find the necessary data attached.* **Consistency with person (e.g. his, him):** Use the same subject throughout the sentence. *Example: I find this information valuable because my coworkers always ask me about grammar.* **Commas:** Use commas after an introductory clause (if it’s still a complete sentence without the portion before the comma). *Example: If there is ever a conflict, the documented work will be available.* *Use “because” or “, and” to separate complete sentences, or begin a new sentence.* *Example: Apply for as many jobs as possible, and follow up with workplace contacts.* **Semicolons:** Use semicolons rarely. Use to separate complete sentences that are closely related. *Example: Engineering is not about coming up with the best design possible; it is about doing the best you can with what is available.* **Concise sentences:** Clear, active sentence usually aid understanding. Be sure that each sentence contains a complete idea—at least a subject and verb. Be sure to complete the idea when using dependent clauses. Tell the reader what the subject did, rather than what was done to the subject. Remove unnecessary or repetitious words or phrases. (See examples of concise sentences in the second column of Table 2 below.)

Table 2 Examples of student mistakes and suggested corrections

Students' Examples	Suggested Corrections
Tips such as working harder than anyone else, being able to build what is designed on the computer, taking advantage of every opportunity, and finding a way to work on something you enjoy are all of what Brian recommended to us.	*Brian recommended that we work harder than anyone else, be able to build what is designed on the computer, take advantage of every opportunity, and find a way to work on something we enjoy.*
As Brian has also found out by his recent promotion is that it does indeed pay off to work harder than everyone else around you because when opportunities arise you will the companies first pick to fill that position.	*Brian found out by his recent promotion that it pays off to work harder than everyone else around him because, when opportunities arose, he was the company's first pick to fill that position.*
Allen said that, anything can be designed in Pro-E, but can it be built?	*Allen said that anything can be designed in Pro-E. The question is, Can it be built?*
That if you want to be successful you need to work harder than everyone else because you will learn from it and it will definitely be noticed, both internally, and externally, if you put in the time.	If we want to be successful, we need to work harder than everyone else because we will learn from it, and it will definitely be noticed, both internally and externally, if we put in the time.
Some other things that I learned were; it's important to document our work, communication is critical, and to find a job you enjoy.	*I also learned that it's important to document our work, communicate effectively, and find jobs that we enjoy.*
Another statement said by Mr. Allen, is that, "Engineering is not necessarily coming up with the best design possible for a given application."	*Mr. Allen also said, "Engineering is not necessarily coming up with the best design possible for a given application."*
What he means with this, is that we should surround with people that are well knowledgeable about a topic that you are working on, surround yourself with online databases that will help you find information that it is related to your project, and surround yourself with software tools that will help you with very complicated projects.	*He means that we should surround ourselves with people who are knowledgeable about a topic that we are working on, online databases that will help us find information that it is related to our project, and software tools that will help us with complicated projects.*
For engineers who are fresh out of college, they should work harder than anyone else, and the effort one puts in will definitely be recognized.	*Engineers who are fresh out of college should work harder than anyone else, and the effort they put in will definitely be recognized.*
This helps so that one can move up to management due to the fact that the understanding of the company is very important when dealing with co-workers and other company contacts.	*An understanding of the company helps one move up to management and is important when dealing with co-workers and other company contacts.*
Brian Allen presented to the Mechanical Engineering Seminar class on some tips that he learned in his experiences at Kato Engineering, and what Kato Engineering is.	*Brian Allen presented to the Mechanical Engineering Seminar class about Kato Engineering and tips that he learned in his experiences there.*
Another suggestion he gave us was to always document our work, it helps when you need to go back through and explain what you were thinking if a customer calls.	*He suggested that we always document our work because it helps when a customer calls and we need to go back through and explain what we were thinking.*

Results

Our coding on the weekly write-up following the presentation on writing and grammar indicates that the students understood the grammatical mistakes addressed and were able to either locate and fix the mistakes or avoid sentence structures where mistakes might occur. The distribution of common mistakes for "before" and "after" the intervention is shown in Figure 2. The average class score for each week is shown in Figure 3. As shown in Figures 2 and 3, as a class, improvements were made. However, toward the end of the semester, many students appeared to backslide and returned to making the same mistakes that their pre-presentation papers exhibited. This may be attributed to lack of time, since they were focused on finishing their capstone and elective senior design projects. Rachel Yarrow's research suggests that secondary students believe grammar "gets in the way of writing" and is only important for the final draft [3]. This belief may hold true for postsecondary students as well.

Students made the greatest improvements regarding correct use of person. All students eliminated inappropriate references to *you*, and most students consistently used first or third person following the intervention. The lack of improvement regarding the use of commas following introductory clauses may be due to the complexity of proper comma usage or confusion about the definition of *introductory clause*. Comma usage in general was a common problem for the students. During the in-class presentation, no student specifically asked any questions about the proper use of commas following introductory clauses; however, some students asked about comma usage in different situations. They may also have felt encouraged to omit a comma erroneously if they were unsure of its correctness because the first author encouraged them to omit semicolons in the same instance.

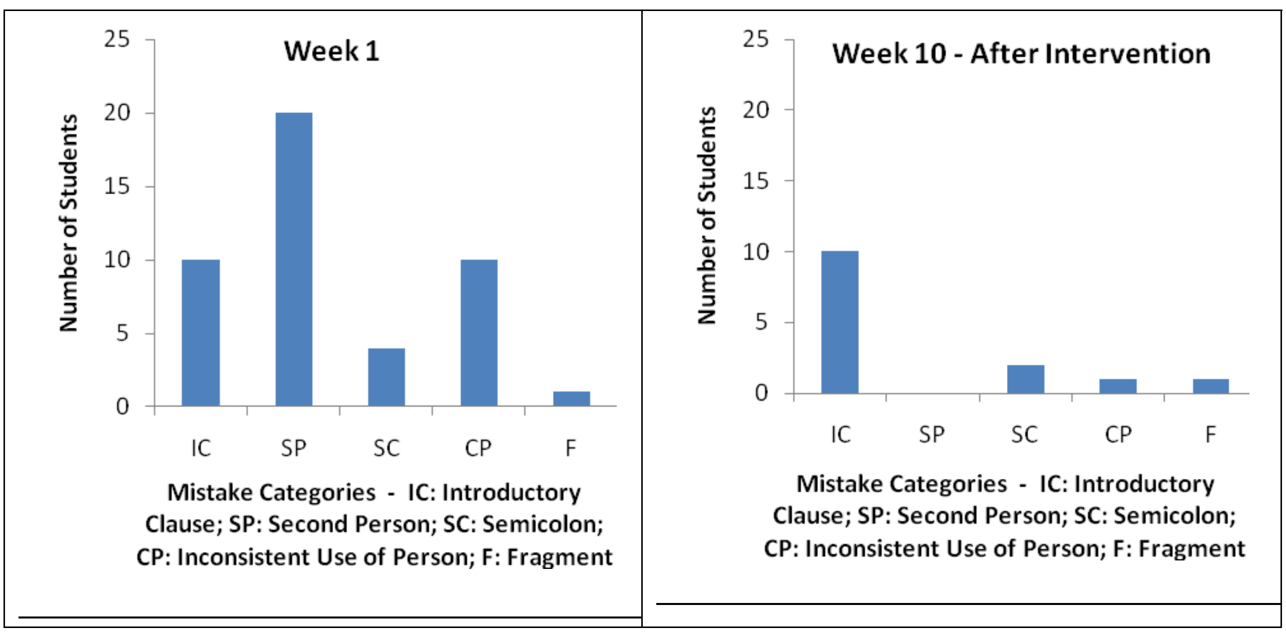

Figure 2 The distribution of common mistakes before and after Intervention

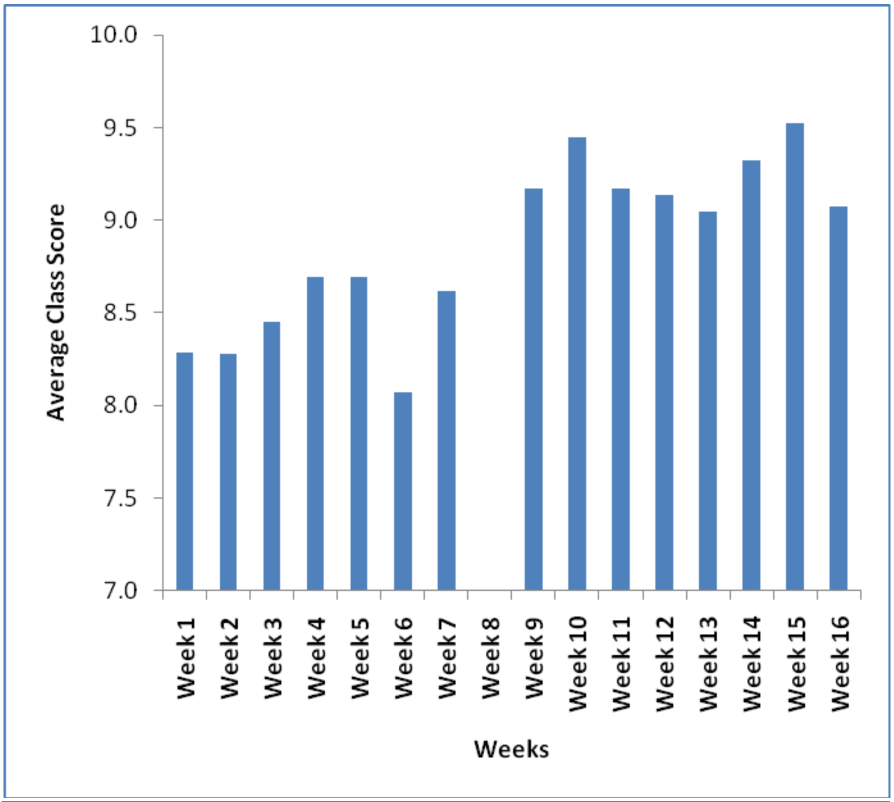

Figure 3 The average class write-up scores for each week.
Week 8: Spring Break, Week 9: Intervention

Concluding remarks

ABET Criterion 3(g) would be met more fully through increased classroom support. Although mechanical engineering students quickly discover that sloppy memos and reports are not tolerated in the workplace, the ABET standards indicate that students should understand this before graduating from college. We recommend that interventions be introduced earlier and more often in order to produce more lasting results.

Students appear able to understand and employ grammatical rules; however, they appear to find them less important than other elements of the writing process, especially when influenced by time constraints [3]. This also indicates that grammatical rules require thought and do not come naturally to many students. Communication courses, especially English 101, may improve student performance by focusing more on grammatical correctness. Additionally, instructors in all disciplines should encourage grammatical correctness and clarity when evaluating student writing. In order to serve our students more effectively, we must ensure that students understand the importance of clear and correct communication and that we address common errors when and where they occur, even outside of the English classroom.

Despite the existence of common grammatical errors in the students' papers, the students demonstrated improvement from the beginning to the end of the seminar course. We recommend that this type of intervention be introduced and regularly reinforced earlier in the students' academic careers in order to achieve more positive and permanent results. For example, in our mechanical engineering program, professors should consider teaming with English graduate students or faculty to provide a direct assessment of students' communication skills. This idea could be expanded to invite experts from the Communication Studies department to provide a similar type of assessment. Ideally these assessments would begin in courses such as Introduction to Problem Solving and Design (ME 201), Engineering Analysis (ME 291), and Mechanical Engineering Experimentation I (ME 336), culminating in Mechanical Engineering Experimentation II (ME 436), Mechanical Engineering Experimentation III (ME 446), Mechanical Engineering Design Project I (ME 428), and Mechanical Engineering Design Project II (438).

These assessments and interventions should be based on actual student writing and should address errors and problems as they appear. Additionally, students should be encouraged to identify and correct their own errors, possibly by receiving a secondary grade for clarity and correctness. If partnerships between departments prove difficult to implement or sustain, individual instructors can still improve their students' skills by addressing grammatical correctness and clear communication in relevant coursework. By devoting a small amount of class time to identifying and correcting common errors in student writing, instructors across the disciplines will better prepare their students to satisfy ABET Criterion 3(g) as well as to succeed in the workplace.

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Letting the Course Follow the Topic

William R. Peterson and, Guanghsu Chang
Minnesota State University, Mankato

Abstract

This paper builds on an earlier paper which chronicles an experiment in teaching a graduate level seminar in engineering management. In the original experiment the students developed the syllabus details to include which subjects to address and the grading scheme. Thus the course addressed topics of interest to the students and for which they were in turn required to find appropriate reading and research material. A different but similar course using this technique is reported as well as the use of the techniques in non-similar courses.

Background – The First Experiment

As previously reported (Peterson, 2001) in the winter semester of 2000 I was assigned to teach a graduate seminar in engineering management for the first time. The course was an elective in two overlapping master's programs – one in industrial engineering and one in engineering management. The course was offered off-campus over a 12-week period. Each class was a three hour and twenty minute block that was to start at 6:00 PM. The catalog's course description (Western Michigan University, 2000) of the course was as follows:

> "ISE 622 Industrial Supervision Seminar (3-0) 3 hrs
> An analysis of the writings, literature, and philosophy concerning line supervision and employee direction in manufacturing industries. Prerequisite: IME 600 or permission of the instructor"

The course's title had been changed to Engineering Management Seminar since the catalog was published and its description had been expanded to include advanced engineering management topics such as change management. The course's coordinator normally taught both the course and its prerequisite. Typically there was a reading packet for this course but as no specific topics needed to be covered during the course each instructor was free to take a different approach.

With the ground rules for the course established, the standard next step was to develop a course plan - course objectives, a syllabus, a grading scheme, and a reading plan for the course based on what should be taught. But by stepping back and applying engineering management and adaption of new technology principles, the first step became to rethink the course's presentation. What is a seminar? Webster's (Neufeldt , 1988) defines it as:

> "seminar…**1** a group of supervised students doing research or advanced study,
> as at a university, **2** a) a course for such a group, or any of its sessions b) a room
> where the group meets **3** any similar group discussion"

Discussion, research, and advanced study seemed to be the key concepts in both the course and in a seminar style of presentation.

The next step was to consider the students in the class. The typical students in these programs were working professionals with several years experience as individual contributors. Some had started supervising professional employees but many had not. The students seemed most interested in concepts that they could immediately apply on their current assignment.

The next step was to review those graduate courses that had appealed to me as a practicing engineering manager. An upper level course Dr. Al Miller presented at The Ohio State University started with a question about what the students wanted to cover or get out off the course which he worked into his lecture and assignments for the course. This approach made a lasting impression on me.

The final step was to review making assignments in an industrial setting to engineers and engineering managers - state my perception of the task and ask for input on solutions to address the task (or to redefine the problem and thus the task). The team who would be assigned the task would then develop a plan (who, what, when) with which both the team and I could all agree. “Could this be done effectively in an academic setting?” became the experiment’s question. I thought it could be done. I saw several potential benefits and several potential pitfalls. The benefits included student buy-in to the course, higher student satisfaction, practitioner-relevant topic selection, reduced instructor workload in reading-material preparation, and increased student involvement in classroom discussions. The potential pitfalls included inappropriate topic selection, increased preparation to cover student-selected topics outside my expertise, an unreasonable evaluation plan, and a student resistance to the concept of setting their own plan of study. The potential benefits were seen to outweigh the potential pitfalls. The resulting experiment was to manage the course as an engineering manager should manage an engineering department with the team setting the goals and project plan subject to managerial approval.

The first night of class I arrived with a syllabus which contained the basics – course description, details of when the course met, my grading philosophy, my contact, and my office hours. The only class topic on the syllabus was that night’s – “Introduction and Course Development”. After introducing myself to the class, I offered them the opportunity to develop the remainder of the syllabus for the course based on the class’s needs and desires, subject to the provisions that the class meet, accomplish the course description, and that a grade be assigned by the instructor. The option being that I could publish a traditional instructor-driven for the course. To get started in setting up the course plan I asked the students what they wanted to get out of the class besides a grade and meeting a degree requirement. This lead to a subdued discussion with the consensus that they wanted to get something they could use out of the course. From here we started listing the board topics and concepts they were interested in studying. A fairly large list was developed which was then grouped into general headings using typical brainstorming techniques.

Next we discussed how we were going to cover these topics. I offered the idea that the students pick the materials to read on the course topics. After discussion it was agreed that each student would find three articles on each night’s topic and at the least one of the articles would be from a refereed journal. This required each student to do his or her own research on the topic and to find articles they found interesting. In turn at each class there would both small group and class discussion of the topics, the articles, differing opinions, and how to apply the material at work. I agreed to supplement their research with brief presentations of material that I believed were important, such as change management. I agreed to lecture in week two and they would bring in one article on the topic. This allowed the class some time to get their articles and to try out the class format and my expectations.

I then asked for grading suggestions. After we went through the inevitable suggestion of all getting an “A”, we discussed the merits of purely subjective – the instructor would somehow pick one – and a mix of objective and subjective – you do something, I’ll publish expectations prior to the assignment, and I’ll judge how you did. The mix was the unanimous choice. The final class decision was 30% for participation (getting the three articles, being in class, being ready to discuss the topic, and actively being in the discussions), 20% for a short report and its subsequent presentation (to allow the students to calibrate the grader), and 50% for a long report and its subsequent presentation (to allow the students to demonstrate their ability to apply what they learned in the class).

The resulting class meetings were lively with small group discussions of their articles (and very seldom did two people have the same article) and opinions in those articles, class discussions of the group sense of their articles, instructor lead discussions of the topic’s implications for engineering managers, and question and answer periods to the instructor on topics that grew from the earlier segments of the class. The short paper and presentation were on a “new” or “current” concept in management that the student would like to introduce into their specific company. The long paper and presentation were on how they would/will go about introducing their concept into their specific company with particular emphasis on obstacles and how they would be addressed and conditions which support implementation and how they will be taken advantage of. With one exception the papers were very good to excellent as were the presentations. Both the students and the instructor critiqued the presentations. One question asked of the students was their willingness to be involved in the presentation. This question drove home the requirement to sell a program to the audience in its presentation.

This driving home a point was discussed the last night of class. After the grades were handed out and the student course evaluations were completed, I made a brief presentation of why I did what I did during the course and what I wanted them to take away from the course. The students were then free to leave, but I offered to stay and open the floor to questions – no one left. We continued the discussion for over an hour before losing any of the students. Two students talked for about two hours.

The Second Experiment

In the 2007-2008 academic year at Arizona State University while teaching in a MS program in Technology (Management of Technology) there was again the opportunity to teach a course similar to the one in the first experiment. In this experiment the course was OMT 598, Special Topic: Seminar in Technology Management. OMT 598, Special Topics, was a placeholder course which could be just about anything but which when taught had the specific topic listed so it showed as such on the student’s transcript.

The basics were a 15 week course, taught one night a week for 3 hours per night. The students were a mix of full time graduate students and working professionals. The full time graduate students were mainly international students with some practical experience in their undergraduate discipline.

Enrollments in the program were low but being rebuilt – this course was being offered as part of the rebuilding process in which the structure of the program was being repositioned and an emphasis on attracting working professionals was being implemented.

As with Western Michigan Michigan's students there was a desire for "stuff" the students could use immediately and in the case of the full time students for "stuff" that they saw a benefit from learning.

In this experiment the same approach was followed: pretty blank syllabus the first night which the students had to populate with items of interest. Unfortunately in this version of the original experiment the number of students was small (5). This small number had a negative impact on topic generation and required a significant contribution from the professor. The small size made the group breakout sessions during class less natural and somewhat impractical. The resulting class discussion was meaningful but had a larger instructor presence than in the original experiment which was less desirable than more peer to peer discussions/arguments.

Again the students were involved, rated the course high, and seemed to learn from the experience. From an instructor standpoint, a better understanding of this student group was possible and it did contribute to program redefinition and content.

Applying the Approach to Non-Seminar Courses

For the last three semesters, MET 600 at Minnesota State University, Mankato has had elements of this approach incorporated. From the graduate bulletin (Minnesota State University Mankato, 2009):

> "MET 600 (2) Manufacturing Research Methods
> Research topics and methods related to manufacturing. The course will look at the current state of manufacturing and explore the research methods and experimental design procedures that are used in the area of manufacturing. Student will evaluate past research and will design a research project in manufacturing."

The first of the three offerings of this course was a last minute assignment to cover a need – to graduate several students needed the course then. Thus the assignment went to the new faculty member since the teaching of the course was not popular. This assignment was also added within a week of the class meeting.

An analysis of the course description and the curriculum seemed to indicate that as in the two earlier mentioned courses this course has an element of flexibility as to coverage and how to get that coverage. The syllabus for this course is minimal. The details are partially provided from student expectations and the remainder is driven by issues raised in completing the unifying task for the course. The text book is a research book appropriate to their field. The writing style manual is the one they will be using to document their capstone paper

The approach taken incorporated several elements and philosophies from the earlier experiment: immediacy of application, student need driven, learn-by-doing/applying (finding how to find and then use their own resources). Since the written goal of this course is to prepare the student to do the research necessary to successfully complete their thesis or alternate plan paper (applied project) this requirement became the basis for the course.

The students in the class have typically include a mix of majors – manufacturing engineering technology and mechanical engineering – and mix of thesis (all mechanical engineers plus a few manufacturing engineering technology student) and applied project papers. The class size has ranged from 12 to 15.

The basis for the course has become the proposal the student will need to make prior to starting their capstone research project. By using the student's own research topic we provide relevance to the research and since they need to submit a proposal soon after the course if they want to graduate in a reasonable time period (2 years or less). Since we use their topic, the research they read and report on is relevant to their study.

The use of breakout session to discuss problem statements, deliverables, and methodology give the students opportunities for peer to peer review and critiques. Since the class has some working professionals and a mix of majors, the peer to peer feedback is diverse and seems to positively impact quality.

Recommendations

This approach can work well with mature, motivated graduate students. Use this approach with undergraduates is questionable. The approach only works for those well grounded in both the theory and practice of the course topic and try to stay current via readings and conference attendance.

The class needs to be looked at carefully because as the size increases the effectiveness may suffer. On the other hand too small a size causes other problems. Groups of three to five students for breakout sessions seem best. The instructor can listen in if there are multiple groups during the breakout sessions but the peer to peer interaction is key.

Teaching a graduate level course in this manner can be challenging - the instructor has to be willing to risk getting topics, which will require research on his/her part if the students want to go outside your comfort zone. This is an inherent risk in letting the students set the agenda within a wide set of boundaries.

In the class format discussed in this paper the instructor must explain why the assignments are given, what the students should expect to get out of them, and how what we did in the class applies.

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Guanghsu Chang, Minnesota State University, Mankato
Dr. Guanghsu A. Chang is an associate professor of the Automotive and Manufacturing Engineering Technology Department at Minnesota State University, Mankato. His research interests involve the study of robotic applications, manufacturing automation, Design for Assembly (DFA), and Case-Based Reasoning (CBR) applications. He holds both MSIE, and Ph.D. degrees from University of Texas at Arlington.

William Peterson, Minnesota State University, Mankato
Dr. Bill Peterson is currently an associate professor of Automotive and Manufacturing Engineering Technology at Minnesota State University, Mankato. He holds a BIE from Auburn University. He spent twenty years in industry prior during which time he earned an MBA and managed engineering, manufacturing, and plants in a wide variety of industries. He has spent the last 16 teaching industrial and manufacturing engineering, engineering management, and the management of technology. He is past president of SEMS and ASEM.

Insights Learned from Conversion of Web-Based On-Line Courses Back to Traditional Classroom Presentations

Harry C. Petersen, PhD
Minnesota State University, Mankato

ABSTRACT

Manufacturing Engineering Technology classes at Minnesota State University in Mankato, Minnesota, including Industrial Safety, and Logistics, had been converted from traditional classroom presentations to web-based on-line classes. We discovered that there were some advantages to on-line courses, such as enhancing presentations, grading homework, and assisting students who missed a class. But, due to time and budget problems and security concerns, these classes were later converted back to classroom presentations again. We found that on-line courses require more time and hardware than traditional classes. There are more costs, some hidden, which also must be considered when developing or converting on-line classes. There are also problems concerning copyright infringement and exam security. This paper provides a case study which discusses reasons for the original conversion, reasons for changing back, and lessons learned concerning presentations, time involved, student progress assessment, scheduling, and results. Information is presented to help departments considering web-based courses with the planning and resource development needs.

Advantages of Web Courses – Why Courses were Converted to On Line Delivery

Two Manufacturing Engineering Technology classes at Minnesota State University in Mankato, Minnesota, Industrial Safety, and Logistics, were converted from traditional classroom presentations to web-based on-line classes. Like many engineering technology departments which are considering development and implementation of new web-based college courses, or converting traditional face-to-face college classes into on-line courses, our primary goal was to reach more students by offering flexibility and reducing travel. There were other advantages we hoped to obtain, as well.[1]

The internet and modern computers and programs offer the opportunity for universities to offer some classes partly or completely over the internet. Mail-order correspondence courses have offered remote learning opportunities for many years, but results and quality of education have been mixed, at best. On the other hand, the internet can provide real-time chat-room discussions, videos, and feedback not possible by mail. Web-based college classes can provide education opportunities to a much wider group of students.

Because our Manufacturing Engineering Technology program includes a two-semester Senior Design Project, some students must travel between the company and the university classes on a regular basis. Some out of town students take the first two years at their local community college, and then complete their four-year Bachelor's of Science degree in Manufacturing

Engineering Technology here. Web-based courses would allow these students to spend less time away from their homes, saving them money while attracting more students.

We decided to put our senior classes on the web to allow students to take these classes remotely. Because we did not have the faculty or budget to also offer these classes face-to-face, it was initially planned to make all senior classes web-based over a period of years. In 2003, the Minnesota State Colleges and University System (MNSCU) was instituted to assist state campuses in developing on-line curricula and services[2], and, in 2004, provided grants to the MET program to put classes on-line.[1] We chose to implement an almost-entirely web-based format, with only one on-campus class meeting per semester to provide lab and presentation time, and one classroom exam. Figure 1 shows the initial plan for course conversion.

Figure 1: 400/500 COURSES CONVERTED FOR 06/07 TO 08/09 ACADEMIC YEAR DELIVERY[1]:

Course Title and Credit	**Face-to-Face Component**	**First Online Ready Term**	**Enrolled Initial Term**
Manufacturing Resource Planning & Control (4 credits) undergraduate	Capstone Project Required	Spring 2006	21
Manufacturing Resource Planning & Control (4 credits) graduate	Capstone and Industry Applied Project Required	Spring 2006	5
Ergonomics & Work Measurement (4 credits) undergraduate	Mid term face-to-face Lab	Spring 2007	23
Project and Value Management (4 credits) undergraduate	Capstone Project Required	Spring 2006	19
Project and Value Management (4 credits) graduate	Capstone and Industry Applied Project Required	Spring 2006	3
Quality Management Systems (3 credits) undergraduate	Mid term Lab	Fall 2006	23
Quality Management Systems (3 credits) graduate	Mid term Lab and Industry Applied Project	Fall 2006	2

Industrial Safety (2 credits) and Graduate Industrial Safety were later added to the schedule.

In the process of converting and evaluating these classes, we learned about both the advantages and the costs of our venture. As we proceeded, we found that the opportunities of offering classes on-line came with problems and costs which must be considered.

Problems and Costs of Web Based Classes– Many are Hidden

The two most visible costs of offering courses on-line were instructor time and the equipment and programs which on-line courses required.

Additional instructor time required included filming time, studio scheduling and access time, technical training time, editing time, conversion time, time spent editing and verifying web instruction, copyright and license issues, login and downloading student homework, discussions, drop-box access, and preparing many more slides, scanned materials, etc. In some cases this was more than twice the time that would be required for a face-to-face class[5]. Additionally, the Inter Faculty Organization union contract at Minnesota State University does not allow for adequate payment for this extra time, which was often provided by instructors on unpaid weekends.

Another hidden personnel cost was the support staff time required to maintain and correct equipment or program failures and incompatibilities, in addition to the additional instructor time these failures required.

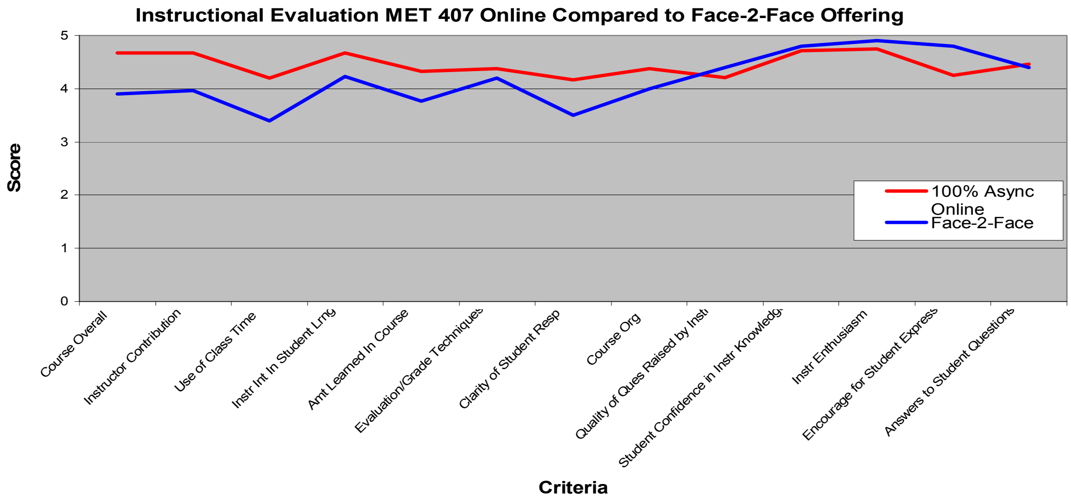
Equipment costs included University studio and audio-visual and editing equipment, servers and storage devices, local computers, computer cameras, green screens, and other materials. Minnesota State University, Mankato, decided to use the D2L on-line delivery system[3,] which is an excellent web-based instructional material delivery system, but must be paid for and maintained.

Other issues, costs, and problems of converting classes to on-line delivery included:
1. Copyrights and intellectual property protection laws, which rises to a new level when putting materials on-line[4]
2. License fees, and the problem of live streaming versus Quick Time downloads
3. Exam and homework integrity, as it is difficult to monitor students,
4. Only one (very intense) day of contact for labs, student presentations, and exams
5. Lack of face-to-face interactive contact with and between students
6. Poor student scheduling of study time meant slipped deadlines and student attempts to do multiple weeks' classes at one time
7. Hardware, equipment, and program compatibility and reliability were continuous problems, especially at start-up
8. Room scheduling was a problem for each single face-to-face meeting, because large blocks of time were required, and the rooms available had already been scheduled for full-semester face-to-face classes.

Assessments, Time, and Budget Motivated Our Return to Traditional Face-to Face Classes

Each class included a final student assessment survey to monitor class delivery and effectiveness. A majority of students surveyed indicated a slight preference for on-line courses, but many preferred traditional face-to-face classes; and we found that almost all of these students could meet on campus. The type of class affected on-line student learning and preferences. Classes with little or no laboratory content, such as Industrial Safety (MET 424) and Manufacturing

Resource Planning and Control (MET 407) gave results similar to or slightly better than face-to-face classes (See Figure 2):



On the other hand, classes with significant laboratory content, such as Ergonomics and Work Measurement (MET 423) did not do so well. Students received much less laboratory experience, depending on the class. Courses like Automation and Robotics (MET 347) were not ever converted to on-line delivery because of the heavy laboratory content.

Grade distributions of on-line classes were similar to the grade distributions on the former face-to-face classes, but a few students did significantly worse on-line than would have been expected, based on past face-to-face performance. Enthusiasm for the material was harder to generate on-line.

We found that there was less opportunity for student-to-student interaction using chat rooms on on-line discussions than occurs in face-to-face classes. Student teams were not really possible except for the single on-campus meeting. Homework, exam, and quiz security was a significant problem, as well.

But some students reported that the on-line classes made learning easier, homework was easier to do because they could review lectures at will, and a number of students reported that the on-line classes made it possible for them to graduate on schedule. Except for team-intensive and lab-intensive courses, the problems could be mitigated, given enough time and resources, if we had enough time and resources.

However, at this time budgets are tight, and we could not justify added time or dollar costs to continue offering courses on-line. We also found that some on-line college courses were weak and of poor quality, which led some universities and employers to question the quality of all web-based courses, including ours. Thus the decision was made to return back to offering traditional face-to-face classes, at the present.

We Converted Back to Face-To-Face Classes, But Retained Many On Line Enhancements

Although we returned to classroom presentation of courses, in the process we learned that face-to-face traditional courses can benefit from the use of on-line delivery technology. There are some advantages to on-line courses, such as enhancing presentations, grading homework, and assisting students who missed a class, which can be implemented and added to traditional classes with little or no additional time or resource requirements, as long as a good delivery system such as D2L is available. In fact, quizzes administered on-line are much easier to correct, and grades can be posted in a real-time basis using a system such a D2L.

Making Power Point lecture slides which are used in lecture also available to students on-line enables these students to review presentations after class. This also means that they can take fewer notes during lecture, giving them more time to learn and interact. It is quite easy to narrate the Power Point presentations, instead of live filming of lectures, as we found by using narrated Power Points instead of live edited filming when preparing on-line web lectures. In fact, the students preferred narrated Power Point lectures to poorly-filmed lectures with a dim, key-stoned, hard to read screen off in the corner. These presentations can be downloaded and reviewed by students multiple times for face-to-face classes, also. This is especially effective when presenting complex calculations.

Handouts can be provided on-line for the students to download, making it unnecessary to duplicate and hand out paper copies during class time. Excel spreadsheets can be used and reviewed by students, and templates provided for complex calculations. Web hyperlinks and videos take students to on-line resources which greatly enhance learning, and take very little preparation time.

By combining the good features of on-line delivery with a single weekly on-campus meeting, the possibility exists to create a new type of hybrid course which combines face-to-face lectures, exams, and labs with on-line delivery of the remainder of the course material. Working students might only need to visit campus once weekly, perhaps on Saturdays.

Conclusions and Recommendations

There are a number of advantages to on-line courses, such as reaching more students, helping working students, enhancing presentations, grading homework, and assisting students who missed a class.

But on-line courses require more time, programs, and hardware than traditional classes. There are more costs, some hidden, which also must be considered when developing or converting on-line classes. There are also problems concerning copyright infringement and exam security.

A more detailed breakdown of the positive and negative aspects of web-based engineering and engineering technology courses can be found in the paper, **"Online Engineering Technology Courses – the Good, the Bad, and the Ugly"**[1]. Quality web-based courses require additional commitment of time and resources, but can provide additional benefits to the students. Each course must be carefully evaluated, with as many advantages and disadvantages weighed.

We learned that face-to-face traditional courses can benefit from the use of on-line delivery technology. Putting Power Point lecture slides which were used in lecture on-line also enables students to review presentations and take fewer notes during lecture. Homework and handouts can be provided, and Excel spreadsheets can be used and reviewed by students. Web hyperlinks and videos take students to on-line resources which greatly enhance learning, and take very little preparation time. And the possibility exists to create a new type of hybrid course which combines face-to-face lectures and labs with on-line delivery of the remainder of the course material.

The MET program was successful in putting courses on-line; we just did not have the resources to continue. But the experience gave us the ability to provide an enhanced face-to-face classroom presentation of the courses.

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Constructing a Civil Engineering Program from the Ground Up

Eric S. Musselman[a], PhD, PE; Andrea J. Schokker[b], PhD, LEED AP

[a]Assistant Professor, University of Minnesota Duluth, Duluth MN 55812
[b]Professor and Department Head, University of Minnesota Duluth, Duluth MN 55812

Abstract

This paper discusses the development and continuing refinement of the curriculum for the new Civil Engineering Program at the University of Minnesota Duluth. Included is a discussion of the program objectives, curriculum development, and integration of assessment into the curriculum.

Introduction

The University of Minnesota Duluth (UMD) is a comprehensive regional university located in Duluth, MN. There is an active student population of 11,664 as of fall 2009 enrolment. There are currently 74 different majors available with one of the newest being Civil Engineering. The program started in the fall of 2008 with the first graduating class in 2012. The program was formed because of a need for a civil engineering program in northern Minnesota and was heavily driven by local industry. UMD was well suited to take on this task as they had relatively recently started a new mechanical engineering program and had (and continue to have) a growing number of engineering students. The program had strong support from many local industries including engineering firms located in Duluth, as well as the mining companies that operate within northern Minnesota. This paper discusses the development of the new civil engineering program to date, including the program objectives, curriculum development, and the integration of assessment into the curriculum.

Program Objectives

The program has two main focuses that distinguish it from many of today's civil engineering curriculums. Both of these focuses are included in the mission statement of the department: "to prepare graduates for professional practice and graduate study through a program firmly based in strong technical skills, fundamentals, hands-on learning, sustainability, and professionalism."

In recent years, the pressure on engineering programs to reduce the number of credits and to include more liberal education courses at most universities in conjunction with financial pressures had led to the scaling back of laboratory and hands on courses and components [1]. Within the development of the curriculum at UMD it was decided early on that there was a need for a program that emphasized practical, hands on learning while still including the technical skills and fundamental knowledge that is required to be a successful engineer. In addition to there being a need for this type of program, it was thought that having an intensive hands-on program would result in graduates who are better prepared to enter the workforce. The justification being that even if you are employed as a design engineer, the more practical knowledge you have about what you are designing or where the data you are using comes from, the better the end product will be.

To have a hands-on program it is critical that lab space be readily accessible and equipped for student use. UMD and the Swenson College of Science and Engineering showed considerable foresight when planning the building as they included significant state-of-the-art laboratory space in the new James I. Swenson Civil Engineering Building. The floor plan of the lab level is shown in Figure 1, with a photo of the completed general projects lab shown Figure 2.

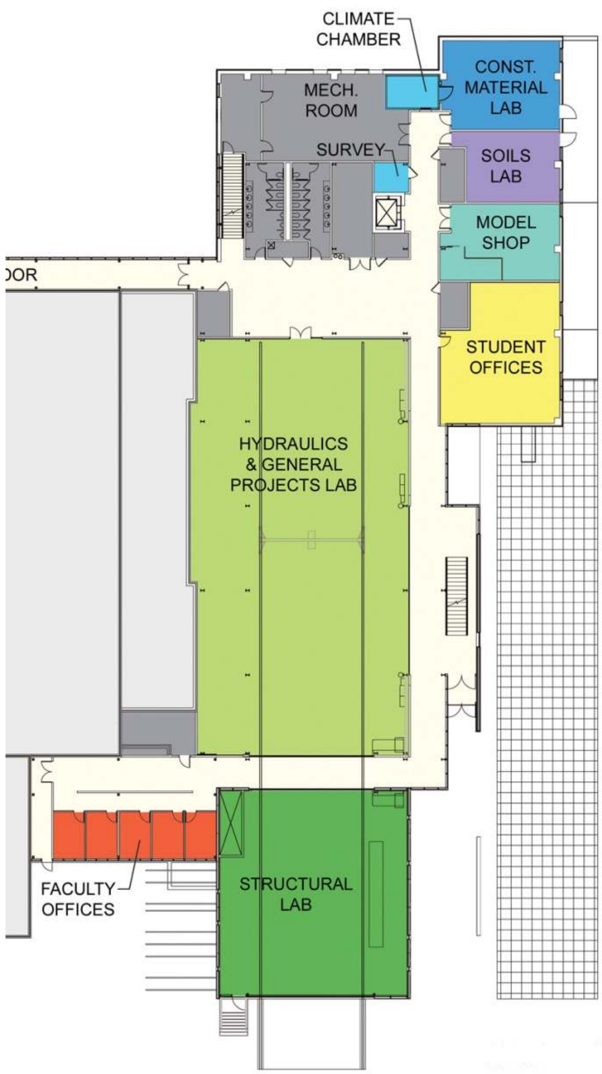

Figure 1: 1st Story Floor Plan of Swenson Civil Engineering Building

Figure 2: General Purpose/Hydrology Lab

The second focus area of the curriculum is sustainability. Sustainability has grown in importance over the past decade, and it will only continue to grow as environmental, political, and economical factors increase the need to engineer green structures and systems. Therefore, to ensure that the graduates of UMD are adequately prepared for the workforce it is essential that they have a thorough understanding of what sustainability is, and how to apply it to their profession. As discussed in the next section, this goal is achieved through both classes focused on sustainability and integration of the topic throughout the curriculum. In addition, just as the building provided space for the hands on focus, the building provides examples of sustainable design. The Swenson Civil Engineering Building in which classes are taught is a LEED Gold rated building.

Curriculum Development

Once the program objectives were established a curriculum to meet those objectives needed to be developed. When the initial design of the curriculum was established, many outside criteria needed to be met. These included: the liberal education criteria for the university, ABET requirements, requirements from the American Society of Civil Engineers (ASCE), knowledge required for the Fundamentals of Engineering Exam, credit limits established by the university, and the needs of employers. Once these requirements were met, the more difficult part of curriculum development begins: developing the structure of the courses, course subject material and prerequisites, and the availability of technical electives – all with input from faculty and industry. The end result of the curriculum is shown in the program description sheet in Table 1.

FIRST YEAR			
FALL SEMESTER		**SPRING SEMESTER**	
Intro to Civil Engineering	1 cr	Liberal education course	3 cr
General Chemistry I	5 cr	Intro to Programming: Visual Basic	3 cr
College Writing	3 cr	Calculus II	5 cr
Calculus I	5 cr	General Physics I	4 cr
Total:	14 cr	Liberal education course	3 cr
		Total:	18 cr
SECOND YEAR			
Engineering Mechanics	5 cr	Principles of Economics	3 cr
Differential Equations w/Linear Algebra	4 cr	General Physics II	4 cr
Engineering Statistics	3 cr	Fluid Mechanics	3 cr
Global Issues	3 cr	Calculus III	4 cr
Total:	15 cr	Engineering Geology	3 cr
		Total:	17 cr
THIRD YEAR			
Soil Mechanics	4 cr	Environmental Eng	3 cr
Structural Analysis	3 cr	Public Speaking	3 cr
Transportation Engineering	4 cr	Hydrology & Hydraulics	4 cr
Infrastructure Materials	4 cr	CAD & Engineering Drawing	3 cr
Project Management	3 cr	Liberal education course	3 cr
Total:	18 cr	Total:	16 cr
MAY SESSION			
Surveying	2 cr		
Total:	2 cr		
FOURTH YEAR			
Senior Design I	3 cr	Senior Design II	3 cr
Advanced Writing	3 cr	CE Technical elective	3 cr
CE Technical elective	3 cr	CE Technical elective	3 cr
CE Technical elective	3 cr	Technical elective	3 cr
CE Technical elective	3 cr	Technical elective	3 cr
Total:	15 cr	Total:	15 cr
TECHNICAL ELECTIVES			
Structures Focus Group Advanced Structural Analysis & Design (3.0 cr) Design of Concrete Structures (3.0 cr) Design of Steel Structures (3.0 cr)		Transportation Engineering Focus Group Traffic Systems Operations and Safety (3.0 cr) Highway Planning and Design (3.0 cr)	
Geotechnical Engineering Focus Group Geotechnical Design (3.0 cr) Rock Mechanics (3.0 cr) Underground & Surf. Excavations in Rock (3.0 cr)		Water Resources Focus Group Design of Hydraulic Structures (3.0 cr) Water Resources (3.0 cr)	

Table 1: Typical Program of Study

Within the curriculum it is apparent how the course objectives outlined in the previous section are met; there is a hands-on focused course in each focus area. Courses with a dedicated laboratory component within the civil engineering curriculum include: Soil Mechanics, Transportation Engineering, Infrastructure Materials, Hydrology and Hydraulics, and Surveying. These courses will include laboratories in the field, lab and on computers. In addition to these courses with dedicated lab sections, many upper level courses will include lab based activities, included many of the design classes.

This emphasis on labs does come at a credit cost as each class with a lab has an additional credit. Much of the emphasis of the curriculum development was on determining what knowledge was essential to a civil engineering graduate and determining the best way to package that information into a course. The results are that some of the tradition courses have been removed or altered. One change was to combine what is traditionally 2-3 credit courses (Engineering Statics and Mechanics of Materials) into 1-5 credit course. This served 2 purposes: it eliminated 1 credit of material that was covered in Physics and it allowed students to begin taking many of their Civil Engineering courses 1 semester sooner as these courses are prerequisites for many of the introductory level courses.

Other courses that were removed as requirements include Dynamics and Thermodynamics. The material in these courses was not completely removed as much of it is introduced in Engineering Mechanics, Fluid Mechanics, and Construction Materials. However, it was decided that the material in these courses did not need the extensive treatment that was able to be given in a dedicated course. Care is taken to ensure the basics required for the FE exam are still covered. The result is a curriculum that allows additional credits of lab while still providing sufficient electives.

The objective of sustainability is not as directly apparent within the curriculum though it is just as integral of a component. Sustainability is integrated into all of the courses, most notably Introduction to Civil Engineering, Project Management, and Senior Design. In each of these classes the sustainability (typically related to the LEED rating system) is included as an important aspect of the final project for the class. In addition, there is an upper level elective class dedicated to the topic of sustainability that is available for the students to take.

Assessment

Assessment is an important tool for any curriculum and even more so when that curriculum has not had the opportunity to be evaluated over multiple years [2]. Therefore assessment has been imbedded throughout the development of the curriculum. It has also been emphasized in the recruitment and hiring of faculty members. There are 17 outcomes (a-q) that are assessed to determine the effectiveness of the new curriculum. The first 11 (a-k) are the standard ABET outcomes assessed by most engineering schools. The next 5 (j-p) are based on guidelines provided by the American Society of Civil Engineers. The final outcome was added to further emphasize and provide a means to measure the focus of the curriculum on sustainability. The outcomes are summarized in Table 2.

a) an ability to apply knowledge of mathematics, science and engineering;
b) an ability to design and conduct experiments, as well as to analyze and interpret data;
c) an ability to design a system, component, or process to meet desired needs;
d) an ability to function in multidisciplinary teams;
e) an ability to identify, formulate and solve engineering problems;
f) an understanding of professional and ethical responsibility;
g) an ability to communicate effectively;
h) the broad education necessary to understand the impact of engineering solutions in a global and societal context;
i) a recognition of the need for and an ability to engage in life-long learning;
j) a knowledge of contemporary issues;
k) an ability to use the techniques, skills and modern engineering tools necessary for engineering practice;
l) an ability to apply mathematics through differential equations; probability and statistics; calculus-based physics; general chemistry; and geology
m) an ability to apply knowledge in the following four recognized major civil engineering areas: structural engineering, geotechnical engineering, transportation engineering, water resources engineering with a depth of focus in one or more of the four areas;
n) an ability to conduct laboratory experiments and to critically analyze and interpret data in the following four (4) recognized major civil engineering areas: structural engineering, geotechnical engineering, transportation engineering, water resources engineering
o) an ability to perform civil engineering design by means of design experiences integrated throughout the professional component of the curriculum culminating in a senior design experience;
p) an ability to explain basic concepts in management, business, public policy, and leadership; and explain the importance of professional licensure;
q) an ability to apply knowledge of sustainability to civil engineering practice.

Table 2: Program Outcomes

Included in the development of each course was a discussion of what outcomes would be covered and assessed. In this way all of the faculty members have been involved in the discussion and have a better understanding of the assessment process. By involving assessment at this stage it also allows for the actual assessment itself to become an integral part of the course instead of just an afterthought. When practical for the outcome being assessed the assessment is based on a dedicated in-class assignment that is consistent from instructor to instructor and from year to year. This allows for a more consistent evaluation of the outcome. Another way consistency is ensured is that each assessment is evaluated by two different people, minimizing grading biases.

The results of assessment are stored for each student in each class. This allows the gathering of data that using typical assessment schemes would be difficult to obtain. For example, it is possible to examine how the order in which classes are taken affect the performance of the students, or how the performance in a certain class predicts the latter performance. This allows for the effect of changes in the curriculum to be evaluated more quickly and more accurately, increasing the benefits of assessment.

Having consistent, integrated assessment can also benefit the instructor. It allows for an unbiased, quantitative evaluation that is very useful for evaluating different teaching styles, techniques or organization. For example, you could evaluate the effectiveness of adding a comprehensive class project to the course by determining if it improves the knowledge of the students in areas that are considered critical to the course.

Conclusion

The development of the new Civil Engineering program at the University of Minnesota Duluth is a unique opportunity to evaluate the current methodology and curriculum of engineering education. UMD has decided to emphasize practical knowledge as well as sustainability while designing their curriculum. The program has approximately 65 students in each class (currently freshman, sophomores, and juniors), which is significantly higher than the 25 that was initially estimated, indicated that there is potential interest in such a program from students. A very active industrial advisory board continues to state that the industry is interested in graduates from the program. An integrated assessment system is in place to identify any weaknesses in the program that need further examination. All of initial steps to create a successful Civil Engineering program have been completed, and the authors are confident that this new program will continue to succeed.

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Surviving ABET assessment and still having time to grow your engineering program:

Keeping the focus on the students

Lance D. Yarbrough, Scott F. Korom and Zhengwen Zeng
University of North Dakota, Department of Geology and Geological Engineering

ABSTRACT

Our recent ABET compliance review, the extensive training, and the transformation of our program has given us a number of ideas. We found that efforts focused on the frontend provided benefits in the form of reduced stress in the long-term (3–5 years). Next, worked with a subset of our constituency to establish few and simple-to-assess program educational objectives. Further, we staggered our assessment cycle in order to reduce assessment data collection, yet increase the usefulness in the evaluation process. We have eagerly incorporated the updated ABET view of multidisciplinary teams, which until recently was unknown to us.

INTRODUCTION

The Geological Engineering program at The University of North Dakota has recently finished an ABET compliancy review. As a relatively small engineering program in numbers of both faculty and students, we would like to share our experience and lessons learned and posit their relevance to any size program. We found it best to have a well-thought-out scalable assessment plan that properly samples cohorts at a summative learning point without duplication. In practice, recently trained faculty were easier to convince of the need for a streamlined assessment plan and processes. Because we found that a single ABET-knowledgeable individual in the program will have a difficult time convincing colleagues of the importance of assessment, we suggest that at least two faculty trained in assessment are necessary for the program's continued growth. ABET accreditation is needed to attract new students, yet the work required to retain that accreditation can certainly seem overwhelming. The "death by assessment" mantra might begin to ring in one's ears. However, it does not have to completely consume your time. With proper training and a willing set of faculty, you *can* offer a growing, improving program, while providing students an enriched engineering education.

HOW DID WE VIEW ASSESSMENT?

The satisfaction of ABET requirements were the program faculty's first thoughts when faced with assessment and planning. Our next challenge was to fully determine the ABET criteria and how to assess that criteria in our program.

The Venn diagram in Figure 1 is an attempt to characterize our idea about assessment as it pertains to ABET. ABET tends to be the brute in the room that is continually getting your attention. That brute leaves little time to assemble a proper Assessment Plan for your department or program. Even the ongoing course and teaching assessment are compressed and compete for your time. Again the diagram points to important questions about your views on assessment. One might ask the following: Does my degree program really have an assessment plan or do we just pile paper during the 5th year of the ABET cycle?

We could continue to comment about how this view of assessment impacts one's career, research time, and tenure, but the focus of this discussion is on students. How does this view impact your students? Have students been provided with enough feedback to improve their skills and judgment? One might realize their course assessment seems a bit weak. Is that because only course grades have been used to assess the program? Are you taking an honest look at your degree program or do you equate your program assessment with everything ABET?

As we understand it, this is the unfortunate view typically taken by those who are tasked with administrating a department's program assessment. In our case, our Dean and Chair were supportive of the need for training and resources. We found that though we were trained, the remainder of the faculty were not necessarily appreciative of our efforts and continued to view assessment as a nuisance that must be tolerated until fed just enough so it goes away until the next cycle.

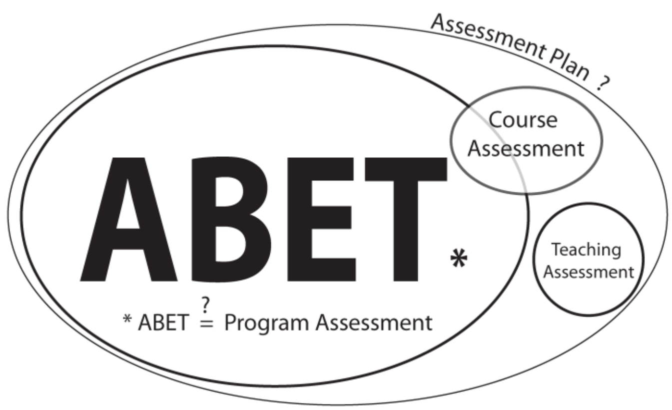

Figure 1 – An illustration of a possible ill-conceived idea of assessment that is all too typical for engineering programs. ABET seems to dominate, if not make up the entire domain of the assessment plan. It may even dominate the view of assessment such that the only plan is to satisfy ABET.

Two of our original misconceptions about ABET and its uses are shown in Figure 1. First, we presumed program assessment was entirely ABET. We were quick to discover that the assessment of our degree program can be robust, but ABET offers the framework that has become the standard. Any plan can be used for assessment, as long as you can map back to each of the ABET criteria. So why not just use the given criteria and focus on the students? Secondly, course assessment was thought to be an important component of program assessment process. Again, we quickly learned that an over reliance on individual student grades is not a proper form of program assessment and will lead to a shortcoming during your next ABET review.

How Can a Paradigm Change Help in Assessment?

In contrast, Figure 2 illustrates a change in our paradigm of engineering program assessment. It is a more balanced view of the components of an Assessment Plan that puts ABET in its proper place, which is entirely within the domain of program assessment. Essentially, ABET is no longer the brute. By starting with an assessment plan that enviably is laden with ABET terms and processes, the mental picture is one of a much smaller, diminutive, and less dominating part of the overall plan. Again, we have little doubt that the majority of program assessments will be dominated by ABET criteria and language, but we believe keeping the perspective like that in Figure 2 will lead to less stress and more opportunities to simplify assessment plans. It is possible with our posited simplified view that more of a department's faculty will become supportive, thus creating a culture of streamlined, targeted, assessment that satisfies many users of the data.

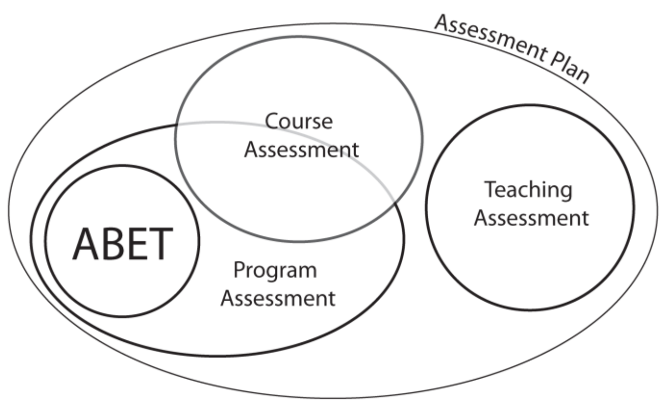

Figure 2 – An illustration of a more balanced view of a department's assessment. ABET should be thought of nothing more than a component of the program assessment and course assessment as an extension of program assessment.

Couse assessment and ABET assessment requirements do not intersect in our paradigm. But this is not to say the student work used for the course grade is not the same used in assessing the program. It is important to realize that the same paper or test problem can be used in both! Simply use a different assessment tool on each. The goal of producing better students includes a well-balanced assessment plan. Not an *ad hoc* policy.

Note that we have increased the prominence of teaching assessment in our view of the ENTIRE assessment plan. This may be wishful thinking on our part but it is a necessary part of assessment. While it is important to streamline an assessment, the hasty use of a single assessment opportunity to collect data for several assessment reports may, in fact, be counterproductive. Many universities use student-based evaluation forms as an indirect assessment of teaching, as well as to assess class materials and perceived goals. This is an important point to make while including teaching assessments in assessment tools designed to be used with overall program assessment. We found that we were more likely to get faculty participation in the assessment plan by decoupling the assessment tools involving teaching and program assessment. Key players are likely to have more buy-in while collecting the required data if they understand that the data will not, in some way, compromise their efforts.

Buy-in from the faculty is a must. It is important to develop a culture of assessment that is student focused. We recommend making a plan that fits the available resources of a department's program, and making it as integrated as possible with other ongoing assessments in the program (i.e., course assessment). Know specific modules in particular courses that offer a summative assessment opportunity and work with those instructors to have the student work evaluated for program assessment at the same time it is assessed for student performance in the course. This simplifies the program assessment immensely.

NEW IDEAS HAVE HELPED CHANGE THE CULTURE

With this new paradigm of assessment now providing a new perspective, we wish to provide a few ideas and processes that have helped us keep focused, while providing students with a fulfilling educational experience.

1. Set up a grid to delegate the assessment data collection. A transparent method of what is collected, WHEN and by WHOM, is critical to a successful program assessment. As new faculty come in they will already know the plan and have opportunities to ask questions prior to data collection. Also, the grid provides a method of accountability for all faculty in the assessment plan.
2. Incorporate assessment participation as a requirement for tenure and promotion.
3. Get into the habit of copious note-taking at meetings involving curriculum issues. Be sure to record the reasons why actions were taken and provide a short narrative background to the decision. Feel free to repeat the condensed record of the discussion each time the topic is revisited in subsequent meetings. The few extra paragraphs may seem redundant, but it helps to focus discussions during future meetings, reminds faculty of reasons why the decision was made (memories are short and faculty move on), and provides a fantastic resource when compiling evidence for ABET Criterion 4 (Continual Improvement).
4. Be sure to identify the faculty in the program! We were under the impression that faculty in the department were the faculty in the program. <u>This is a very dangerous assumption</u>. If you do not define your program faculty, the ABET Program Evaluator will do it when the team arrives at your campus and their assumptions may be to include or exclude faculty who have nothing to do with your program. We have 11 full-time faculty in a multi-disciplinary department and only 4 have been identified as the program faculty for the engineering degree program. We go a step further and identify the membership of the Geological Engineering Curriculum Committee (GECC) as the program faculty. In theory, any faculty member of the School or University can be a member of the GECC. In practice, it is a subset of the department faculty. This arrangement may be advantageous to other multi-disciplinary departments, which are becoming more common in these economic tough times. By limiting the program faculty to only those who wish to participate in the degree program, you have several benefits: 1) those individuals who make the effort to be part of the program faculty tend to have more buy-in to the success of the program, 2) for the purpose of satisfying Criterion 5 (faculty), the program needs only to provide information about those individuals in the program faculty and not the

entirety of the department, 3) smaller group dynamics tend to be more productive and focused, 4) similar to the last point, a focused group dealing with curricular issues can take on a more expanded role and manage the entire degree program. There is no minimum number of faculty specified by ABET.

5. Always remember that ABET is an assessment of the <u>program</u>, not of individual students or the department. Also, a student in the program should only be assessed <u>once</u> per performance criteria. If your assessment plan includes formative assessment opportunities, these should be listed separately from summative data when used for ABET evaluations.
6. "Multi-disciplinary" may not mean what you think. ABET does not have an official definition. However, there are guidelines that have come from Dr. Dayne Aldridge, Accreditation Director for Engineering (Aldridge and Lewis, 1997). Dr. Aldridge was asked for the ABET definition of multidisciplinary teams as used in Criterion 3. His response provides two definitions that may be used depending on a program's needs. First, programs and an engineering school can work together to provide students with different specialized knowledge and skills to contribute to the team. So civil engineers and mechanical engineers can work together augmenting each other's design experience. This approach requires extensive coordination between programs or departments. Second, a multidisciplinary team may be more appropriate to smaller-sized programs. This definition requires team members to assume the role of specialists during the design project. For example, a geological engineering design challenge may have individual members becoming the group *expert* for fundamental areas such as groundwater, rock mechanics, soil mechanics or environmental components of the design. ABET requires programs to document protocols to select roles for team members and to assure team members worked as *specialists* in the area chosen. It should be noted that programs using the specialist team member roles must be sure they distinguish the design challenge from a typical student work group experience. To be sure roles are followed and assessed, the selection of these roles should not be left to the students. Clear designation of the roles is needed so that students can make special or unique contributions to the teams' purpose.

TRAINING IS CRITICAL TO A SUCCESSFUL ASSESSMENT PLAN

We recommend that a program have at least two faculty members who have had recent training in ABET assessment (Rogers, 2009). This is not to pay homage to the old saw "misery loves company" but does offer a distinct advantage to the success of assessment in your program. If one individual is trained and (unfortunately) becomes the *life* of the assessment, then that energy is gone when that particular person moves on or becomes disinterested in the process. A second person offers the first a sounding board and *confidant(e)*, of sorts, to help advance the program assessment to a department-wide effort.

Ideally, all program faculty should attend a training seminar about assessment. These can be with school, university, or national organizations. ABET offers many opportunities, from an intense one-day fly-in workshop to the 5-day Institute for the Development of Excellence in Assessment Leadership (IDEAL) workshop.

SUMMARY

The intent of this paper is to encourage faculty to begin early in the accreditation cycle to evaluate their program and to begin collecting assessment data. From time to time, it is a good practice to step back and evaluate the success of a program, and satisfying ABET criteria is a requirement for a successful and healthy program.

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BIOGRAPHICAL INFORMATION

LANCE D. YARBROUGH, Ph.D., P.E., is an Assistant Professor in the Geology and Geological Engineering Department at The University of North Dakota. He is a member of the department's assessment committee and is a 2010 ABET IDEAL scholar. He is licensed in Mississippi as both a Professional Engineer and a Registered Professional Geologist.

SCOTT F. KOROM, Ph.D., P.E., is an Associate Professor and the Director of Geological Engineering at the University of North Dakota. He is a licensed Professional Engineering in North Dakota.

ZHENGWEN ZENG, Ph.D., is an Assistant Professor in Geology and Geological Engineering Department at The University of North Dakota. He is a member of the geological Engineering Curriculum Committee and the GGE Committee for ABET Assessment, was trained for ABET's "Sustainable Assessment Process."

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