Numerical Methods in the ChEn curriculum: One Program's Evolution over 30 Years (Extended Abstract)

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1980's – First ChEn course in the curriculum is Numerical Methods

- Ted Davis introduced required ChEn Numerical Methods course in the Sophomore year (following Freshman Fortran prerequisite) as the first "foundational" course in our ChEn sequence.
- Overarching goal: prepare ChEn students for professional practice and for possible research careers in computationally-intensive ChEn fields and applications
- In each following core ChEn course, students then completed numerical projects building on principles of that course
- The Numerical Methods course was built on concepts from linear algebra: linear equation sets, nonlinear equation sets, nonlinear ode's and sets, boundary value problems, and pde's
- Advantage: After that key Numerical Methods course, students were proficient at programming, at formulating numerical approaches, and at coping with challenging numerical problems
- Problems:
    - In the sophomore course, students hadn't seen yet how the equations arose from physics and chemistry, so they lacked physical insight into what physical parameters might cause equations to become numerically challenging
    - Some students, especially those less skilled at programming, were more challenged in perceiving the logic of the numerical methods,
    - Some students expressed frustration at the perception that this course was a high hurdle to clear to enter the chemical engineering principles courses.
- Mounting challenge: Late 90's, needed to add 1 credit to absorb the Freshman Fortran programming course, which would no longer be taught by CSci with a pre-numerical methods focus

Late 1990's - Numerical methods instruction distributed through the ChEn curriculum

- Several factors made change imperative
    - Semester conversion - No longer any proper-sized (quarter) slot for the '90's course.
    - Math, Phys, Chem courses expand in the first-year program; also, desire for earlier start in Analytical, PChem, and/or MatSci.
    - Less room in the Sophomore curriculum to cover for the loss of a numerically-focused Fortran or C++ course
    - Employers expressing more wish for facility with Mathematica/Matlab (which had by now appeared in the engineering Math courses)

- Implemented modules to teach numerical methods and rudimentary programming in the midst of the principles courses, as the relevant problems appear in an engineering context.
    - Algebraic equation systems numerical methods in "mat/energy balances"
    - Ordinary differential equations num. methods in "rxn eng"
    - Pde's and other topics in "transport" courses
    - Coding done within a Mathematica (later, Matlab) environment. Students were still writing at least rudimentary code, but with graphics support and with ability to compare their code with the built-in functions.
- Advantage: Allowed us to address each type of numerical method challenge as it arose naturally in the ChEn coursework, with physical insight intact.
- Problems:
    - Though with effort could be done well, very taxing and challenging for instructors and TA's.
    - Fast-paced within the modules; students who did not pick up Mathematica (or Matlab) conventions firmly and just-in-time could be left behind.
    - Relied on careful collaboration among all instructors, including "non-computational" lecturers (valuable, but at times vulnerable)
    - At worst, danger of devolving into diffuse, unfocused treatment of computation over the curriculum.

2007 - "Experiential" approach, followed by Junior Spring Numerical Methods course to review and develop principles

- Had to repackage the computational approach approach again to accommodate new biomolecular engineering required course, and to make computation instruction more robust, and to better prepare students for computational research,
- Sophomore year , introduce Matlab TOOLS only
    - Very little coding (except simple iteration associated with staged separation).
    - Address both transient problems and staged equilibrium calculations
    - Mostly rely on Matlab as an appliance, keeping focus on material and energy balances reasoning.
- Through Sophomore and Junior year, encourage students to use these tools through the curriculum, perhaps encountering difficulties that create "teachable moments"
- Finish Junior year with full Numerical Methods principles course
    - Difficulties with tools now mastered – not a difficulty any more
    - Intermediate concepts now addressed well and uniformly.
    - Vistas now opened to students interested in advanced numerical methods through computational research and grad course.
- Advantages:
    - Students now become motivated before the Numerical Methods course to learn about numerical methods; they have a chance to see the dangers/limits of using Matlab routines simply as an appliance.
    - For selected students, good launch into computational research or grad course
    - For all, solid (though delayed) background for all students (who are at least then able to critique numerics of HYSYS, sometimes ANSYS, etc.)

- Disadvantage: Some students still need review/primer (depends on student's math background) on simple programming logic and debugging in the Sophomore year.

Reviewing where we're at now:

- What we've lost with this trend since the 80's: Loss of core value that ALL students need to be able to conceive of, write, test, and execute programs and should be prepared for a computationally intense career. N.B.: Some constituents no longer feel this is necessary, but the pendulum may swing (e.g., new NSF and AIChE focus on "Simulation Based Engineering and Science".)
- What we gain with this trend :
    - Capable use of numerical (Matlab) tools in the Junior year (e.g., solving McCabe Thiel in Junior Lab) even before fully grasping all concepts of Numerical Methods.
    - Num Methods course placement at the end of the Junior year still allows it to be well appreciated and used by those who do want to go into computation-intense field.

Concluding question for ChEn educators:

WHAT ARE CHEN UNDERGRAD BEST PRACTICES?

Acknowledgments:

Dr. Richard McClurg (currently affiliation, SSCI/Aptuit in West Lafayette, IN) was instrumental in designing some of these approaches to computation education in the curriculum in the 1990's. H. Ted Davis is fondly remembered for his early and enduring inspiration for thoughtful approaches to undergraduate education, especially in computation since the 1960's.

Alon McCormick has taught Chemical Engineering at the University of Minnesota since 1989. He studied at Tulane and at UC Berkeley, and he enjoyed undergraduate internships at Shell and Exxon. His graduate students have focused on problems of nanostructure control and characterization in catalysis, adsorption, membranes, chromatography, the synthesis nanoparticles, glasses and gels, and (more recently) nanoemulsification; many of them have taken up related interests in companies and in academics. Alon has taught in much of the undergraduate Chemical Engineering curriculum, has served as the Director of Undergraduate Studies in Chemical Engineering, and currently serves on the University of Minnesota Senate Committee on Education Policy and on the AIChE Education and Accreditation Committee.

Principles of Particle Technology: Philosophy, Topics & Experiments

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Introduction

Generally there are key basic experiments that define the development of the subjects that we teach. For example, the experiments of Joule and Reynolds underpin thermodynamics and fluid mechanics. In the classroom we attempt to convey the results and conclusions of fundamental experiments in a period that is a minute fraction of the time in which the original experiments were done and the corresponding concepts developed. The philosophy of the lecture-laboratory course is to enable students the run basic experiments for themselves with the intention that they will develop a deeper understanding of fundamental concepts and relationships from their "hands-on" experiences.

Such is the approach in "Principles of Particle Technology", a junior-level 3-credit class in Chemical Engineering that has two lecture periods and one 2-hour laboratory period per week during a 15-week semester. Particle technology is particularly amenable; key basic experiments can be done within the laboratory session and the apparatus can be simple. In addition, the chronologies of the lecture and laboratory sessions are arranged to be in step with each other. Students work in pairs on the same experiment in a single laboratory session; each experiment is completed within a single session. Typically, the enrollment is in the range of 30-36 students corresponding to 3 laboratory sections. The requirements for the course are admission into the upper division of Chemical Engineering, completion of the two-semester lower-division physics sequence, and at least co-enrollment in Fluid Mechanics. There is a single midterm and a final exam.

Students complete 8 experiments in 8 laboratory sessions and there are 3 homework assignments in addition to the written work associated with each laboratory. The Chemical Engineering Department is an undergraduate-only program, so no graduate-student assistance is available. The instructor-of-record is responsible for setting up each lab, tearing down each lab as well as the grading; another responsibility is the implementation of "continuous process improvement" by improving the experiments and their descriptions. This has been the same person since the course's inception; it was first run in 2003. It was developed from an elective lecture-only course that this individual gave in 2000; it was found that particle technology is a rich subject for class-demonstrations and the experiments to be described grew out of these. The apparatus for the experiments was constructed with readily available components and simple bench-top or hand tools; no machine-shop work was required.

Two texts have been used over the history of the course, viz. "Introduction to Particle Technology" (1) and "Fundamentals of Particle Technology" (2). The latter one is currently in use; it has the advantage of being free and on-line, and the course sequence follows the first seven chapters. Sections of "Perry's Chemical Engineers' Handbook (3) are also additional sources that the students are expected to read. Normally in course work, students' homework comprises problems at the end of chapters in the assigned text. Here, these problems are essentially replaced by doing equivalent calculations with data that students have generated in the lab coupled with the plotting of good graphs with their data. The experiments are robust in the sense that poor experimental technique will often still lead to data that can be used to do the calculations, but the final results may be poor.

The students' written work from the lab generally comprises: (i) plotting their data – in a linear form where applicable, (ii) doing the basic calculations and these usually involve using quantities derived from model fits to their data, (iii) answering questions which, where possible, involve using their plots. In addition to grading the calculations and the answers to the questions, students' graphs are graded with a scheme set up for ensuring correct axis titles and units, correct numbers of significant figures on axis labels, use of unconnected markers for data, suitable fits to the data with consistent behavior at limits (particularly, the origin) represented by a smooth curve or line, and tick marks on the axes.

Lab 1. Particle-size analysis by sieving
Lecture topics (2-3 classes) include the types of distribution, the bases of describing distributions, methods of measurement, sieve designations, the Tyler & US Sieve series and particle shape with equivalent diameters. The lab comprises: (i) determinations of mesh sizes and openings for samples of screen for which microscopes and rulers are available, and (ii) sieve analysis of −5/8″ pea gravel (Menards), and (iii) sieve analysis of −20 mesh household sugar (Flavorite). Two spinning rifflers of different capacities are used to obtain representative samples as demonstrations at the start of the lab. The importance of representative sampling for particulate samples can not be overemphasized. The larger material is sieved using standard 8″ sieves in the US Sieve Series and a mechanical shaker (Ro-Tap RX-29). The smaller material is sieved is using a nest of hand sieves (Mini-sieve micro sieve set, Scienceware Cat. No. F37845-1000). The purpose of sieving two materials is to convey a sense of the size ranges that are amenable to sieve analysis.

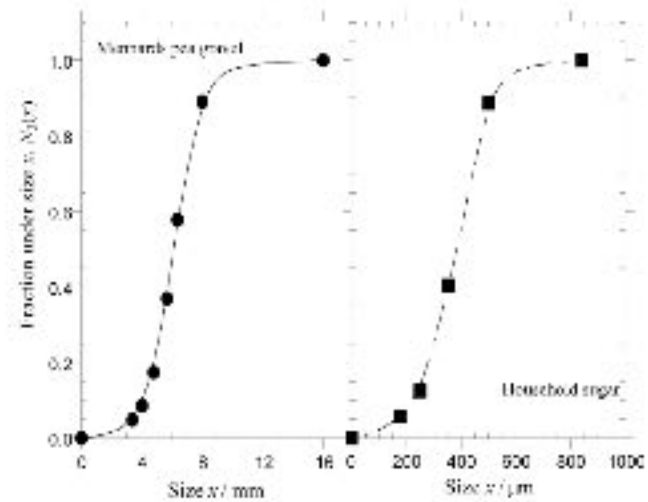

Figure 1. Typical particle-size distributions obtained by sieve analysis

Fig. 1A shows results on a representative sample of −5/8″ Menards Pea Gravel.

Data ●; smooth curve ————————

Fig. 1B shows results on a representative sample of −20 mesh Household Sugar.

Data ■; smooth curve —— —— ——

Students construct size distributions from masses of material retained on each sieve. From their distributions, they determine: (i) medians and modes, (ii) expected fractions below and above certain sizes that do not correspond the screens used, and (iii) fractions within certain ranges. Fig. 1 shows typical results.

Labs 2 & 3. Fluid flow through porous media – water and air through sand.
Lecture topics (4-5 classes) include the characterization of the packed bed (porosity, volumetric concentration, bulk density), superficial and interstitial fluid linear velocity, Darcy's law, permeability, the Reynolds number for flow through a packed bed, empirical correlations for friction (Kozeny-Carman, Carman, Ergun) and the Sauter mean diameter.

Figure 2 contains a schematic diagram of the apparatus used the measuring the flow of water through beds of sand[1] (Sand, White Quartz, −50+70 mesh; Aldrich Cat. No. 27,473-9) in Lab 2. The lab period starts with a brief discussion of the application of Bernoulli's equation to the setup and how the standard form of Darcy's law, usually cast for horizontal flow, should be modified. Students do three separate experiments in which they determine static head-volumetric flow relationships (ΔH vs. Q) for the flow path: (i) in the absence of sand, (ii) with a bed of sand, and (iii) with a second bed containing double the mass of sand. They also measure the corresponding bed heights and the internal diameter of the column. Figure 3 contains typical results.

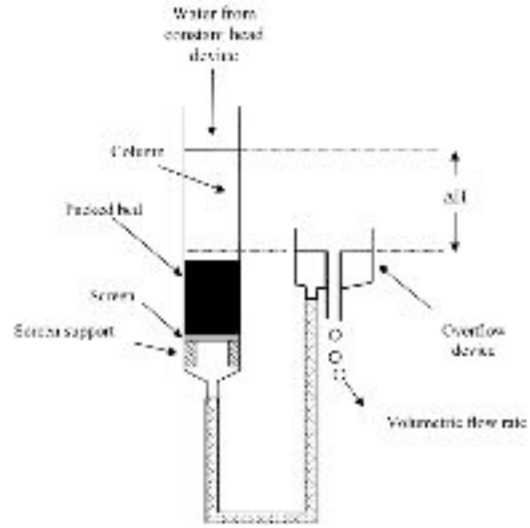

Figure 2. Apparatus for experiments with water flowing through sand

In their analysis of the data, students (i) correct the packed-bed data for the frictional effects of flow through the apparatus, (ii) calculate the beds' porosities, and (iii) manipulate Darcy's law and Kozeny-Carman equation so they then calculate the mean particle size of the sand – they then reconcile their answers with the size description of the sand.

Figure 4 contains a schematic diagram of the apparatus used the measuring the flow of air through beds of the sand in Lab 3. The period starts with a brief discussion of the application of Bernoulli's equation to the setup and how conditions differ from the previous experiment with water (Do we need to measure a static head term?). Students do three separate experiments in which they determine pressure-volumetric flow relationships (ΔP vs. Q); they are for the flow path: (i) in the absence of sand (mostly they find that this too small to measure, so they do not need to correct their bed data), (ii) with a bed of sand, and (iii) with a second bed containing double the mass of sand. In their analysis of the data, students (i) calculate the beds' porosities, and (ii) manipulate Darcy's law and Kozeny-Carman equation so they then calculate the mean particle size of the sand – they then reconcile their answers with the size description of the sand. Figure 5 contains typical results.

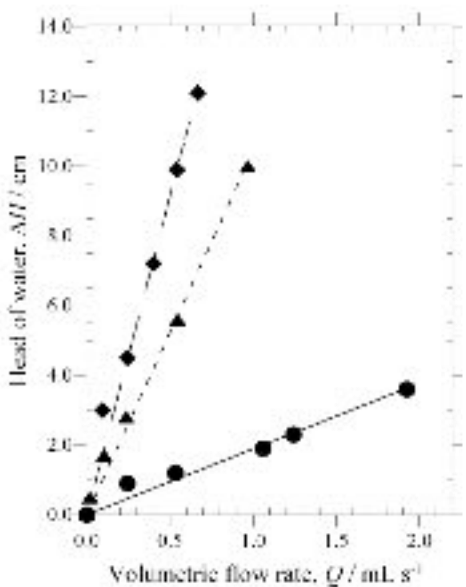

Figure 3. Typical data for the flow of water through sand
Data for flow through the apparatus in the absence of sand ●;
Best-fit line ————————;
$\Delta H = 1.89Q$ R^2=0.97
Data for flow through the apparatus in with a bed of sand, mass ≈ 15g, ▲
Best-fit line – – – – – – – ;
$\Delta H = 10.4Q$ R^2=0.99
Data for flow through the apparatus in with a bed of sand, mass ≈ 30g, ♦
Best-fit line — — — — — ;
$\Delta H = 18.3Q$ R^2=0.98

[1] The same sand is used throughout.

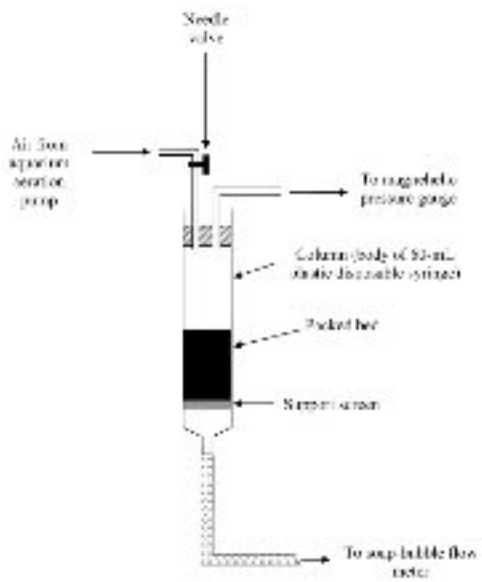

Figure 4. Apparatus for experiments with air flowing through sand

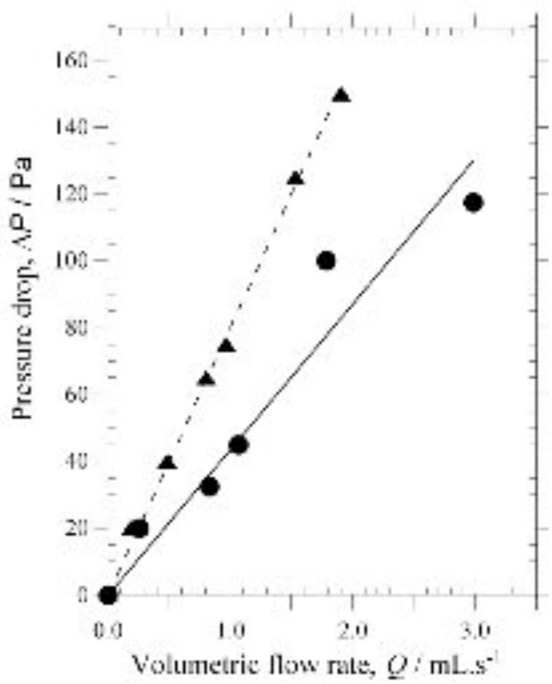

Figure 5. Typical data for the flow of air through sand
Data for flow through sand, mass 37.4 g, bed height 4.1 cm ●
Best-fit line ——————————; $\Delta H = 43.6Q$; R^2=0.93
Data for flow through bed of sand, mass 79.1 g, bed height 8.6 cm ▲
Best-fit line — — — — — — — — ; $\Delta H = 80.0Q$; R^2=0.998
(The data for the flow of air in absence of sand is not shown; the correction is negligible in this case.)

The assignments associated with Labs 2 & 3 are submitted together; in the event that the students recognize that the mean-particle sizes from the two experiments disagree, they should then be stimulated to check their calculations. Discrepancies are often attributable to the use of incorrect values of the viscosities of water and air, and, less often, the density of air. A tacit objective of the two labs is to get the students to remember the magnitudes of the densities and viscosities of air and water.

Lab 4. Filtration rates of −200 mesh limestone

Lecture topics (3-4 classes) include the application of Darcy's law to filtration, terms (medium & cake resistance, specific resistance to filtration, moisture ratio), various cases (constant rate, constant pressure) and the design of constant-pressure systems from batch studies (area & time requirements).

The apparatus comprises: (i) 2-L filter dome that sits atop a round plastic block (Kontes) to which a vacuum pump is attached, (ii) a calibrated vessel inside the filter dome for the collection of filtrate, and (iii) a glass filter funnel with a glass frit inside (the filter medium) whose outlet passes through a rubber bung into the filter dome. Students do three experiments, viz. a drainage experiment (no applied pressure drop) with the filter medium alone and filtration experiments at two pressure drops.

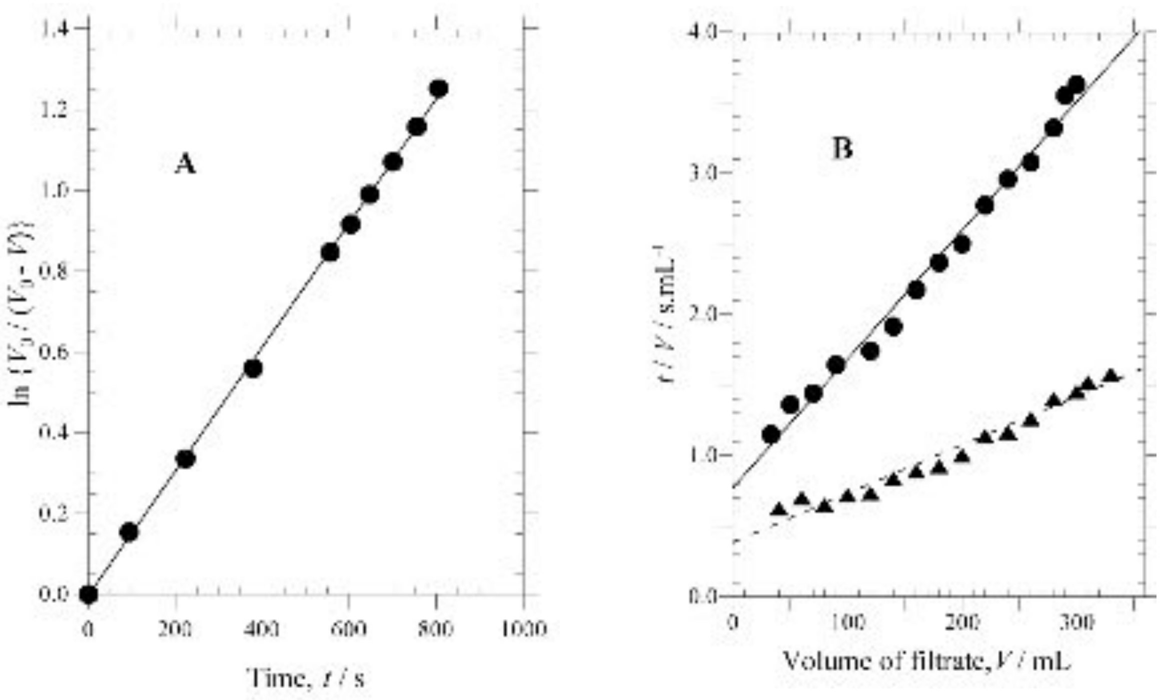

Figure 6. Typical data from the drainage of water (A) through the filter medium and for the filtration of −200 mesh limestone out of water (B).
Fig. 6A shows results from a drainage experiment.
Data ●; Best-fit line ————————;
$\ln\{V_0/(V_0 - V)\} = 1.53\times10^{-3}t$ R^2=0.999
V_0 is the initial volume of water charged to the filter medium (350 mL) and V is the volume of filtrate at time t.
Fig. 6B shows results from the filtration experiments at two different pressure drops.
Data at ΔP = 8 in Hg ●; Best-fit line ————————;
$t/V = 9.10\times10^{-3}V + 0.776$ R^2=0.99
Data at ΔP = 16 in Hg ▲; Best-fit line — — — — — — — — —;
$t/V = 3.40\times10^{-3}V + 0.387$ R^2=0.97

They calculate the following quantities: (i) the resistance of the filter medium (from the plot of the drainage data - see Fig. 6A), (ii) the moisture ratios of the cakes, (iii) the volumes and height the cakes (to be compared with their measured values), and (iv) the porosities of the cakes. From standard plots (see Fig. 6B), they calculate the specific resistance to filtration and the resistance of medium. Finally they calculate the mean particle size of the limestone; they are asked to reconcile their answer with the description of the limestone. They compare their values of the medium resistances from the drainage and the filtration data, the porosities of their two cakes, and they are expected to offer explanations for significant differences in these two quantities.

Lab 5. Single-particle sedimentation

Lecture topics (5-6 classes) include single-particle sedimentation, Stokes' law, the single-particle Reynolds number, the need for empirical correlations to calculate terminal velocity, the drag coefficient, the drag curve and its tabular representation (Heywood tables), applications of the drag curve and the design of sedimentation basins. Students attempt to measure terminal velocities of nine different particles from which they calculate the drag coefficient and the

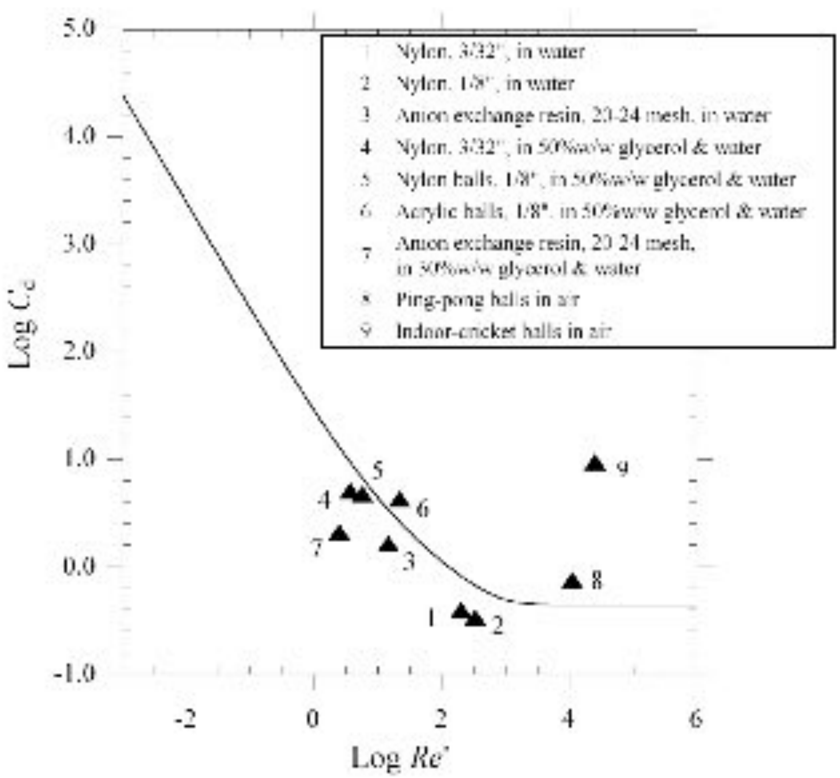

Figure 7. Typical data from the measurement of terminal velocities of single particles in various media.

Data ▲; the drag curve ——————————

C_d is the drag coefficient and Re' is the single-particle Reynolds number.

single-particle Reynolds number; they also plot their own drag curve from the Heywood tables. Figure 7 contains typical results; students are expected to offer explanations for significant deviations from the drag curve.

Lab 6. Particle-size analysis by hydrometry of −250 mesh limestone
This lab requires the direct application of Stokes' law to calculate sizes of particles that have fallen through various distances at particular times after a well-mixed suspension is allowed to settle. They measure the specific gravity of the suspension after various settling times with a hydrometer, requiring the direct application of Archimedes' Principle. The experiment follows that of the ASTM procedure (4) except for a major modification; purpose-built hydrometers are

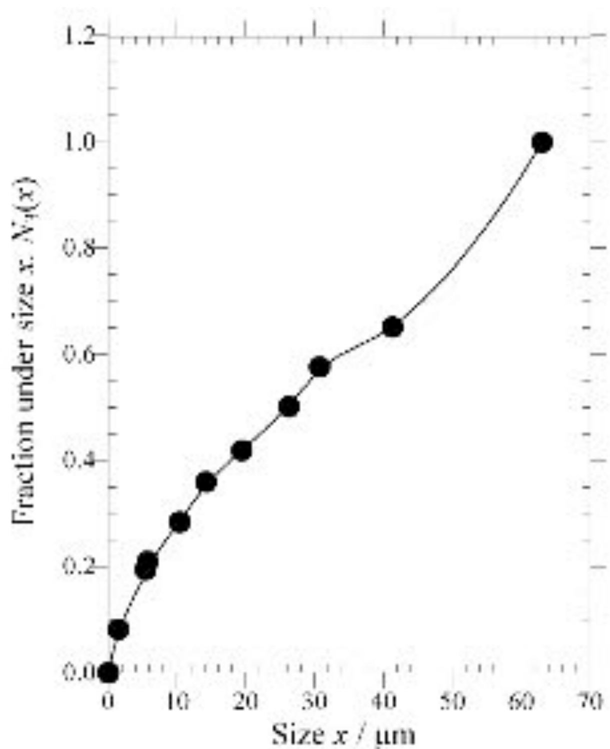

Figure 8. Typical results from the particle-size analysis of −250 mesh limestone by hydrometry
Data ●; smooth curve ——————————

used with a specific-gravity range of 1.000-1.010 so much diluter suspensions are employed than those specified in the ASTM procedure (4). Figure 8 contains typical results. Students use their particle-size distributions to answer the similar questions to those posed in Lab 1.

Lab 7. Batch settling of +325−200 mesh limestone
Lecture topics (3-4 classes) include the modification of single-particle equations to treat hindered settling and the development of the equations for the describing volumetric fluxes of particles. The design of continuous thickeners (area requirements) from batch-settling studies is the concluding topic. In the lab students measure the velocities of the interfaces between settling particles and "clear" liquid after the suspensions, of various compositions, have been well shaken. Students calculate the particle fluxes from the interfacial velocities; they then design a continuous thickener with the best-fit equation of their flux data. Figure 9 contains typical results.

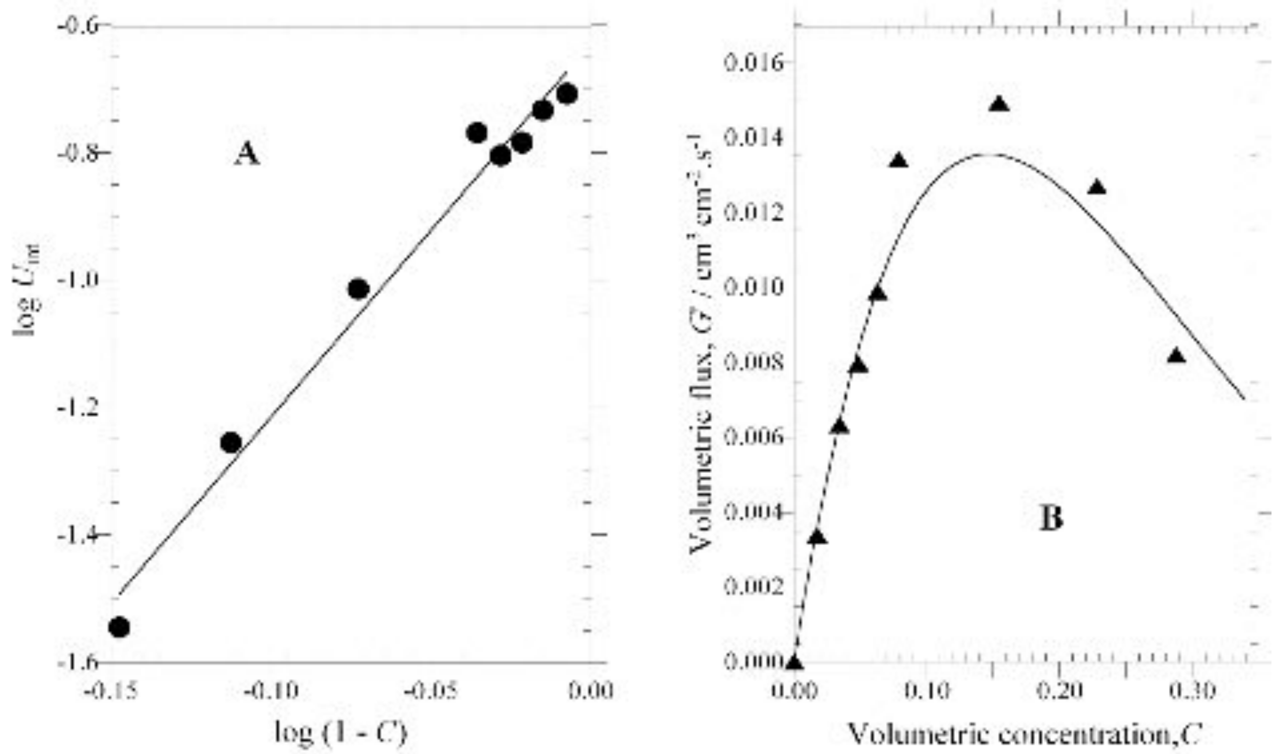

Figure 9. Typical results from batch settling experiments with +325 −200 mesh limestone

Fig. 9A displays the data for the interfacial velocities between "clear" and settling particles, U_{int}, plotted against the initial volumetric concentration of particles, C.

Data ● ; best fit line ————————————

$\log U_{int} = 5.86 \log(1-C) - 0.628 \equiv n \log(1-C) + \log U_t$ $R^2 = 0.98$

U_t is the single-particle terminal velocity.

Fig 9B displays the volumetric particle fluxes, G', derived from Fig 9A.

Data ▲ ; best fit curve ———————————— with the function: $G' = U_t \times C \times (1-C)^n$

Lab 8. Fluidization of sand with water

The treatment of the up-flow section in a continuous thickener in lectures leads naturally into the topics relating to fluidized beds (2-3 classes). These include the fluid linear velocity of minimum fluidization, fluid linear velocity and bed expansion (the Richardson-Zaki equation) and types of fluidization. Figure 10 contains a schematic diagram of the apparatus used in the lab. Students measure the bed height (*L*) and the superficial linear velocity of the water in the column above the bed. They fit their data to the Richardson-Zaki equation from which they calculate the average single-particle terminal velocity of the sand; with this they estimate the mean particle-size and reconcile their answers with description of the sand. (The size and density of the particles puts the terminal velocities outside the Stoles' law regime, so the use of the Heywood Tables is required.) Figure 11 contains typical data.

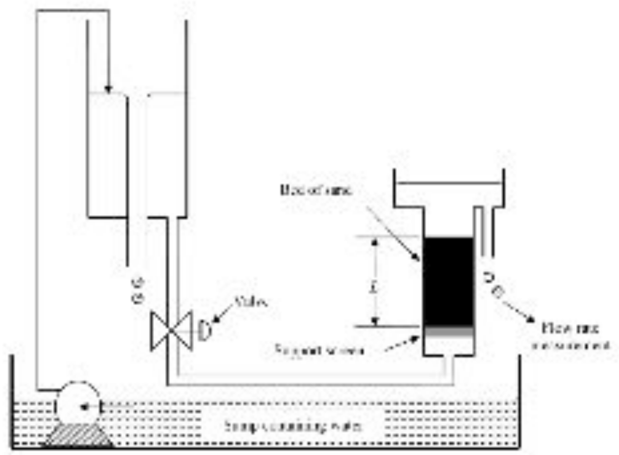

Figure 10. Apparatus for the fluidization of sand by water

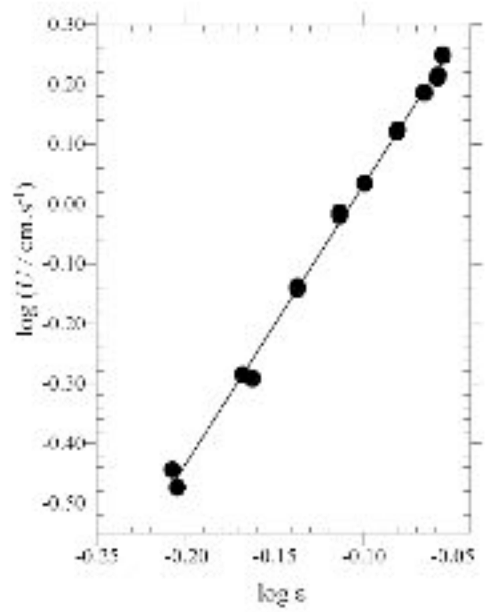

Figure 11. The Richardson-Zaki plot with typical results for the fluidization of sand with water

Data ●; best-fit line ————————

$$\log U = 4.65\log \varepsilon + 0.497$$
$$R^2 = 0.997$$

U is the linear velocity of the fluid above the bed and ε is the voidage (porosity) of the expanded bed.

Lab 9. In-class experiment: fluidization of InsulAdd[2] with air

The experimental work in the course ends with an in-class experiment with air and InsulAdd; this is to demonstrate the different features of gas and liquid fluidization. Before the experiment starts, we estimate the volumetric flow rate for the onset of fluidization (Q_{mf}). InsulAdd fluidized by air corresponds to Group A in the Geldart classification. Figure 12 shows a schematic diagram of the apparatus and Fig. 13 contains typical results.

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[2] This is a solid material that contains hollow spheres with density of about 0.8 g/mL. Originally, it was developed to help insulate the exterior surface of the space shuttles – see http://www.nasa.gov/topics/nasalife/green_paint.html. It is now sold as additive for paint to increase its insulating properties – see http://www.nasa.gov/topics/nasalife/green_paint.html

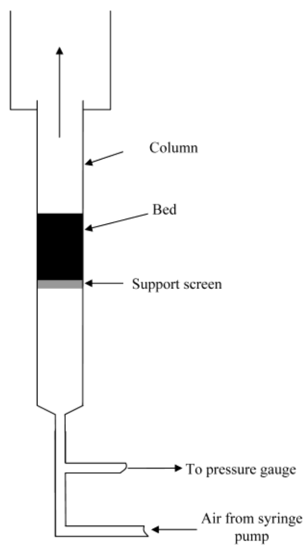

Figure 12. Apparatus for the fluidization of InsulAdd with air

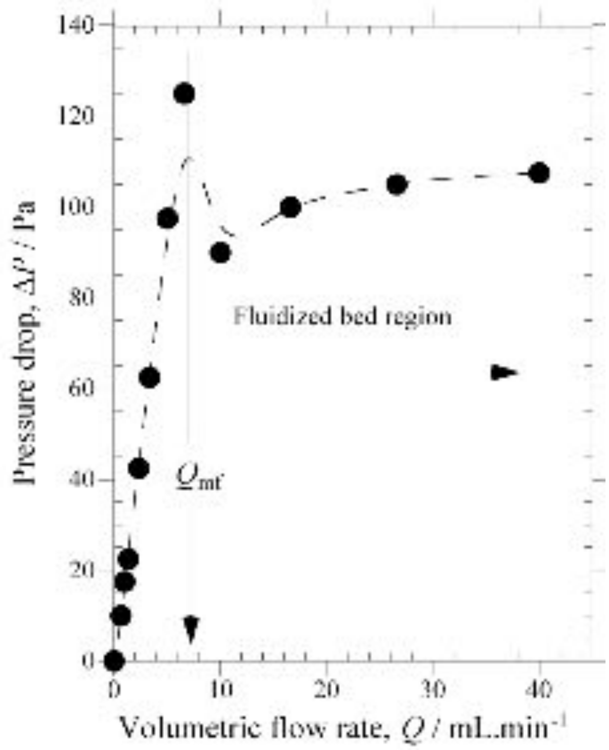

Figure 13. Fluidization of InsulAdd with air – typical results from an in-class experiment

Data ● ; smooth curve —————————————

The vertical line indicates the demarkation between the fluidized and packed bed regions. Q_{mf} is the volumetric flow rate at the onset of fluidization as the flow is increased from the packed-bed region.

In conclusion

The consequence of replacing a single class period in the week for a 3-credit course with a laboratory is fewer topics are covered in comparison to the 3-credit lecture-only version. However, the philosophy and hope behind "hands-on" work is that a deeper and a longer-lasting understanding of the basics will result from the experience; this course is designed to cover the basics of particle technology. Topics introduced are met again in later courses, such as Separations (packed columns) and Chemical Reaction Engineering (fluid-solids reactors). In the capstone design sequence, Chemical Engineering Design I & II, there are at least one or two projects that require particle technology.

The lab component provides additional benefits; students plot up to 24 graphs and the grading is designed to get them into good habits. They are exposed to various methods of measuring flow rates and pressures and well as to the basic technique of determining particle-size distributions. As a whole the course provides the opportunity to reinforce the basic laws and concepts of physics, e.g., Newton's laws of motion, Archimedes' Principle, pressure and friction. In addition the course is an ideal compliment to fluid mechanics using its basic principles throughout, especially those involving friction and the empirical correlations involving dimensionless groups.

Acknowledgement
I wish to thank Duane Long for technical assistance.

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Biographical Information

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Keith Lodge has developed two laboratory-based courses, one in process control and the other in particle technology. He also teaches heat and mass transfer in which he brings a hands-on approach to the class. His general research interests include Thermodynamics, Physical Chemistry & Particle Technology in Chemical Engineering, Environmental Engineering & Science, and Partition Coefficients & Activity Coefficients. Recent publications describe his work concerned with fugacity measurements (*Fluid Phase Equilib.* **2007**, *253*, 74-79), octanol-water partition coefficients (*J. Phys. Chem. A.* **2010**, *114*, 5132-5140) and porosity measurements of taconite pellets (*Powder Technol.* **2010**, *204*, 167-172).

Alternative Formative Assessments to Enhance Conceptual Knowledge Transfer in the Topic of Buoyancy: a Pilot Study

Derek Wissmiller, University of Wisconsin-Stout

Abstract

A pilot study was performed to investigate the effect of alternative formative assessments on conceptual knowledge transfer relating to the topic of buoyancy. The performance of a group of sophomore-level engineering students (N=52) was evaluated relative to the type of formative assessments they had been assigned. Students who performed well on formative assessments containing non-numerical type questions tended to show a deeper level of conceptual knowledge than those students who had been assigned formative assessments containing only conventional numerical calculation type questions.

Introduction

Learning is a constructive process in which new knowledge builds upon prior knowledge.[1, 2] It is for this reason that there is increased interest in inductive instructional methods like inquiry-based learning, problem-based learning, and just-in-time teaching to name a few. A common feature of these inductive methods is that questions or problems form the context for learning.[3] Thus, formative assessments based on questions/problems can play a fundamentally important role in student learning.

The degree to which homework/activity questions impact student learning can be evaluated by considering them relative to Bloom's taxonomy. In order of increasing cognitive complexity, Bloom classifies the educational cognitive domains as knowledge, comprehension, application, analysis, synthesis, and evaluation.[4] Formative assessments commonly found in engineering textbooks tend to fall under the domain of application, requiring students to apply particular solution procedures to determine numerical values. Blooms taxonomy has been further divided into four categories of knowledge for each cognitive level; factual, procedural, conceptual, and metacognitive.[5] Thus, within the application domain, engineering education curriculum tends to emphasize procedural knowledge, rather than conceptual.

Although it is important for practicing engineers to be able to apply numerical problem solving procedures, engineers must also be able to make intuitive predictions regarding the behavior of a system, a skill which is highly dependent upon conceptual knowledge. [6] Further, practicing engineers regularly employ the higher order cognitive domains of Blooms taxonomy by analyzing, creating (synthesizing), and evaluating systems. Therefore it is of interest to develop homework/activity questions in engineering education that highlight conceptual knowledge and reach towards the higher levels of Bloom's taxonomy.

Apart from Bloom's taxonomy, the impact of formative assessments can be considered in light of the Kolb model of learning.[7] According to the Kolb cycle as shown in Figure 1, learning begins when a person has a concrete experience. The learning process continues when an individual reflects on that experience relative to their prior knowledge (reflective observation), develops a conceptualization to explain the experience (abstract conceptualization), and then tests their conceptualization (active experimentation). The results observed after testing one's conceptualization represent yet another concrete experience which can be reflected upon to develop further conceptualizations to be tested and so on.

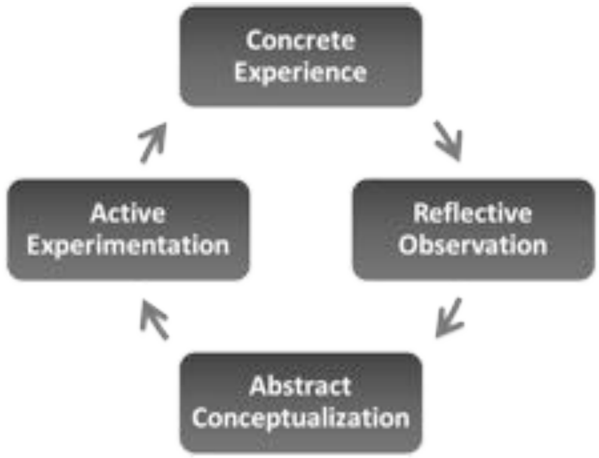


Figure 1: Kolb cycle of learning.[7]

The types of questions/problems commonly found in engineering textbooks may fail to engage learners in deep levels of reflective observation as they may fail to trigger students to think about their prior experiences, especially those concrete experiences from outside the classroom. If learners fail to make connections to their prior experiences (reflective observation) they will fail to develop abstract conceptualizations that reconcile new knowledge with prior knowledge. Without such conceptualizations, learners are unable to test their ideas (active experimentation) and identify potential misconceptions or other gaps in understanding. This can lead to erroneous understandings and limit students' abilities to transfer knowledge beyond the classroom.

This paper presents the findings of an investigation into the impact of formative assessment questions which deemphasize calculation. The questions/problems studied here are similar to those typically found it conventional engineering textbooks, but rather than asking students to determine numerical values, these questions ask students to compare two situations without need for numerical calculation. These non-numerical problems are similar to those found in concept inventories; instruments which are designed to quickly assess student conceptual understanding.[6] However, unlike concept inventories, these questions are employed here as formative assessments to enhance student learning, rather than summative assessments to gage student understanding.

Anecdotal evidence has shown that when students are presented with non-numerical questions, they tend to approach them from a conceptual context rather than defaulting to calculation based solution procedures. As such, these questions appear to be more likely to trigger students' prior knowledge than numerical calculation questions. Additionally, these questions appear to target the higher cognitive domains, including analysis and evaluation. This preliminary investigation focuses on the impact of such formative assessments on student learning.

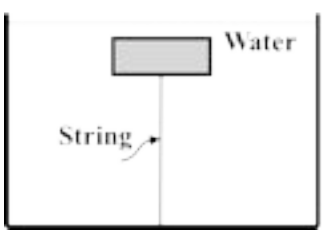
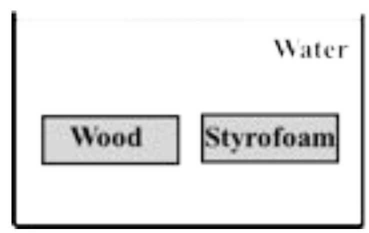
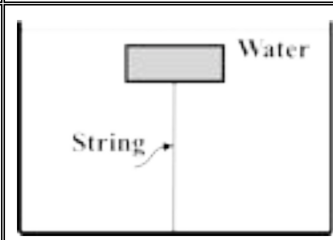
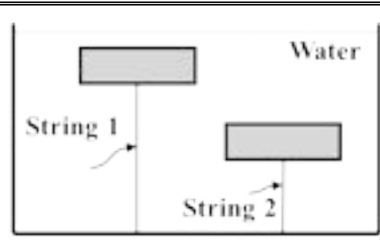
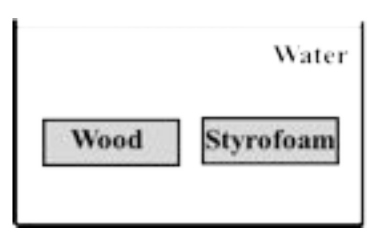
Methods

Buoyancy has been chosen as the subject in which to investigate the impact of assessment methods on conceptual learning. This is a topic familiar to common experience and is therefore a topic for which students will likely have preconceptions which they must overcome. Additionally, buoyancy is a subject which can be understood on the basis of foundational concepts without the need for a higher level understanding of fluid mechanics.

The research subjects employed in this study are students from a sophomore-level course in engineering statics (N=52). These students are familiar with the concepts of force, pressure, and free body diagrams; topics which are prerequisite for understanding buoyancy. However, these students have not yet formally studied fluid mechanics, and as such, any preconceptions they have are not the result of any formal education in the subject.

Each of the students was asked to read a one page handout which introduces the topic of buoyancy as a way of *learning* about the subject. Immediately following this, students were asked to complete a formative assessment (Activity X) involving the topics they had just *learned*. In Activity X, students were asked to calculate the tension force in a string which holds a Styrofoam^{TM} block under water such as that shown in Table 1. This numerical calculation problem is similar to the types of instructional assessment often employed in engineering education.

Table 1: Experimental test matrix.

	Activity X Numerical Calculation *Determine the tension force.*	 Non-Numerical *Which string has greater tension?*	**Activity Y** Conceptual Explanation *Why does Styrofoam rise faster?*
Group A			
Group B			

Approximately half of the students in the study (N=24) were randomly selected and given a version of Activity X which included an additional non-numerical question (Group B). In this non-numerical question students were asked to compare the tension forces on two identical Styrofoam™ blocks held under water at different depths with a string as shown in Table 1. The Activity X assessments were collected by the instructor and the students' performance recorded. These activities were then returned to the students the following class period along with an answer key for the corresponding version of the activity. In an effort to control the sources of input for student learning, no grading marks or other feedback were written on the student papers.

During the third class period, students were asked to complete a summative assessment (Activity Y) in which they considered a wooden block and a Styrofoam™ block (identical size) submerged at the same depth under water as shown in Table 1. Students were asked to explain why the Styrofoam™ block is observed to reach the surface of the water faster than the wooden block when released simultaneously. These activities were collected and student performance analyzed relative to the version of Activity X assigned.

Results and Discussion

Student performance on the numerical calculation question from Activity X was very high, with only 3 of 52 students answering this question incorrectly. These same three students also answered Activity Y incorrectly. This may suggest that procedural knowledge is perquisite for developing an informed understanding of conceptual knowledge. However a sample size of three is clearly far too small to make meaningful conclusions.

For the remaining students who correctly answered the numerical calculation question, their performance on Activity Y is outlined in Table 2. Of the students who were assigned only the numerical calculation question on Activity X (Group A), 44% correctly answered the explanation question on Activity Y. Of the students who were assigned both the numerical calculation and non-numerical questions on Activity X (Group B), 64% correctly answered the explanation question on Activity Y. This suggests that exposure to non-numerical questions increases students' conceptual knowledge beyond what is attained through exposure to numerical calculation questions alone. However, due to the small sample size in this study, this finding is not statistically significant ($z = 1.34$).

Table 2: Student performance on Activity Y relative to Activity X.

	Group Size	**Activity X Performance**		**Activity Y Performance**	
	Number of Students	Numerical Calculation	Non-Numerical	Number Correct	Percentage Correct
Group A	27	Correct	Not Assigned	12	44%
Group B	22	Correct	Assigned	14	64%
Group C	14	Correct	Correct	10	71%

When comparing students who correctly answered the non-numerical question from Activity X (Group C) to those who were assigned only the numerical calculation question (Group A), a statistically significant trend does emerge with 71% of students in Group C answering Activity Y correctly compared to 44% in Group A ($z = 1.64$, $p < 0.1$). Thus, conceptual knowledge may be enhanced for students who perform well when prompted with a non-numerical question, compared to students who are only assigned numerical calculation questions.

If students who demonstrate a higher level of understanding in non-numerical questions are more likely to have a better understanding of conceptual knowledge, then it is of interest to increase performance on these types of questions. It seems reasonable that increased practice with such formative assessments would lead to increased performance. Future studies will seek to investigate this hypothesis.

When interpreting the results of Activity Y, the information being attained must be carefully considered. When students correctly answer this question, they demonstrate that they can provide a clear explanation of why the Stryofoam™ block rises faster. For students who incorrectly answered this question, their answer may simply reflect an inability to provide a clear explanation, rather than a lack of conceptual understanding. If the results are interpreted in this way, it follows that increased performance on the non-numerical question leads to an increased ability to provide clear explanations within conceptual contexts. Given the ever increasing importance of written communication skills, such a conclusion would still provide incentive to increase performance on non-numerical questions.

Aside from the impact on conceptual knowledge, the results of this study reveal the difficulty of non-numerical questions. While 93% (49/52) of students correctly answered the calculation question on Activity X, only 58% (14/24) correctly answered the non-numerical question. This suggests that the current methods of instruction are not adequately preparing students with the necessary critical thinking and problem solving skills to address such questions. This is cause for concern considering that these non-numerical questions reflect the fundamental basis of the types of analysis and evaluation performed by practicing engineers.

An additional observation of this study is the degree to which new knowledge can lead to confusion or rejection of prior knowledge. When answering Activity Y, 12% (6/52) of students incorrectly answered that both of the Styrofoam™ and wooden blocks would rise to the surface in the same amount of time, despite being told that the Styrofoam™ block would rise faster in the problem statement. These students were all partially correct in their reasoning, noting that both blocks experience the same buoyancy force. However, these students failed to take into account the gravitational force on the blocks (weight). This highlights the need for instructors to help students in connecting new knowledge to prior knowledge by creating learning environments which allow students to apply the Kolb cycle. Whether employed as formative or summative assessment, questions such as this will likely provide an opportunity for conceptual learning to occur. For example, by testing one's theory that both blocks rise at the same time (active experimentation) and receiving feedback that this is incorrect (concrete experience), a student is forced to further reflect until developing an accurate conceptualization of the problem.

This study will be repeated with other groups of students to increase sample sizes and improve the generalizability of the findings. Additional studies will be performed to investigate the cognitive processes students employ when they approach non-numerical problems versus numerical calculation problems. Further, future work will investigate whether continued practice with non-numerical problems leads to increased performance on questions of this type.

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What is Involved in Establishing a New Engineering Program? An Update on the New Computer Engineering Program at UW-Stout

By

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Abstract

A new program in Computer Engineering was recently launched at the University of Wisconsin – Stout. Approval for this program was received from the Board of Regents Education Committee of the University of Wisconsin (UW) System in August 2008. Program enrollment has grown from 0 to approximately 100 students in the last three years, a student Branch of the IEEE (Institute of Electrical and Electronics Engineers) was formed, and the first 'graduation' is scheduled for May 2012. Some of the issues and considerations encountered during the early development phase were described in a previous ASEE paper[1]. In this paper thorough description will be provided regarding program development, course and laboratory development, student and faculty recruitment and development and accreditation issues with the goal of providing a clear picture of what is involved in establishing a new engineering program.

Background

The University of Wisconsin – Stout has a rich history of preparing students for professional careers in a variety of applied fields. Founded by James Huff Stout in 1891 as Stout Manual Training School to provide training in manual arts and domestic science training[2], the scope and name of the institute have changed over the years, but the primary mission of providing practical, hands-on instruction has remained constant. In March 2007, UW-Stout was designated "Wisconsin's Polytechnic University" by the UW System Board of Regents. The area of technology and engineering has been a key part of Stout's focus for many years. During the late 1950s UW-Stout established the industrial technology program which focused on the application of engineering and scientific concepts to manufacturing related industries. A strong professional studies area provides a foundation for those seeking a future management career track. Over the years, the industrial technology program evolved into the present-day Engineering Technology program, which currently has an enrollment of approximately 400 students spread out over six concentration areas in electrical, facilities, mechanical design, nanotechnology, plastics, and production operations. In 1995 Stout received permission to offer the Manufacturing Engineering Degree. With an enrollment of 230 students, this program is currently the largest ABET-EAC accredited undergraduate program in manufacturing engineering in North America. Although the Engineering Technology[3] (ET) and Manufacturing Engineering[4] (MFGE) programs both include aspects related to electrical / computer engineering (e.g., circuits, electronics, digital logic and control systems) the need for more focused, in-depth preparation in the areas of embedded systems was recognized several years ago. Such recognition led to UW-Stout's request to the Board of Regents Education Committee of the University of Wisconsin (UW) System to authorize the establishment of a dedicated program in Computer Engineering. Final approval was given by the UW System Board of Regents on August 22, 2008. As a point of interest, approval was also granted at the same time to authorize a new program in Plastics Engineering (PE) at UW-Stout.

Program Overview and Development

The process of requesting a new program in the University of Wisconsin System is a thorough one – including such aspects as a background of the need for the program (from regional, state and national perspectives), a description of how the program 'fits' with other programs in the system, description of personnel and equipment needs, budgetary items, enrollment and staffing projections, and a detailed description of the curriculum. The original curriculum sheet is shown in Figure 1, and has proved to be a faithful guide as the program has unfolded.

One of the unique aspects of most Computer Engineering programs is that they are a wonderful blend of the 'software' side of computers (including Computer Science courses such as programming languages, Data Structures, Computer Organization, etc.) and the 'hardware' side typically found in an Electrical Engineering program (including courses in Circuit Analysis/Design, Digital Logic, Electronics, Control Systems, Microprocessors, etc.). The combination of these two disciplines provides students with a solid background which allows them to work in a wide variety of areas. At UW-Stout, this dual nature (and the underlying courses in mathematics) yields the additional perk that graduating seniors can finish with an automatic minor in Computer Science and an automatic minor in Mathematics. In addition, if they choose to take three additional courses (two biology courses and a course in biomedical instrumentation) they receive a third minor in Biomedical Instrumentation.

Embedded systems engineering is a key component of the Computer Engineering program at UW-Stout. In this program an embedded system is viewed as any object that contains a computing device (e.g. a microprocessor, microcontroller, or a digital signal processor) with the object itself not functioning as a general purpose computer. This definition allows us to consider any object from a simple appliance (like a digital watch) to complex portable integrated devices such as medical instrumentation and 4G cellular devices containing gigabytes of memory and a complex operating system supporting a variety of applications. Students are encouraged to engage their imaginations and engineering skills to solve real-life problems using embedded systems technologies (hardware and software) as well as the knowledge they gained from other coursework leading up to the embedded systems course.

Three years have passed since Computer Engineering became an official program at UW-Stout. In that time, faculty resources have expanded; enrollment has grown from zero to approximately 100 students; laboratory facilities and equipment have been added and developed; new courses have been developed and taught; a Program Advisory Board has been formed and become actively involved; a student branch of the IEEE (Institute of Electrical and Electronics Engineers) has been formed which actively involves students, faculty and industrial partners; students have participated in cooperative (internship) opportunities; and preparation has commenced for an upcoming accreditation visit. It is anticipated that the first graduating class will be May 2012. A lot has happened in three years! In an effort to provide a flavor for what is involved in the initial development and unfolding of a new

UW-Stout Computer Engineering Program							
First Year							
MATH	153	Calculus I	4	MATH	154	Calculus II	4
CHEM	135	College Chemistry	5	PHYS	281	University Physics I	5
ENGL	101	Freshmen Composition	3	ENGL	102	Freshmen Reading & Writing	3
CS	144	Computer Science I	3	CS	145	Computer Science II	3
		Health & Wellness	1	SPCOM	100	Speech	2
		Semester Total	***16***			***Semester Total***	***17***
Second Year							
CEE	205	Circuit Analysis and Design	4	CEE	215	Electronics	4
CEE	225	Digital Logic	3	CEE	235	Signal and Systems	3
MATH	250	Diff. Eqs. and Linear Algebra	3	CS	244	Data Structures	4
PHYS	282	University Physics II	5	CS	245	Intro. Computer Organization	3
INMGT	300	Engineering Economy	2	MECH	293	Engineering Mechanics	3
		Semester Total	***17***			***Semester Total***	***17***
Third Year							
STAT	330	Probability & Statistics	3	CEE	345	Microprocessor Sys. Design	3
CEE	325	Digital System Design	3	CEE	355	Applied Electromagnetics	3
CEE	335	Automatic Control Systems	4	MECH	294	Mechanics of Materials	3
CS	441	Computer Architecture	3	MFGE	275	Thermodynamics & Heat Trans.	2
MATH	270	Discrete Mathematics	3	PHIL	235	General Ethics	3
		Semester Total	***16***			*Humanities/Soc. Science Elec.*	3
						Semester Total	***17***
FourthYear							
CEE	405	Senior Design I	2	CEE	410	Senior Design II	2
CEE	425	Data Com. & Cp. Networking	3	CS	442	System Programming	3
CEE	445	Embedded Systems	3			*Health & Wellness Elec.*	1
CEE Elective*			3			*Humanities/Soc. Science Elec*	3
		Gen. Ed. Technology	2			*Humanities/Soc. Science Elec*	6
		Humanities/Soc. Science Elec	3			***Semester Total***	***15***
		Semester Total	***16***				
						Program Total	***131***
**CEE Elective: Choose CEE 435 (Digital Signal Processing) or CEE 455 (Fund of Wireless Communication)*						Date: April 2011	

Figure 1. UW-Stout Computer Engineering Curriculum.

program, the following sections highlight specific program developments or milestones on a yearly basis

Initial Planning Years (2005-2008)

Although final approval of the UW-Stout Computer Engineering program came in August 2008, activity started long before that. Initial planning for the program began in approximately 2005 and involved the following steps:

- Meeting with on-campus faculty, administrators and selected employers regarding the need and feasibility of establishing a Computer Engineering at UW-Stout.
- Completing a needs survey to determine employer demand (i.e., verify if jobs will be available for graduates).
- Developing an industrial advisory board for input on curriculum and legislative issues.
- Completing an "Entitlement to Plan" submitted to the University of Wisconsin System.
- Completing a telephone survey of employers in Northern Wisconsin to determine the present and future demand for a Computer/Electrical Engineering program in Northern Wisconsin, identify the incoming sources of Computer/Electrical Engineers in Northern Wisconsin and, determine the orientation of the Computer/Electrical Engineering program.
- Receiving UW System approval to write an "Authorization to Implement Plan" document.
- Gathering all data needed to complete the final proposal.
- Drafting the final proposal for Computer Engineering at UW-Stout.
- Submitting the final proposal to two external reviewers at other universities for curriculum review.
- Presenting the final proposal to all on campus committees and receive approval from all committees.
- Defending the final proposal at the UW Board of Regents meeting.
- Receiving "Authorization to Implement" the new Computer Engineering program at UW-Stout from the UW Board of Regents!

Year 1 (2008 /2009)

It became official! The program was approved in August 2008 and two new faculty (Joe Bumblis and Bob Nelson) arrived on campus. The year started with 0 students in the program. There was a lot of room for growth! Activities for that very busy year are summarized below.

- <u>Faculty teach ET, MFGE and PE students and plan new courses</u>
  Four faculty with a background in Computer / Electrical Engineering were now on campus. Planning and preparation of the new Computer Engineering (abbreviated CEE at UW-Stout) courses (which had initial offerings the following year) was in full swing, while the new faculty joined in the on-going effort of teaching electrical / computer aspects to students in the ET, PE and MFGE programs.

- Develop informational material for new program

  To successfully operate a college program a number of fact sheets, pamphlets, program guides and presentations are needed to answer the questions of prospective students and their families and to properly direct current students. Many of these were developed the first year of the program.

- Plan for equipment / laboratory needs

  When the Computer Engineering program was approved, three rooms were already dedicated for laboratory instruction in the electrical / computer areas. These labs were used for teaching ET, PE and MFGE students. Additional laboratory space and new equipment was needed for CEE courses. Planning for the laboratory expansion was initiated this year. Several pieces of new equipment (computers, oscilloscopes, function generators, etc.) were secured.

- Program Advisory Board formed

  Active involvement of an appropriate Program Advisory Board is one of the keys to successful operation of a college program. Although all faculty members at UW-Stout have industrial experience, the focus of a faculty member is not quite the same as someone involved in the engineering and/or business on a daily basis. Members of Program Advisory Boards provide key insights to faculty regarding program and/or course content, market/technology trends, etc. The CEE Program Advisory Board was formed in Year 1 of the program and included several on-campus members along with off-campus members from the following organizations: Microsoft Corp. (Redmond, WA); General Electric Healthcare (Madison, WI); Medtronic (Brooklyn Park, MN); RadiSys Corp. (Portland, OR); Mel Foster Co., (Eden Prairie, MN); City of Eau Claire – Office of Economic Development (Eau Claire, WI); Open Silicon Inc. (Eau Claire, WI); Hutchinson Technologies . (Eau Claire, WI); Silicon Graphics Inc., (Chippewa Falls, WI); 3M Corporation (Menomonie, WI); AREVA T&D (Seattle, WA).

- New faculty recruitment/hire

  At least two faculty members are needed to teach electrical/computer aspects to ET, PE and MFGE students. An additional faculty member was needed to join the current faculty to carry out planning and implementation of the following year's CEE courses. A nationwide search resulted in Dr. Cheng Liu joining us as a new tenure-track faculty member.

- Student recruitment

  Extensive efforts were made to 'get the word out' about the new Computer Engineering program at UW-Stout. This involved distribution of informational material in a variety of forms and meeting with prospective students and their families. Clarifying what "Computer Engineering" involves and highlighting the opportunities and challenges before them helps students determine if this is the 'right' program for them.

- Student transfers

Although the year started with no students in Computer Engineering, several students transferred into Computer Engineering from other programs on campus. The year concluded with 13 Computer Engineering students on campus.

Year 2 (2009 /2010)

We began the year by welcoming a new faculty member and our very first freshmen class! The year began with 33 eager students. Activities for the year are summarized below.

- <u>First freshmen class arrives on campus!</u>
  Our first freshmen class was composed of 20 eager students from Wisconsin and Minnesota.

- <u>First meeting of the Program Advisory Board</u>
  The first two meetings of the Program Advisory Board were held in Year 2. The majority of the members were able to come to campus and several others attended remotely. Use of conferencing software allowed on- and off-campus attendees to hear each other and follow all presentations.

- <u>Faculty continue teaching ET and MFGE courses and teach first CEE courses</u>
  Five faculty with a background in Computer / Electrical Engineering were now on campus. Planning and preparation of the new CEE courses continued while all faculty joined in the on-going effort of teaching electrical / computer aspects to students in the ET, PE and MFGE programs. In addition, CEE 205 (Circuit Analysis and Design) and CEE 225 (Digital Logic) were taught for the first time during the Spring 2010 semester.

- <u>Co-op/Internship opportunities explored through company visits</u>
  Providing real-life experience is a crucial part of a successful engineering program. To foster the development of such experiences requires the 'groundwork' of visiting companies to investigate how we might work together to forge opportunities for the students to learn about the engineering profession while contributing to company goals in a positive manner.

- <u>New equipment arrives and lab renovation begins</u>
  Additional equipment was secured and laboratory renovation began to create additional laboratory space.

- <u>Student recruitment</u>
  Extensive efforts continued to meet prospective students and their families to clarify what in the world "Computer Engineering" involves and highlighting the opportunities and challenges before them. This will be an on-going effort from here on out!

Year 3 (2010 /2011)

The year begins with 64 eager students. As we welcome the new students and the program continues to unfold, significant activities are summarized below.

- Initial laboratory renovations are completed and additional equipment arrives
  Additional laboratory space became available for CEE courses as the initial lab renovation was completed. Additional equipment was also secured.

- Several new courses taught
  The first two CEE courses (CEE 205 and CEE 225) were taught for the first time during the Spring 2010 semester. During Year 3 initial offerings were provided of several more CEE courses, including CEE 215 (Electronics), CEE 235 (Signals and Systems), CEE 325 (Digital System Design) and CEE 335 (Automatic Control Systems)

- Preparation for new courses continues
  With one year to go in our initial program, planning continued for 7 new courses that will be offered during Year 4.

- Student Branch of the IEEE formed
  According to the Institute of Electrical and Electronics Engineers (IEEE)[5]: "A Student Branch gives students the opportunity to meet and learn from fellow students, as well as faculty members and professionals in the field. An active IEEE Student Branch can be one of the most positive elements in a department offering programs in IEEE designated fields of Engineering, Computer Science and Information Technology and others… IEEE Student Branches are established at over 1,500 universities and colleges throughout the world." With the help of faculty members and students, the UW-Stout Student Branch of the IEEE was approved on August 3, 2010. The Student Branch quickly organized and elected their first officers on September 23, 2010. A quick trip to the web page (http://stoutieee.uwstout.edu/) will clearly show their many activities, including hosting several industrial speakers (from Medtronic, 3M and Microsoft); sponsoring an all-day, 3-company tour of 3M, Medtronic and Sauer Danfoss; hosting a workshop to construct multimeters; and participating in a "Meet and Greet" on the University of Minnesota campus attended by IEEE Branch members from several campuses. The UW-Stout President (Maxwell Steuer) was selected as the student representative for Region 4.

- Students participate in first co-op/internship

  Students have begun to participate in co-op/internship opportunities at the following organizations: Rockwell-Collins (Cedar Rapids, IA), Plexus Corp. (Neenah, WI), Tripler Army Medical Center (Honolulu, HI) and Marshfield Clinic (Marshfield, WI).

- Preparation for accreditation visit

  A question commonly asked by prospective students is whether the Computer Engineering program at UW-Stout is accredited. By the very nature of the ABET accreditation process, initial accreditation cannot occur until after a student graduates from the program. The first "graduation party" is planned for May 2012 – which means the first campus visit by ABET will likely occur during the Fall 2012 semester. Preparation for that visit commenced in earnest during Year 3 of the program. Faculty attended ABET workshops, student outcomes and educational objectives were defined, and rubrics were worked on. A lot of work still needs to be done, but faculty got a good start on the process during year 3.

- Approval received for additional faculty

  As additional CEE courses continue to roll out, it became obvious that at least one additional CEE faculty is needed to provide proper training to students in the four programs: ET, PE, MFGE and CEE. Faculty recruitment will be carried out in Year 4.

- Program Advisory Board becomes more actively involved

  During one of the Program Advisory Board meetings, the board members expressed the desire to become more actively involved in several areas of the program including the selection of curriculum content and mode of instruction, creative ways of providing training / information in topics / areas beyond the scope of what can be discussed in class and in fostering university / industry partnerships. This is good news!

Anticipated Summary of Year 4 (2011 /2012)

During the present school year we anticipate completion of the first 'round' of activities for the Computer Engineering program at UW-Stout. The year will begin with approximately 100 students and should conclude with our first commencement activities. As we look forward to this year, we anticipate a number of exciting events including the following.

- Several new courses taught

  The final set of new CEE courses will be offered this year, including CEE 345 (Microprocessors), CEE 355 (Applied Electromagnetics), CEE 405 /410 (Senior Design I/II), CEE 425 (Data Communications and Computer Networking), CEE 435 (Digital Signal Processing) and CEE 445 (Embedded Systems). It will be a very busy year!

- Growing involvement in IEEE Student Branch

The UW-Stout IEEE Branch got off to a great start during Year 3 of the program and has planned a whole slate of activities for Year 4. In addition to sponsoring several speakers and multiple company tours, student members will be providing tutoring to other CEE students, as well as the opportunity for CEE study groups.

- Growing involvement in co-op/internship program
  The number of companies expressing interest in UW-Stout CEE students continues to grow and will spur additional student involvement.

- Request for accreditation visit and completion of ABET self-study
  The groundwork was laid in Year 3 for our accreditation request to ABET. An on-campus visit is anticipated during the 2012 Fall semester, which means that the extensive self-study will be submitted at the end of this school year. A lot of work will be done this year!

- Recruitment of another faculty member
  A nationwide search for an additional faculty member will be conducted during the Fall 2011 semester with hopes of having another faculty on campus for the Spring 2012 semester.

- First Commencement for Computer Engineering students
  Our first commencement exercise is anticipated for May 2012. We will celebrate! The fruit of our hard work is beginning to show forth!

Challenges and Rewards

In previous sections attempts have been made to describe the elements of what was involved in the establishment of a new Computer Engineering program at UW-Stout. To round out the picture of what is involved in this undertaking specific challenges will also be highlighted. Some of these challenges are common to both new and existing engineering programs while others are unique to new programs. First and foremost, it is noted that initiating and launching a new program is an intense undertaking and requires a very strong commitment – by the institution itself; the faculty members launching the program; the industrial partners working with the faculty and students; and the students themselves. This commitment involves extensive financial resources – not only for faculty and staff salaries, but also for new equipment and laboratory renovation, training, travel to companies, and a whole host of other expenses. In addition, there needs to be allocation of adequate time and financial resources to plan and prepare the extensive documentation needed to promote the program and to guide prospective and current students; adequate time allocated for faculty and/or staff to meet with prospective students and their families and visit regional schools; adequate time to plan, prepare and launch new classes and other activities; allocation of adequate space for laboratory facilities, faculty offices and classrooms; allocation for time and resources to plan and prepare for ABET accreditation (which should include the appointment of a specific person to be the ABET coordinator who will work with faculty and staff to prepare the extensive documentation needed for accreditation); time and resources to encourage the growth of student professional organizations; adequate time and financial resources to visit regional companies to foster relationships that will be mutually beneficial to students and company; and adequate time, financial resources and staff to plan and conduct meaningful meetings with the Program Advisory Board and similar organizations.

In addition to resource challenges (of time, money, space, etc.) for the new program it should also be noted that launching a new engineering program also can greatly increase other resource needs on campus. For instance, the course load in supporting classes (e.g., mathematics, computer science, physics, chemistry, English, etc.) will go up; adequate space is needed in dormitories and food service options, etc. The list goes on and on. It should also be noted that programs like Computer Engineering have additional challenges in the form of decisions about what direction certain courses should take. For instance, one of the challenges faced at UW-Stout is to decide what platform should be used for the embedded systems courses. In general 'embedded systems' can be developed based on processor-centric systems, FPGA (field programmable gate array)-centric systems, or Mixed-signal environments like those found in many embedded applications. The choice will depend largely on the industries students will likely work with. Decisions like this become very important because they dictate the type of hardware and experiment stations that are purchased. Inadvertent mistakes in these areas can be very costly.

Although launching such a program involves a great number of challenges, there are also great rewards. To be able to offer students the opportunity to attend a local / regional university and receive training in a specialized field such as computer engineering is very rewarding. To see the excitement of students launching a new professional organization – or to see the first co-op students thrilled over the things they are learning and seeing – such experiences are priceless.

Summary

Establishing a new engineering program is an extensive and expensive undertaking. In this paper an example of such an undertaking is presented by providing a thorough description of steps taken to request, prepare and launch a new Computer Engineering program at the University of Wisconsin – Stout. Details are provided regarding program / curriculum development, course and laboratory development, student and faculty recruitment and development, establishment of a Program Advisory Board, establishment of a student Branch of the IEEE, and accreditation aspects. In addition, specific challenges and rewards are highlighted.

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The Implications of ASME Vision 2030 for Mechanical Engineering Programs

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Abstract

The American Society of Mechanical Engineers (ASME) is nearing the conclusion of *Vision 2030*, a multi-year effort to define the future of mechanical engineering education. The society has surveyed over 1000 employers of mechanical engineers and involved many industry representatives in this effort to determine what important skills a mechanical engineer will need in the year 2030. The recommendations of *Vision 2030* include significant, broad changes to mechanical engineering education at the undergraduate and graduate levels. They also bring to light the dualistic nature of engineering education, with faculty and courses focused either on the practice of engineering, or on an academic research-oriented approach to engineering. This paper discusses the potential effects of the recommendations on mechanical engineering programs, including the curriculum, faculty, and reward structure. The mechanical engineering program at the University of Minnesota Duluth is analyzed as a specific example, and a plan for implementing the *Vision 2030* recommendations is presented along with a discussion of potential difficulties including limited resource availability and accreditation issues.

Introduction

The American Society of Mechanical Engineers (ASME)[1] is the lead society which provides an interface between employers who hire mechanical engineers and academic institutions that produce them. Each year ASME sponsors the International Mechanical Engineering Education Conference to which industry representatives, mechanical engineering department heads, and engineering deans are invited. This paper is based primarily on information gathered during and after the 2011 Mechanical Engineering Education Conference.

The primary goal of the conference was to review, discuss, and revise a draft of the document *Vision 2030: Creating the Future of Mechanical Engineering Education*[2]. The document is the result of a multi-year effort to define the future of mechanical engineering education. The society surveyed over 1000 employers of mechanical engineers and involved many industry representatives in this effort to determine what important skills a mechanical engineer will need in the year 2030. The recommendations of *Vision 2030* include significant, broad changes to mechanical engineering education at the undergraduate and graduate levels that the ASME feels are necessary if future ME graduates are to meet the needs of industry and society.

Academia, unfortunately, is in a poor position to implement these recommendations. The demand for BSME programs has grown significantly over the past five years, while universities have experienced budget cuts and restrictions in resources over the same time period. This has led to a situation where many BSME programs are understaffed and are barely able (or unable) to meet the demand for courses, much less to implement significant curricular changes.

Not ready to practice

The ASME recommendations focus on producing engineers who are ready to practice engineering in the current global environment. Many employers of mechanical engineers report having developed training programs, some as long as two years after graduation, to prepare new graduate engineers to effectively practice engineering within their organizations[3]. Industry representatives at the conference repeatedly stated that BSME programs should produce "engineers who are ready to engineer.[3]" As shown in Figure 1, the vast majority of mechanical engineering graduates (including those with masters degrees) go into practice, so it follows that the educational system should emphasize the preparation of graduates for engineering practice. Some of the weaknesses observed by industry representatives in recent mechanical engineering graduates are stated below.

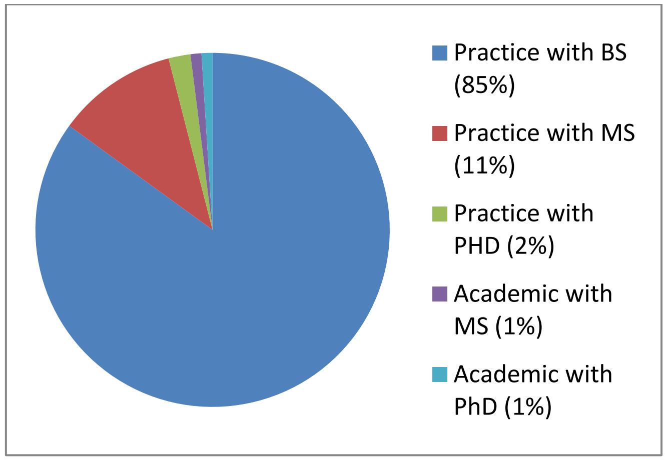

Figure 1. What do U.S. BSME Graduates do[4]?

Observations from industry[2]:

- Graduates do not reflect the current and growing diversity in the general population
- Engineering graduates lack practical, hands on experience
- Graduates are not able to formulate and solve complex, multidisciplinary, system-level real world problems.
- Graduates are not prepared to provide leadership and drive innovation at the level necessary to maintain the competitive position of the United States in the world.
- Graduates lack the professional skills (project management, business practices, communication ability, and multicultural awareness) to be effective engineers.
- Graduates do not fully appreciate the impact of engineering decisions on environmental and/or economic sustainability.

The academic perspective

Mechanical engineering educators were also heavily involved in the information-gathering process used by the Vision 2030 Task Force. The task force assembled the following statements on the weaknesses of current mechanical engineering programs based on the information gathered from this group.

Observations from academia[2]:

- The current mechanical engineering curriculum is not successfully attracting and retaining women or minorities.
- New graduates forget much of their technical education shortly after graduation, and use little of it during their professional careers.
- Many faculty members have less than five years practical engineering experience.
- Engineering faculty members are often very narrowly focused on their areas of specialization and tend to emphasize technical depth in their courses.
- Most BSME programs appear to be preparing students for graduate school and research-oriented careers rather than engineering practice, and this is out of proportion to the actual career paths chosen by graduates.
- The reward structure in academia heavily favors research-oriented faculty over practice-oriented faculty.

Vision 2030 Recommendations

Based on the information gathered over a two-year period from industry, academia, practitioners, and other stakeholders in the mechanical engineering profession, the Vision 2030 Task Force formulated the following recommendations for mechanical engineering academic programs.

ASME Vision 2030 recommendations for undergraduate degree programs[2]:

1. Should contain the same number of semester credits (120-128) as current degrees
2. Engineering fundamentals must be retained
3. A learner-driven degree with considerable curricular flexibility
    a. Pre-defined tracks (design, manufacturing, research, etc.)
    b. Many electives to allow students to "pursue their passion"
4. More practical content
    a. More hands-on experiences (how things work, how they are made)
    b. More design content, preferably distributed throughout the curriculum (a design spine)
    c. Emphasis on formulating and solving practical (big picture, multidisciplinary, systems level) engineering problems
5. Less technical content and more professional skills
    a. Innovation and creativity
    b. Communication
    c. Leadership
    d. Ethics
    e. Sustainability
    f. Business and economics

ASME recommendations for graduate degree programs[2]:

1. A stand-alone professional masters degree focused on providing more technical depth for practicing engineers (M. Eng.)
2. A Master of Science/Ph.D. track for research emphasis

Analysis

The recommendations for changes to mechanical engineering education are certainly worthy and are clearly based on the needs of industry. Each recommendation, however, presents some difficulty in implementation, especially in these times of shrinking budgets and severely limited resources.

The implementation challenges facing each recommendation for undergraduate programs are discussed below.

1. Should contain the same number of semester credits (120-128) as current degrees

   This simply means that for everything that is added, something must be taken away. This is an age-old problem faced by mechanical engineering programs which were first reduced from five years to four, and then asked to include additional content as the field of mechanical engineering continued to evolve. New materials, techniques, and analysis tools are added each year to an already crowded curriculum. To implement the recommended changes within the 128 credit limit would be very challenging, especially in the face of accreditation constraints.

2. Engineering fundamentals must be retained

   What is the definition of "engineering fundamentals?" Any mechanical engineering faculty will have difficulty making the distinction between fundamental and non-fundamental courses, with definitions of engineering fundamentals ranging from basic math and science courses to third-year courses in fluid mechanics and thermodynamics. More guidance is needed here. Does this mean graduates must be able to pass the current FE exam?

3. A learner-driven degree with considerable curricular flexibility

   Industry seems to have a vision of college students as passionately pursuing their goal of gathering as much knowledge as possible in their area of interest. Although this is accurate in some cases, most college students are undecided as to what they want to study, and are rather short-sighted. Many students are likely to take the easiest or most convenient route through a degree program rather than "pursuing their passion" for mechanical engineering. Leaving too much choice up to the student is dangerous. Well-designed, coherent tracks seem to be a better option than just a large basket of elective courses.

4. More practical content

   Providing practical hands-on experiences, active discovery-based learning, and realistic problem-solving and design experiences are admirable goals, but very resource intensive. Such activities require small class sizes and increased numbers and skills in the faculty. They also require a great deal of space and equipment to be realistic. Many BSME programs have reduced their hands-on experiences, laboratories, and design options simply to save resources.

5. Less technical content and more professional skills

   Many BSME program faculties lack the talent or resources to teach topics outside of the core of mechanical engineering, like multi-disciplinary approaches to problem solving, innovation, communication skills, and professional skills. Removing technical content may also threaten program accreditation.

The implementation challenges facing the recommendations for graduate programs are discussed below.

1. A stand-alone professional masters degree focused on providing more technical depth for practicing engineers (M. Eng.)

   This is offered by some universities, but it usually amounts to a "coursework only" version of an M.S. degree. Professional Masters students often select courses from the same pool as M.S. students, and those courses are taught by faculty members with a strong research emphasis, not a practice orientation.

2. A Master of Science/Ph.D. track for research emphasis

   This track seems to be acceptable as it is, and that is no surprise since the vast majority of mechanical engineering educators (the "content providers") followed this same track.

The situation at the University of Minnesota Duluth

As is the case with many ME programs, the Department of Mechanical and Industrial Engineering (MIE) at the University of Minnesota Duluth (UMD) has been operating in an environment where the number of students is growing and the resources (space, equipment funding, faculty, and staffing levels) are staying the same or shrinking. Despite this, the department is better equipped than most to implement the changes recommended by *Vision 2030*.

The department has significant laboratory space and equipment to support hands-on activities, and the BSME program at UMD lists hands-on orientation as one of its strengths. Many students have cited this strength as their reason for choosing UMD. Laboratories must be run by faculty and maintained by staff members, however, and the limited resources experienced in recent years have forced the department to limit the number of laboratory course offerings. Laboratories that used to be taught separately have been combined to reduce the demand on faculty, and this has resulted in a reduction in the number of lab activities for students.

The department has also been very pro-active in providing students with real-world engineering experiences. Our senior design capstone course continues to execute projects with many client companies, and those companies have hired many of our graduates. Many students also take advantage of coop and internship opportunities which have grown in recent years. The reward system at UMD, however, heavily favors research-oriented faculty over practice oriented faculty, and the department needs more practice oriented faculty if we are to continue to provide real-world, practice oriented engineering education. Other universities have implemented a 'Professor of Practice" title in order to address this situation[5].

The MIE department is also better equipped to deliver education in professional skills than most other mechanical engineering departments. Because the department faculty also supports degree programs in Industrial Engineering, Environmental Health and Safety, and Engineering Management, they have the skills necessary to deliver this content. The department recently proposed, with the Department of Civil Engineering, to offer an undergraduate minor in Engineering Management with a strong emphasis on engineering practice and professional skills. This seems likely to offer our students exactly what industry is looking for in engineering graduates.

When it comes to graduate education the department has offered a M.S. degree in Engineering Management and a Master of Environmental Health and Safety for over ten years, and now supports the M. Eng. degree offered by the Swenson College of Science and Engineering. All of these degree programs offer significant practice-oriented content, and additional technical depth, to engineering graduate students. These offerings also seem to be directly in line with the needs of industry.

Conclusions and recommendations

The recommendations put forth by the American Society of Mechanical Engineers in *Vision 2030* are worthy goals for mechanical engineering programs to pursue. Although the current draft form of the document needs some further definition and explanation, it clearly reflects the expected needs of industry over the next 20 years. Although the MIE department at UMD is better equipped than many ME departments to address these recommendations, meeting these goals by 2030 will require a significant increase in the resources available to the department. It will also require the department to emphasize the practice of engineering side-by-side with engineering research. To this end it is recommended that UMD create a Professor of Practice track for practice-oriented faculty members similar to the tenure track now available to research-oriented faculty members.

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Mind Trekkers Science and Engineering Festivals:
Inspiring K-12 students to explore STEM

Stephen Patchin, Cody Kangas, and Jamie Lindquist
Michigan Technological University

The Challenge

On May 5, 2010 the National Science Board published a report titled "Preparing the Next Generation of STEM Innovators: Identifying and Developing Our Nation's Human Capital." Sponsored by the National Science Foundation, this report "presented recommendations on how to support the identification and development of talented young men and women who have the potential to become our Country's next generation of science, technology, engineering, and mathematics (STEM) innovators."[1]

The report produced three keystone recommendations. First was to provide opportunities for excellence. The focus of this effort will be inspire and develop each students' abilities in the areas of STEM, both with formal and informal methods. The Board's recommendation under this point included "leverage NSF's *Broader Impacts Criterion* to encourage large-scale, sustained partnerships among higher education institutions, museums, industry, content developers and providers, research laboratories and centers, and elementary, middle, and high schools to deploy the Nation's science assets in ways that engage tomorrow's STEM innovators."[2]

Another key recommendation was to cast a wide net, working with multiple grade levels and demographics. Providing opportunities for students to realize their potential and for educators to aid them in identifying their aptitudes is the foundation of this component. The final component is fostering a supportive ecosystem. A culture must be created that celebrates achievement and innovative thinking. A cornerstone of this is "creating a national campaign aimed at increasing the appreciation of academic excellence and transforming stereotypes towards potential STEM innovators."[3]

With the support of the National Science Foundation, the National Research Council explored successful approaches to STEM education in K-12 schools. Their findings were published in a report titled "Successful K-12 STEM Education: Identifying Effective Approaches to Science, Technology, Engineering, and Mathematics." The report stated that "effective instruction capitalizes on student's early interest and experiences, identifies and builds on what they know, and provides them with experiences to engage them in the practices of science and sustain their interest."[4]

Teachers use scaffolding to build the knowledge base that acts as a springboard to a broader understanding of science and engineering. The more inspirational and impactful

[1] National Science Board. Preparing the Next Generation of STEM Innovators: Indentifying and Developing Our Nation's Human Capital (NSD-10-33), v.
[2] Ibid, p 2.
[3] Ibid, p 3.
[4] National Research Council. Successful K-12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics (ISBN-13: 978-0-309-21296-0), p 18.

experiences that a student can experience, comprehend, and retain, the greater number of synaptic channels are available for innovative and in-depth reasoning to occur.

International Efforts

On February 16 and 17, 2011, the International Public Science Events Conference was conducted in Washington D.C. Sponsored by the National Science Foundation its purpose was to share efforts being initiated across the globe to actively engage students, families, and communities to explore STEM fields of study through participatory learning. The conference highlighted the use of science and engineering festivals in embedding the importance and excitement of STEM education in each nation's culture.

Masataka Watanabe of Japan's governmental Science & Technology Agency presented on his country's efforts which included the National Science and Technology Week that takes place in mid April. Implemented in 1960, communities and schools are required to conduct activities celebrating the wonders of science and technology that week. In 1992 they established the Youngsters Science Festival which is attended by over 420,000 students annually in over 100 cities. The events consist of science shows, exhibitors, and workshops.

The European Science Events Association was founded in 2001. The association consists of 100 members from 37 countries, each hosting science related events or festivals annually that are from one weekend to one month in duration. Cost to conduct these events ranges from 10,000 to one million Euros. Smaller events can center around programs like the Exhibition Ship, a mobile science center that travels the inland waterways of Europe.

Ren Fujun is the Director of the General of China Research Institute for Science Popularization. The government controlled agency's mission includes: raise youth awareness of scientific outlook, improve education, extend the reach of compulsory education including in rural areas, extracurricular science and technology activities, organize instruction between science and technology professionals, and coordinate out-of-school science and technology activities. Their National Science and Technology Week, annually sponsored by industry, consists of science and technology festivals in both rural and urban locations. Surveys conducted by the Institute showed the 68% of those attending sponsored S & T events were more interested in science and technology after they attended the event. To effectively reach rural areas of China with these informal science education programs, the Institute has worked with museums in China to construct 'Science Wagons', bringing the hands-on learning to areas with little available educational resources.

Alaa Ibrahim, educated in the U.S., returned to his home of Egypt and founded the Cairo Science Festival. The event consists of activities such as: dialogues with scientists, lunch with a Nobel Laureate, star gazing, open houses at universities, and Science Cafes that allowed discussions between the community and research scientists on specific topics in an informal setting. Countries around the world are turning to major events to educate and inspire students and their families about the importance and excitement of STEM fields of study. These sustained events are constructed to create a culture that: places a high value on success in STEM courses, ignites a passion for learning in STEM areas through hands-on discover-based events, encourages regular communication between STEM professionals and community members and their families, brings STEM education outside the classroom and school day hours, and celebrates informal learning and innovation.

Meeting the Challenge

In 2004 Michigan Technological University conducted its first annual YES! (Youth Engineering and Science) Expo at Chrysler Arena in Ann Arbor, Michigan. This STEM career awareness event brought together industry, institutions of higher education, and government to participate in the event. The goal: inspire middle and high school students to explore education and careers in engineering and science. The program moved to Ford Field in Detroit with K-12 attendance growing from 5,000 students in 2004 to over 15,000 in 2008.

YES! Expo event format focused on two elements. Corporations, universities, and other organizations hosted exhibits staffed by their representatives allowing students to explore both academic opportunities and their associated careers. The second element was based on an engaging educational programming platform highlighting technology, education, and careers. The Expo brought together 60 companies, 25 universities/colleges, the State of Michigan, professional societies, and community organizations. Post event surveys were conducted after the 2006 and 2007 events. Below are the results of the 2007 survey, which correlated with the results of the 2006 surveys.[5]

Statement: My participation in YES! Expo…..	Srongly Disagree	Disagree	Agree	Strongly Agree
led me to a better understanding of my career goals	4.10%	14.10%	37.60%	44.20%
made me think more about my continuing education after graduating from High School	2.60%	5.00%	28.10%	64.30%
increased my interest in studying engineering in college	6.90%	18.20%	41.60%	33.30%
increased my interest in studying science in college	5.90%	17.50%	45.40%	31.20%
caused me to decide to take different class in high school than I planned to take	10.20%	30.50%	32.30%	27.00%

[5] Amato-Henderson, S., Cattelino, P., Lehman, J. (2008). Outreach to Prospective Engineering Students: Michigan Technological University's YES! Expo. *International Journal of Engineering Education*, Siri T61.15.

made me decide to work harder in school	4.10%	13.60%	34.20%	48.10%
gave me a much better understanding of what engineers do	3.20%	8.50%	41.80%	46.50%

Table 1

YES! Expo had a positive effect on student's opinion of and interest in pursuing science and engineering curriculum and careers.

Mind Trekkers Science and Engineering Festivals

The AT&T Mind Trekkers Science and Engineering Festival took place over four days. At each location Mind Trekkers tried to partner with local institutions of higher education. The purpose was two-fold. First, these institutions had established networks with educators in the area. Second, the ancillary goal of these Festivals was to create or expand a relationship between the educators/students in the area and the higher education institution. The Festival would help cultivate these relationships, allowing further supporting programming to develop.

Date	Location	Partner	# of participants
3-May	Traverse City, Michigan	Traverse Bay Area ISD*	1,400
4-May	Sault Ste. Marie, Michigan	Lake Superior State University	1,500
5-May	Escanaba, Michigan	Bay College	800

6-May	Iron Mountain, Michigan	Bay College	1,200

*The original higher education partner was Northwestern Michigan College. NMC struggled to find space to host the event since it was conducting final exams the week of the event. A decision was made by Mind Trekkers to move the host site to the Traverse Bay Area Intermediate School Districts Career and Tech Center.

The AT&T Mind Trekkers Science and Engineering Festivals had three components. The first component was the hands-on activities related to STEM fields. These activities were 30 seconds to 3 minutes in length, allowing students to engage in many activities during a fairly short period of time. These activities were identified as having a WOW! factor, or a component that defied traditional logic. These activities were conducted by undergraduate/graduate students at Michigan Tech. These students were energetic role models for the young grade 4 – 12 participants.

The second component of the event was local businesses from the areas from which the events took place. These businesses brought displays, story boards, products, and in many cases hands-on activities. The business displays were staffed by STEM related professionals working in the organization who were able to share: what kind of activities they perform on a daily basis, what was their education experience like, how do they balance family and work life, what do they like most and least about their jobs, and even what they enjoy doing during their personal time. Potential first generation college students have exhibited interest in careers that would allow them to live in or close to the communities they were raised in.

The final component included in the festivals was representatives from post-secondary education institutions. College and university representatives provided students with a wide range of information including: what students courses needed to take to prepare for college, what kinds of students courses would need to take to complete degrees they were interested in, what degrees each institution offered, and information about costs and financial aid.

Informal surveys were mailed to the teachers of the classes that attended the Mind Trekkers events. These surveys were completed approximately three weeks after the events were conducted. The table below provides the results of these surveys.

Survey Question	Yes	No
Did attending the Mind Trekkers Festival make you interested in attending college?	82.70%	17.30%
Are you more interested in Engineering now than you were before the Festival?	54.60%	45.40%

Are you more interested in Technology now the you were before attending the Festival?	70%	30%
Are your more interested in Mathematics than before you were before attending the Festival?	39.80%	60.20%

Impact of the Mind Trekkers program can be summed up by a letter from Rhonda, a Biology Instructor at Iron Mountain High School in Michigan:

> "Since we live in such a rural area, many of my students have not had the chance to experience science activities outside the realm of the classroom. To me, the event felt like a traveling hands-on science museum. It was exciting to see my students engaged in science, math, and technology activities that they would not normally be exposed to."

Michigan Tech students that are the event staff for the Mind Trekkers program have now created a student organization on campus titled Mind Trekkers. The goal of this student organization is to recruit students that are interested in helping expand the program. Numbering over 300 students in the first 6 months of its existence, members play a vital component as role models, activity developers, and event staff.

Members are helping to develop an outreach training program for current and future membership which includes the Michigan Campus Compact College Positive program. Students are taught words and phrases to use to describe college life, expectations, and formulas for academic success. As Mind Trekkers members and advisers continue to build the program they will be including presentation skills and lesson plan writing for the activities they create which will be published on the Mind Trekkers website for teachers to reference.

The Mind Trekkers program is evolving in three strategic directions. First, refine the training program for its undergraduate and graduate staff to perform high quality and impactful outreach. The students would like to expand this to other campuses, widening the scope of the outreach efforts. The second strategic initiative will be to expand the reach of Mind Trekkers. A proposal is being crafted for the National Science Foundation Informal Science Education RFI to create Mind Trekkers Science and Engineering Festivals across the northern tier states from Michigan to Washington State over the next 4 years. The focus will be working with small universities and colleges in these areas to energize rural areas with the excitement of STEM, hands-on style. The final strategic initiative will be to increase the work with foundations and corporations to support the growth of Mind Trekkers Science and Engineering Festivals. Support can come in the form of monetary donations to support the programs, furnishing STEM professionals to tell what the company does and act as role models, provide hands-on activities from their R & D labs that represent innovative research concepts that are being developed in their labs, or host events where Mind Trekkers team members from student organizations at the universities can interact with the scientists and engineers working at their companies.

Science and Engineering Festivals are being used as a tool to change the way STEM is viewed, embraced, and taught in communities around the world. Mind Trekkers is developing a pipeline of motivated K-12 students entering STEM fields of education, an army of undergraduate/graduate students learning and performing outreach to help motivate these K-12 students, and workers entering the workforce that have embraced a culture of outreach they will carry into their corporations and households. Mind Trekkers is a sustainable model that will help build the workforce of the future.

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Learning Structural Analysis in "A Building that Teaches"

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Abstract

The Swenson Civil Engineering Building, opened in 2010, was constructed with the goal of providing a space in which, and from which, Civil Engineering students can learn. Multiple exposed structural systems allow students the opportunity to visualize the way in which the building is designed to carry load. The building is LEED certified. A large high-bay lab is open to view, so that class work and research is visible to students as they pass through the halls of the building.

The high bay lab features two 15-ton gantry cranes. The gantry cranes have been analyzed in the final project for Structural Analysis (CE 3115). The final project is the culmination of a semester focused on the calculation of loads and deflections in statically determinate and statically indeterminate structures, with an emphasis on beams and frames. The gantry crane project provides an opportunity for students to apply several concepts learned in the text and in lecture. They are required to idealize the three dimensional structure as a two-dimensional structure with support reactions and appropriate connections between the structural members. The students are then asked to solve for the support reaction forces and moments using methods of structural analysis. Students learn to use structural analysis software to check the accuracy of their hand calculations, and to provide further results. Overall, the project is an in-depth analysis of this structural system.

The project is enhanced by the fact that the gantry crane is on site, in the Civil Engineering building, and can be seen in active use as part of other projects. The fact that the crane is a tangible structure, central to the workspace of the department, engages the interest of the students. The crane project represents one aspect of using the newly constructed Civil Engineering building as a "teachable space."

Introduction

Structural Analysis (CE 3115) is a core course required of all Civil Engineering majors with a focus area Structural Engineering. It is a three credit, junior level course, meeting for 50 minutes three times per week. The course is organized with an average of one graded problem set per week, two midterms, a final project and a final exam.

The Structural Analysis course, and specifically the final project for the course, is designed to develop in students the ability to apply knowledge of mathematics, science and engineering, the ability to communicate effectively, and the ability to use the techniques, skills and modern engineering tools necessary for engineering practice.

Topics covered in the Structural Analysis course that are incorporated in the final project assignment include shear and moment diagrams, influence lines, and methods for calculating support reactions for statically indeterminate structures. Additionally, the final project includes an introduction to the modeling software RISA 2D[1]. Modeling software is a modern tool necessary for engineering practice, and one of the goals of the Structural Analysis course is to provide students with an introduction to software that will serve them well in practice, and also in preparation for additional courses such as Finite Element Methods. The students worked in groups of three to create the final project report. This allowed for group discussion of the solutions to each phase of the project, and provided students with an opportunity to develop the skills necessary to work as part of a team.

Gantry Crane Structure

The Swenson Civil Engineering Building opened for use in the fall of 2010, and is a LEED certified building designed with an emphasis on sustainable use. A notable element of the high bay lab area, shown in Figure 1, is the 15 ton gantry crane. This crane is located on a structural strong floor, and is used in research projects, materials testing and teaching.

A schematic drawing, taken from the preliminary construction drawings for the building project, is shown in Figure 2. Although there are many exposed structural elements in the building to choose from, the gantry crane is a "stand-alone" structure, not connected to other structural elements except for the floor supports. The floor support reactions are calculated as part of the project. The statically indeterminate frame is a commonly analyzed type of structure in the course, which also makes the crane an appealing subject for further examination by the students.

Figure 1: 15 ton gantry crane located in the high bay lab of the Civil Engineering building

[1] RISA 2D, educational version, http://www.risa.com/products.html

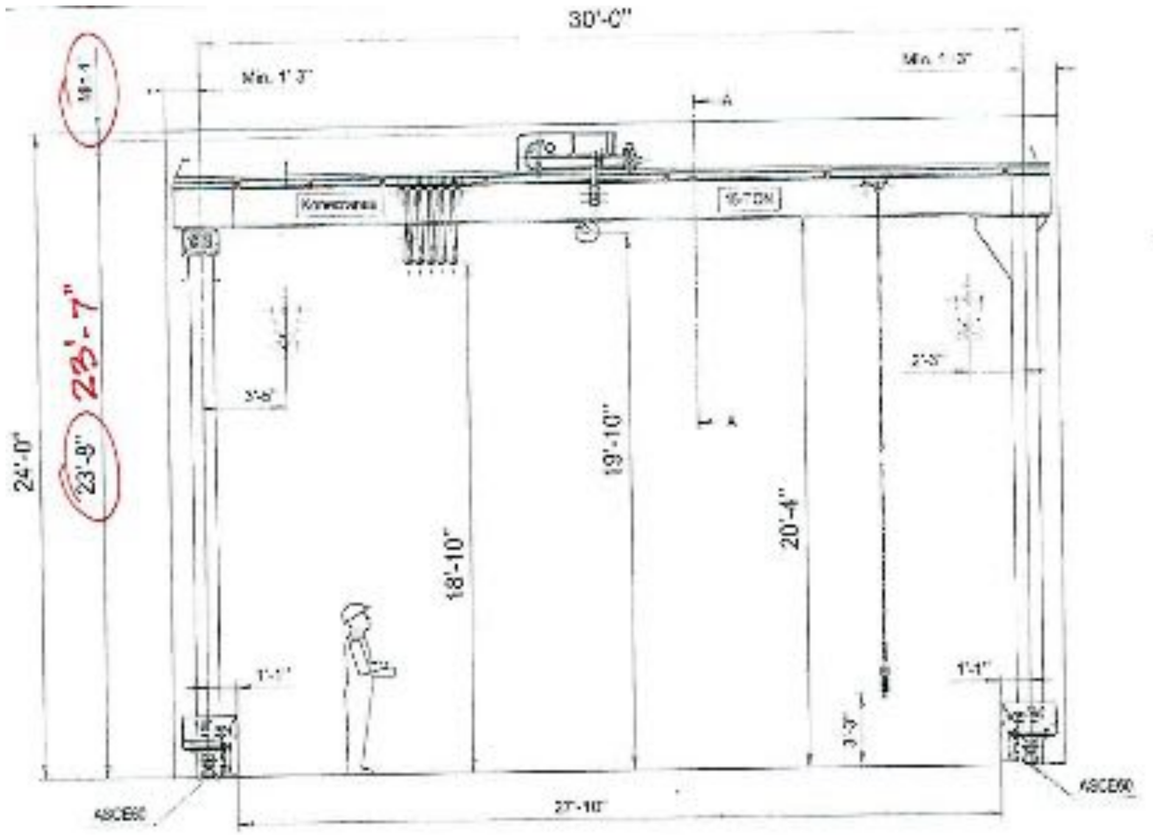

Figure 2: Schematic drawing showing the preliminary design for the gantry crane, including dimensions.

Gantry Crane Project Assignment

The first task of the project was to create an idealization of the structure. Students were asked to represent the three-dimensional structure as two-dimensional. They were asked to make assumptions about loading, supports and connections that would simplify the structure so that it would resemble a 2D frame such as those appearing in the course text[2]. This first step of the analysis procedure highlights the challenges involved in analyzing actual structures, rather than textbook examples. The students were encouraged to apply their knowledge of structural engineering to make observations about the design of the structure. For example, the fixed connection on one side of the crane bridge allows the structure to carry moment in that connection, and it can be readily observed that the structure is designed to have a greater cross section in the region where it carries this moment. An initial class discussion was held to reinforce these ideas, and to make sure the idealization of the structure was correct, prior to the students beginning the next phase of the project.

The students were asked to use the force method of analysis and the displacement method

[2] Hibbeler, R.C. "Structural Analysis," 7th ed., Prentice Hall, 2008.

of analysis, two topics studied extensively earlier in the semester, to quantify the behavior of the structure under load. These quantities include support reactions and shear and moment diagrams. The students were required to submit a professional quality report, including a verification of their hand calculations using the modeling software RISA.

In order to familiarize the students with RISA, a lecture was devoted to the use of the software, its applications, and the prevalent use of RISA and similar computer programs to solve engineering problems. The utility of the computational approach was underscored when the students were able to compare the relative ease of application with that of their own hand calculations. A sample of the output generated by the RISA software is shown in Figure 3.

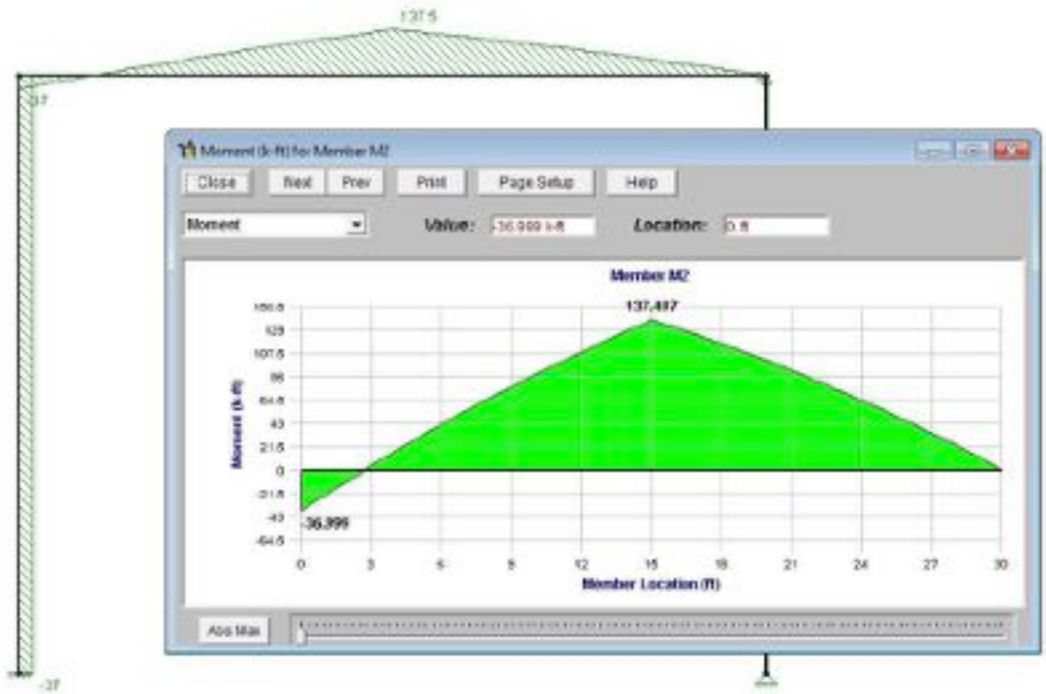

Figure 3: RISA generated moment diagram showing the moments generated when the crane is loaded with 15 tons at midspan.

The final part of the project involved the construction of influence lines. This topic was covered extensively in lecture and was found to be conceptually challenging for many students, particularly the concept of qualitative influence lines. It has been shown that the qualitative influence line may be scaled by a scale factor to recover a true influence line for the structure. Students were asked to use RISA software to develop a quantitative influence line and determine the scale factor, then plot the actual influence line using this data.

Evaluation

Grades were assigned by taking into account the objectives of the project. The students were to apply knowledge of mathematics, science and engineering; accuracy of the results was emphasized. This emphasis was particularly placed on conceptual understanding; for example checking that the correct signs appeared on the moment diagrams denoting tension and compression, and that the statically indeterminate structure (unlike a determinate structure) was associated with nonlinear moment diagrams.

The student's ability to communicate effectively was also evaluated; each report was evaluated for clarity, organization and effective presentation. Students were evaluated on their ability to use the techniques, skills and modern engineering tools necessary for engineering practice. They are expected to be able to perform both hand calculations and also be proficient at using software to evaluate the behavior of a structure under load.

The mean score on the project was an 88.4%. In general, the students performed well on the hand calculations and showed an understanding of the use of RISA modeling software. The part of the project that required calculation of actual influence lines based on qualitative influence lines was the most challenging, and many students performed incorrect calculations.

Conclusions

The fall semester of 2010 was the first semester in which this project was assigned. The project is considered successful; students were able to apply their knowledge of structural analysis to a hands-on problem. The goal for future semesters is to improve the effectiveness of the project as a tool for helping students to integrate knowledge from different topics presented in the Structural Analysis course. To this end, several revisions to the assignment are under consideration. First, the in-class RISA tutorial will be improved through use of the 3D RISA modeling software available to students in the computer lab. In the previous project, 2D RISA software was used. Though the 2D software is more straightforward for a 2D structure, the use of 3D software will better prepare students to perform 3D analysis in other courses in the structural engineering focus area.

Though most of the project topics were clearly understood by the students, further clarification is required in the portion of the project calling for the construction of influence lines based on qualitative influence lines. Further explanation in lecture is required to allow students to understand the procedure fully. It may be useful to approach influence lines by direct calculation prior to construction using qualitative influence lines.

The gantry crane project was beneficial in helping the students integrate different topics in the course that can be applied to the analysis of a single structure. The calculation of support reactions, and moment and shear internal loads has a clear relation to the design parameters for the structure and its supports. If the project is to be extended, the calculation of stresses may be performed and the crane may be evaluated from a design perspective.

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