Session 1653

A paradigm shift in the approach to freshman engineering education

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Abstract

The first engineering course taken by entering freshmen offers an opportunity to lay the foundation for forthcoming years. At Vanderbilt University, this first course is an introduction to computing in engineering. The focus of this skills-based course, required of all freshmen engineers, has traditionally been to instruct students on how to use various computing tools in engineering. While this strategy was extremely relevant a few years ago with emergent computing hardware, current freshmen are typically computer literate, with increasing knowledge on applicable tools such as Excel and programming. Thus, to accommodate the needs of today's undergraduate and to enhance the freshmen experience in engineering, this introductory engineering course is undergoing a paradigm shift towards challenge-based learning and problem-solving approaches. This new paradigm is currently being implemented in four sections of this course, with the remaining six sections serving as control.

The focus of the new paradigm is the approach to and process of engineering problem solving with and without the aid of computing tools. Students are presented with different types of discipline-specific engineering problems in each of the modules. Student progress is evaluated on the basis of the problem solving process rather than end-result. It should be noted that it is essential for engineering students to not just solve problems, but to solve problems efficiently. Thus in some cases, identical problems are presented across modules so the student can assimilate the appropriateness and thus selection of the tool for a given problem.

A survey and a pre-course content-based assessment were given at the start and end of the semester to both control and test sections. A sub-set of problems was used across both the control and test sections as homework problems for comparison of the two approaches.

Introduction

In the past decade, the use of computers has exploded in all facets of life including education. With the increasing use of computing tools in engineering and engineering problem solving, many schools introduced engineering within the context of learning these computing tools for future learning. Thus, in many cases the first engineering course taken by students, typically in their freshman year, is an introductory course in various computing tools (software packages) useful in engineering education. These courses include an introduction to computers, networking, the internet, and skills training for applications that range from word processing to spreadsheets to mathematical tools such as Matlab. While such a course was appropriate in the past, the current crop of entering freshman is increasingly savvy about the use of computers, the network and the Internet. Almost every student uses e-mail on a regular basis and has used word-processing software for writing reports. In addition, there is an increasing cohort of students who have used basic spreadsheet functions and have basic programming skills.

This change in the baseline of the entering freshman points to a need for a paradigm shift in the engineering curriculum especially for the freshman student. Engineering problem solving and design are the cornerstones of engineering education that form an appropriate introduction to engineering. On the other hand using computing tools such as spreadsheets and mathematical packages to solve engineering problems is still very relevant in today's world. Recent pedagogical advances indicate the learning is enhanced when situated in the context of real world problems leading to problem-based or challenge-based learning (Bransford, 2000). Thus, combining all of these ideas, an introductory engineering course was developed and implemented using challenge-based instruction at Vanderbilt University.

The focus of the course was changed from a skills level course, which was directed toward educating students on how to use various computing tools to solve engineering problems, to educating students on how to solve engineering problems with the aid of various tools including computers. Students were thus presented with different types of real world engineering problems from all disciplines within engineering and learned the basic principles of problem solving in the context of these problems. In addition, engineering design was incorporated in the form of a semester long design project performed under the guidance of specific faculty within an engineering discipline.

Thus, a paradigm shift in the introduction of engineering to freshman is presented bringing time-honored traditions of engineering problem solving to intersect with modern computing tools in the environment of challenge based learning; the aim is to provide students with a foundation for subsequent semesters in their engineering education toward life-long learning. The paper present the various aspects in the implementation of the new paradigm and presents some preliminary assessment results that indicate the promise of this methodology.

Problem Based Learning

Many researchers use problem oriented situations to facilitate learning (1-3) because it encourages the use of powerful cognitive skills necessary for life long learning. These ideas originate from theories like situated cognition that emphasize how problem contexts help individuals appreciate the utility of knowledge and how concepts interrelate (e.g., see reference 4). These theories also emphasize the need for learners to take an active role in transforming new information into useful knowledge that they can apply to new situations. Several methods of instruction based on these theories include problem-based learning in medicine (3) and law (5), and case-based reasoning (6). These approaches give students authentic situations to explore course content while simultaneously allowing them to practicing important cognitive skills that will help them during their profession. Typically, instruction begins with presenting meaningful problems to students who then decompose the problem and search for relevant information. A knowledgeable coach provides assistance at various times to guide learners through the process. These ideas have been extended from these professional schools to middle school classrooms using anchored instruction (1), case-base reasoning, and project-based learning (7). The complexity of these challenges, combined with the novice learners, makes it difficult to mediate students' learning to ensure everyone in the class is learning. These situated approaches to learning attempt to engage students in meaningful research for important information in pursuit of helping them construct their own knowledge. Computer technology provides an additional mechanism to help teachers with the instructional process necessary to sustain a generative learning environment in a classroom.

Learning Objectives for the First-Year Course

In order to meet the needs of today's freshmen, a paradigm shift based on engineering design and problem solving is being considered for the freshmen year. It is believed that a focus on defining various types of problems and the problem solving process will provide a better foundation for an engineering education than a course that focuses on how to use computing tools to solve problems. The main difference between the modalities is in the way content is presented. In order to compare the two paradigms, certain assessment tools were developed and implemented which include pre-course and post-course assessments and surveys.

In defining this new approach to freshman engineering, the authors established a "wish list" of what an ideal first-year engineering student should be able to do well in order to advance to the next level of education. The list below is the result of that discussion.

By the end of the first semester of the freshman year, engineering students will be able to:

1. Employ the engineering problem solving process to solve basic engineering design and analysis problems.
2. Solve basic analytical problems using engineering software tools, and be proficient and efficient in the use of computing instruments.
3. Work more effectively in small groups as a result of further developed group problem solving skills.
4. Complete the design problem solving process from experience with a semester-long, discipline-specific design project.
5. Begin building professional relationships with faculty members within the student's chosen department.
6. Resolve basic engineering and professional ethical problems.
7. Make an informed decision on an engineering major based on exposure to various fields of engineering from active representatives in those fields.
8. Utilize the common solid foundation to logically lead into the introductory major-specific courses.

With this wish list in mind, a series of tools were developed to address each of the objectives. This is our first major move toward a more comprehensive and integrated freshman year in recent years. These tools took the form of the following:

- *Modules* that illustrate the different types of engineering problems that can be solved and exercises designed to develop problem-solving skills. These modules began with simply identifying the different types of problems that exist in engineering (design, analysis, and troubleshooting). As knowledge and skills improved, problem solving tools including engineering paper were introduced and problem sets assigned in order to gain practice using those tools. Philosophies of setting up problems, following a formal design process, applying theories to problems, and diagramming were incorporated.

- *Modules* that utilize widely used engineering computing instruments such as Excel, MATLAB, technical writing techniques, web development tools. Since computing is a fundamental function in modern engineering, we cannot deny students the knowledge of widely used computing tools. Engineering problem sets were created for weekly assignments demonstrating high-level computing tools (i.e. Solver, Goal Seek, Maple) within Excel and Matlab. These problem sets were presented in the context of real life problems in the various engineering disciplines as an initial exposure to the vocabulary and problem statements within each field.

- *Modules* that demonstrate an integration of math and science principles into engineering problems. Overlaying across all modules is the idea of integrating math and science to illustrate the usefulness of those concepts in engineering applications. Keeping track of the Calculus I and General Chemistry syllabi, problems were created such that they reinforced concurrent concepts being presented in those classes. This emphasized the importance of those concepts for future use in upper-level courses in science, math, and engineering.

- *Case studies* that will be used to develop group problem-solving skills and understanding of small group dynamics. With group involvement being an increasingly important cornerstone of engineering work, several activities and assignments were developed to strengthen group skills. These ranged from two-person to five-person groups and covered all the steps of the design problem solving process. In order to gain presentation skills, each assignment required a portion of the students to present their results to the class. On average, each student made class presentations approximately 2-3 times over the course of the semester. In addition to these requirements, each instructor varied the conditions of how the group was to interact with each other (i.e., no face-to-face communication, only communicating through drawings, over obstacles such as fall break) to vary the dynamics of the interaction.

- *Case studies and ethics debates* that instigate awareness of engineering ethics. Ethics is a key component in engineering practice; therefore, an ethics module that ended with a class-wide debate on current engineering/technology ethical issues was introduced. Ethics is forming an increasingly essential part of the engineering curriculum and exposing student to it early in their academic career helps to hone their ethical principles in better preparation for the professional world.

- *Design project* that specifically fosters awareness of major-specific engineering content and emphasizes faculty mentoring. An over-arching semester design project is essential in this framework as a means of pulling all the previous topics together. Our project format was designed to provide for major-specific projects, to be design oriented, to cover current research topics within a discipline, and to build student-faculty relationships within the students' departments. Additionally, the project served to initiate the students' professional development in issues of project and time management, writing proposals, and adapting to multiple engineering design changes.

- *Engineering panel discussions* – Participants included a practicing engineer, a faculty member, an undergraduate student, and a graduate student. The reason for having such diversity was so students can gain insight into the characteristics of the various stages and career paths within each field of engineering. The practicing engineer participants were chosen among alumni (when possible) who expressed an interest in the undergraduate experience. After brief presentations from all the participants, students asked questions of the panel. Faculty members in each department were encouraged to attend their respective panel discussion that resulted in positive dialogue between students, faculty and alumni. These panels were also open to upperclassmen that were interested in attending. Attendance to a minimum of two panels was mandatory.

New Course Implementation

Implementing a new version of an existing course poses many challenges, especially if multiple sections are taught in the same semester by multiple instructors. The need was identified that the course had outlived its full effectiveness by not having changed significantly for about five years. The course material and website has been widely considered out of date for several years. Engineering students today are entering their freshman year with a significant amount of computing experience compared to their counterparts five years ago. The problem exists that Vanderbilt University, like many other engineering schools, offers an introductory course on how to use computing tools to solve mathematical and engineering problems. However, the emphasis is on the "how to" aspect of computing rather than delving into the techniques of solving problems.

While there was a clear need for change, it was unclear if the proposed change would significantly affect student learning. Thus, the new format with an emphasis on problem solving was introduced in four of the sections ("alternate" group)while the remaining sections continued with the existing "how-to" format of the course ("control" group), both with the same course number and name. In addition to changing the mode of instruction to a problem-based approach, the order of modules was rearranged to begin the semester with formal problem solving procedures. A comparison of the two formats is shown in the table below.

Three-dimensional modeling using VRML was removed from the new format. While VRML helped lay the foundation for three dimensional geometry, VRML as a tool is not considered useful in upper level courses or in future career paths. VRML was replaced with engineering ethics and placed at the end of the semester. By completing the primary modules for problem solving earlier in the semester, students were able to utilize these skills in their semester projects. Additionally, this allowed the semester to end on a less intense note. The differences, if any, were assessed throughout the semester in the form of surveys and assessment questionnaires.

Week	Computing-based Format	Problem-based Format
1	▪ Introduction, laptop setup, Pre-assessment	▪ Introduction, laptop setup ▪ Pre-assessment
2	▪ Internet, WWW, Email	▪ Intro to Problem Solving Engineering Graphics
3	▪ HTML Programming ▪ PowerPoint	▪ Teambuilding ▪ Intro to Excel – statistics &
4	▪ 3-D Modeling – VRML	▪ Excel regression, solver ▪ Matrices
5	▪ Learning Styles ▪ Teambuilding	▪ Excel solver, goal seek
6	▪ Intro to Excel ▪ Curve-fitting	▪ Building problems in Excel ▪ Group Activity
7	▪ Spreadsheets ▪ Other Excel functions	▪ Intro to Matlab ▪ Graphing & curve fitting
8	▪ Intro to Matlab	▪ Mid-Term Exam ▪ Symbolic math (Maple)
9	▪ Intro to Vectors	▪ Matlab Programming
10	▪ Matlab Programming	▪ Modeling & Simulation
11	▪ Matlab & Maple ▪ Symbolic math	▪ Intro to Networks, Internet, WWW
12	▪ Modeling & Simulation exercise	▪ HTML Programming
13	▪ Project Presentation Preparation	▪ Engineering Ethics
14	▪ Project Presentations ▪ Post-Assessment	▪ Project Presentations ▪ Post-Aassessments

Website:
The course content for this introductory course has been delivered online for about seven years, a feature that has gotten much positive feedback from students and faculty; however, the content has been under severe scrutiny. Therefore, we developed a new website to be used by the four sections following the alternate format. Both web sites contain modules focusing on the major aspects of the course: problem solving, teambuilding, Excel, Matlab, networks, HTML and ethics. (The ethics module is the only completely new material being taught in the new format.) However, the design of the modules took a new approach.

Within each module, clear objectives were identified, a brief explanation of the concepts was provided, examples of problem solving techniques and actual problems were illustrated, and assignments designed to fulfill the objectives were listed. The purpose of the modules is to provide basic introductory information on the topic at hand; however, the students were forced to rely on peer collaboration and external research to gain enough knowledge to complete the assignments, thus encouraging learning outside of the classroom.

Assignments:

In the traditional format of this course, the assignments were constructed to reinforce the computing skills associated with the material. In the new format, we chose to construct assignments emphasizing analytical and design problem solving skills that involved using the computing tools covered in the modules. Thus, class discussion focused on the concepts necessary to solve the problems and some basic information about the computing. The students were responsible for figuring out how to use the tools to accomplish their goals specifically. Each module had several assignments associated with it that increased in conceptual difficulty as well as intensity of computing. Specific engineering examples were used to reinforce the problem solving process in a more "real-world" context rather than putting forth "math course"-type problems that are purely analytical. Several sample problems from the first Excel assignment are shown below.

A new sewage treatment plant in Franklin, Tennessee recently went online. The effluent (treated wastewater) is discharged into the nearby Harpeth River. The EPA is conducting an environmental impact study of the new plant. As part of the study, they're measuring the temperature of the river downstream. The text file "harpeth-temps.txt" contains the results of these measurements from a recent month. You have been asked to make the following analyses:

- **a)** Describe the data forming the population (include min, max, mean, median, mode, range, variance, standard deviation).
- **b)** Create a random set of three sample populations containing 10, 20 and 50 data points respectively. Describe the statistics of the sample for each. Use Excel for random selection of the sample data set.
- **c)** What is the percentage error for each sample mean and variance in comparison to the population?
- **d)** Plot histogram for the population and each of the sample data sets and compare their distribution.
- **e)** If you were to submit your findings to the EPA, which set of data would you use for your calculations?

An environmental engineer has obtained bacteria culture from a municipal water sample and allowed the bacteria to grow within a Petri dish. The following data was obtained.

Time (in minutes)	Bacteria Concentration (in ppm)
0	6
1	9
2	15
3	19
4	32
5	42
6	63
7	102
8	153
9	220
10	328

a) Enter the data into an Excel worksheet and plot the data several different ways. Use the resulting graphs to solve the following problem:

Suppose the growth of Type A bacteria is governed by a process described by the equation

$$C_A = a\,e^{bt}$$

and the growth of Type B bacteria is governed by the process described by the equation

$$C_B = a(t^b)$$

b) What type of bacteria is the engineer dealing with?

You have been given an unknown substance for analysis. As a poor undergraduate student, you have been given access to a primitive mass spectrometer and have used it to take a series of readings to determine the relative atomic mass of the substance. The results of your experiment are found in the text file "spectro-results.txt". Plot the data, determine the substance's molecular composition and identify the substance. Justify your answer.

For each problem, the students were expected to formally list the steps they followed to reach their conclusions. Each problem set (approximately 6 problems) must be types neatly and submitted online to the class website. As with most real-world engineering problems, students were encouraged to work together on all assignments, but were required to report with whom they collaborated.

Case Studies:
Several case studies were used to illustrate concepts within team building, small group dynamics, and engineering ethics. Team building and small group dynamics were covered early in the semester with ethics being at the end of the semester. Small groups were established to work through the case and write up their conclusions and recommendations. In order to change the group assignments from the semester project configuration, we reassigned groups to focus on other problems, thus simulating a more "real-world" arrangement of multiple group assignments. Following the theory of situation-based learning, the case studies allowed the students to place themselves in the real-world scenario in order to understand the various factors that must be considered in solving real-world problems. A sample case study from an early teambuilding exercise is shown below.

Background
The paint job is the single most expensive item in the manufacture of an automobile. This may be accomplished using a spray booth (ventilated to the air) and solvent-based paints. Two undesirable issues arise in this process:

- A significant portion of the paint is lost due to "overspray", and
- Upon drying, huge amounts of solvents are lost to the air and contribute to air pollution (additional waste solids are also produced from the overspray, contributing to solid waste).

Assume that the government has just promulgated a new regulation that requires the automotive industry to reduce their solvent emissions to the air by at least 50% over the next 10 years.

Question
Given this situation, suggest ways to meet this requirement without reducing automobile production.

Students formed heterogeneous groups based on personality type indicator results and followed a formal problem solving process in order to recommend ways to reach a reasonable solution. Each group's results were written up in a formal paper as well as discussed in class. Class discussion involved each group informally presenting their recommendations, then as a class, discussing the merits of each and deciding on a "best practice." Clearly many of the details of this problem are ignored; however, the students start to get a feel for types of engineering problems and gain experience in following a formal problem solving method.

In continuing with the computing aspect of the course, one of the goals was for students to realize the attributes of the various computing packages available to aid them in solving problems efficiently and need to use appropriate tools for appropriate problems. To emphasize this aspect, a basic trajectory problem from a freshman physics text was assigned repeatedly after each module. Thus students were asked to solve the same problem by hand (i.e. using the calculator), using Excel and again using Matlab. This type of problem provides exposure to math and physics principles, modeling concepts for graphical representation in Excel and Matlab, and Solver characteristics for applications in Excel. Students were regularly asked in class as to which solving environment they preferred for several different types of problems. This type of discussion allowed the students to consciously think about which characteristics of each computing tool they found easiest to use and why.

Ultimately the problem sets throughout the semester were structured to incorporate the necessary analytical problem solving techniques, but also to demonstrate math and science principles in an engineering setting by utilizing computing tools. The learning objectives involving understanding of the analytical problem solving process (#1), solving basic analytical problems efficiently using engineering software tools (#2), and providing for a common solid foundation to logically lead into the introductory major-specific courses (#9) were fulfilled using this methodology.

Group Activities:
Various group activities were developed mainly to reinforce the dynamics of working in small technical groups. We listed the fundamental steps of the problem solving process and developed a group assignment for each.

The main steps we used are below:

1. Define the problem.
2. Gather pertinent information.
3. Generate multiple solutions.
4. Analyze and select a solution.
5. Test and implement the solution.

Assignments were created to focus on each of these steps over the course of the semester. This structure of assignments had in-class presentations with most of the work occurring outside the classroom. An additional feature was that these assignments were done in the semester project groups with the theory that the groups would work better as a unit with practice.

Conditions for group interaction were altered for each activity. In the activity above, the group members were forbidden to communicate face-to-face, thus illustrating how most engineering groups today work when members are spread out over the country or world. Feedback from the students was mixed. Frustrations were present because of communication issues, but overall the vast majority felt it was useful.

A sample assignment is shown below:

Design Decisions – A Better Bike Rack???
Assigned: October 31
Due: November 7

Problem:
Your design group has been assigned the task of developing a better bike rack.

Assignment:
This task focuses on making design decisions. As a group, you are to determine which design criteria you must use and how they are to be ranked. Your results should contain a decision matrix illustrating your conclusion. You need *at least* 5 alternative designs and *at least* 5 design criteria. Try not to use the ones listed in the example – come up with your own.

As with the previous group activity, approximately half of the groups will be presenting their results to the class. Presentations should be no more than 6 minutes in duration. All groups should submit their results on PowerPoint slides with a log of group activities.

There is one catch to this assignment…group members are forbidden to speak to each other face-to-face. Communication via telephone, email, instant message, electronic chat and fax are permitted; however, the parties must not be in the same place – not even for meetings. If you meet regularly, meetings must be done from separate locations. Be prepared to comment on this experience in your presentation.

Panel Discussions:
According to beginning of semester surveys given on the first day of class, approximately 36% of our first-year students state they are unsure of their choice of major. Initially this does not sound like a big problem; however, as with many schools, we are feeling the pressure of departments wanting to offer a discipline-specific course in the first-year. This shortens the amount of time students will have to make an informed decision on their major. A series of 10 extracurricular panel discussions were offered on each degree-granting program VUSE. The panels consisted of a practicing engineer, a faculty member, a graduate student and a senior undergraduate student. The purpose of the diversity in the panel was to give exposure to the various levels of education and to different career paths. The practicing engineers invited to participate were mostly local alumni who have had several different careers since their graduation. The format for the panels was simple: each participant gave a 5-10 minute overview of his or her background, and the remaining time was used for questions from the students. Each session lasted a little over an hour. Respective department faculty and school deans were invited to attend, which proved to make discussion more interesting according to student feedback.

Design Project:
The group project is the focal point of ES130. It is intended to further expose students to engineering and their potential major, give students a sense of the Engineering Process, and develop students' teamwork skills. It is our intent that they follow the "Engineering Process" from start to finish during the course of the semester. Each group must select their own project from the project list in their group major, and then follow the Engineering Process toward completion. To assist them, a series of due dates have been set to allow each group to keep the instructor informed of their progress. Each group gives an oral presentation in class discussing

their project. Additionally, there is a school-wide Project Fair, usually scheduled for the day after the last day of class, where all freshmen groups display their projects for the faculty and deans of the Engineering School.

Students choose their semester project based on their most likely major and interests. As seen from the project descriptions, each project has a real world application and is presented in a commercially viable format such as a contractual bid, consulting project etc. In proposing and performing the project, the students had to consider several aspects of the project:

- Technical,
- Financial,
- Legal,
- Marketing,
- Safety/Liability and
- Ethical.

Samples of project descriptions are shown below.

Automated Determination of Welding Quality (ME/CS)

The Space Shuttle Main Engine (SSME) is a welded structure which must operate at extremely high temperatures and stresses with virtually 100% reliability. NASA is interested in a system, which will evaluate the quality of the welds in the SSME after construction but before use. It has been determined that non-uniform welds are potential problems with respect to weld durability. This quality evaluation is to be performed by a computer evaluation of the surface appearance of the welds. It is recommended that a video camera/image capture system be used for this task. Examples of real welds will be provided for visual evaluation and simulated welds of controlled configuration will be provided to test your developed software. You will not be responsible for the actual image capture necessary for the final system. Your final product should be a system/software, which will produce a relative weld quality rating (0 -10) which will correlate with the actual quality of the weld.

Representation of Self-Assembled Monolayers (Chem E)

Self-assembled monolayers are molecular films that form spontaneously when a metal substrate is placed in a solution containing appropriate organic molecules. These films have applications in chemical sensing, corrosion inhibition and nanoscale science and technology. Researchers in the chemical engineering department have developed a strategy for forming self-assembled monolayers in an environmentally benign aqueous solution. As researchers in this field, you are asked to fit the experimental data to determine kinetic rate constants, gain physical insight on the delivery mechanism, and develop 2-D and 3-D animated representations of the delivery process.

Detection of Peripheral Vascular Disease (BME)

While there are much more visible health care issues which affect fewer people (such as cancers), diabetes does not get a lot of attention. Diabetes affects an estimated 15.7 million people in the United States -- 10.3 million have been diagnosed, but 5.4 million are unaware they have the disease. It is a disease that one manages rather than cures. One of the big problems is that the poor solicit health care by crisis; their primary care physician is the ER. In a diabetic, the crisis is often peripheral vascular disease (blood vessels collapse) and they loose a limb, or it gets gangrene and the person gets sick or dies from the sepsis. The goal of your research and design team is to design an inexpensive way to screen non-technically adept users for the onset of peripheral vascular disease. Possible solutions could involve thermography (temperature detection) and automatic data transfer (99% of all US households have a phone). Ethical issues involve understanding delivering medical care to the poor.

Results from the implementation of the panel series and the design project and their impact on students is described in another paper (session 2793).

Assessment

In order to assess the effectiveness and differences in the two course formats, two assessment tools were used: surveys and content-based questionnaires. Engineering students enrolled in ES130 from both the control as well as alternate format sections were given a beginning-of-semester survey to obtain information about student background and knowledge baseline across all sections. The survey acquired data regarding student background from the student perspective as well as student opinions. Question topics include those about student major selection, knowledge about engineering, prior level of physics, math etc., and prior computer skills. In addition to the survey, a pre-course content-based questionnaire was also given on the first day of class to assess entering domain knowledge of the students. This questionnaire consists of three engineering problems that address design, analysis and troubleshooting aspects of problem solving. Students were given a maximum of 30 minutes to solve the problems using any computing tools available to them (calculator, computer, brain power, etc.). A return of 100% was obtained for the surveys (357 students) and nine of the ten sections (309 students) completed the questionnaire with 100% return from those sections.

Summary of the problems that comprise the questionnaire are given below:

Question 1: To develop a device that will turn on a car's windshield wipers automatically when rain falls
Question 2: To analyze the deflection of a long narrow beam that carries a uniform load (equation given).
Question 3: To interpret a (erroneous) data set provided.

In the last week of the semester, the survey was modified and given to all students. A 91% return was obtained. Questions were modified to reflect change in the time line and assess student perspective of the course and their knowledge. In addition, nine of the ten sections were also given the content-based questionnaire that consisted of the same problems as in the pre-course questionnaire. A return of 100% was again obtained for the completed questionnaires. The assessment questionnaires were coded by an independent party and were blinded to all the investigators during the rubric and analysis process. Each investigator, in turn, was asked to complete the questionnaire as well. Rubrics were developed for each problem to assess the student's approach and the problem solving approach. Three sample answers were scored using the developed rubric. The scores were subsequently compared among the investigators and any ambiguities in the rubrics were resolved. The consensus rubrics were then used to score the student responses to the post-course questionnaire.

Summary of the rubric questions used are given below:

Question 1:

A. Shows knowledge of the design problem solving process.
B. Identification of factors that could influence the design.
C. Identification of additional information needed to solve the problem.
D. Provide a description or drawing of the design.

Question 2:

A. Identify the relationship between height and width.
B. Presence of calculations.
C. Presence of analytical problem solving process.

Question 3:

A. Identification of flaws in the data set.
B. Identification of what additional information is needed.

Responses from all students to the surveys were analyzed and responses to specific questions were compared across the semester. The results were evaluated and compared both by section and by course format. According to student feedback, aspects of the alternative format of ES130, including the discipline-specific design project, better assisted them in choosing a major and better identified them with being an engineering student. Thirty-nine percent of the respondents stated that the discipline-specific design project significantly aided them in making a decision on a major. A natural extension from these results is that many of the students involved in the design project format felt more closely connected with a faculty member in their department of interest. The project format also motivated students in their area of interest. Students indicated a greater ownership over their project and interest in their potential major.

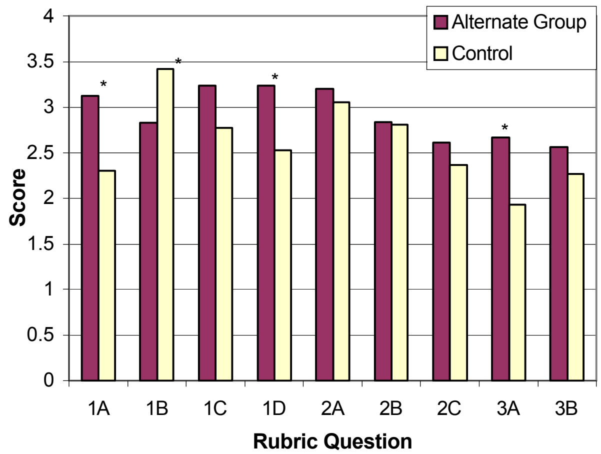
Clearly the vast majority of all first-year students experienced a gain in proficiency in the use of various computing tools such as Excel and Matlab. The difference in levels of proficiency and problem solving skill was shown in the assessment results. Students in the alternate group were asked to rate their level of skill (on a scale from 0 to 5) in the problem solving process assuming they began the semester at a 0 or 1. Approximately 75% of the students rated themselves at a 4. Most of the remaining population rated themselves at a 3 with a small percentage rating themselves at a 5. In addition, nearly all of the students from the alternate group indicated that the approach to problem solving helped them to better learn the course material.

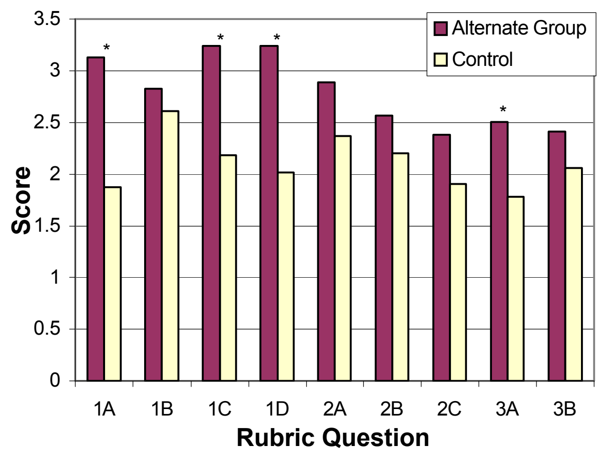
As a preliminary analysis, a sample of 40 responses (20 from the control and 20 from the alternate group) to the post course questionnaire was scored using the developed rubric by each of the investigators. In addition to student identity, each investigator was also blinded to whether the responses were from control or alternate group at the time of scoring. Students with blank responses were given a score of 1 indicating an inadequate response. Scores were then averaged and compared using the student's t-test.

Preliminary analysis of the scores indicate statistically significant differences in the scores of the alternate group as compared to the control group for questions 1A, 1D and 3A. Average scores were computed with and without blank student response scores shown in the 2 graphs below.

Average scores without blank responses

Average Scores including blank responses





Although similar trends in the scores were observed in both analyses, better differentiation between the two groups was observed when the blank scores were included. The statistical differences observed indicate that students from the alternate sections were more organized and used some version of a well-defined problem solving process especially with respect to the design problem. This is particularly encouraging and students in the alternate group were given multiple opportunity to realize as well as implement these concepts via the design project, group activities as well as lectures. Student ability to communicate their design idea either via a drawing or a verbal description was also increased. Students in the alternate group were able to recognize the existence of a flaw in the data associated with question 3 although they were unable to identify the flaw. This may be attributed to a lack of experience in the domain as well as a lack of instruction in this area of problem solving.

It was interesting to note that a significant number of students in the control group did not attempt to answer these questions. All students were given the same amount of time and the questionnaires were completely voluntary in that students were not given course credit for their response, regardless of their group. This may indicate the level of identification the students in the alternate group may have with engineering and its problem solving aspects as compared to the control group. Thus these students were more comfortable in the problem-solving environment and thus provided responses. This recognition may be lacking in the control group. Further analysis will have to be conducted to verify this finding. As a side note, students were also asked to state what computing tools were used in solving the problems. In the 40-sample analysis, it was observed that all students indicating the use of computers (Excel or Matlab) belonged to the alternate group.

Conclusions

The Vanderbilt School of Engineering is considering a paradigm shift in the context of the introductory Engineering course required for all freshman engineering students. The course was modified from a skills based approach to a problem based approach and implemented in four of ten sections of the course in Fall 2002. The remaining sections were continued in the "how-to mode" and served as a control. The focus of the new format is to integrate engineering principles and engineering problem solving including design with real world problems to deliver instruction in a challenge based environment. In addition, an engineering design based semester project was incorporated with faculty involvement to educate these students about the engineering design process in the context of their selected major. This increases the students' awareness of their intended major and their decision-making ability on that major.

In the new form, the course continues to teach the computing tools needed for subsequent semesters through the use of various contextual problems. Thus, changes have been made to the mode of instruction rather than to topics of the syllabus taught as is evidenced in the comparative table. The freshmen students received the course changes favorably. It enables them to have an early exposure to engineering including such key experiences as teamwork, ethics, and an engineering design project. While it remains to be seen how the modifications to the course will affect student retention and career development, the proposed structure addresses some of the deficiencies in the existing course format.

Preliminary results clearly indicate an increased awareness of engineering problems and the problem solving process. In particular, the design aspects of the engineering curriculum was well addressed as indicated by student responses. Thus, it is believed that the propose paradigm shift may better prepare students for subsequent years as an engineering student and better inform students about engineering and their major. Further analyses will provide additional insight into the process allowing the new paradigm to be further refined and utilized in the near future.

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