

## Module-based Freshman Engineering Course Development

Christopher J. Rowe, Anita Mahadevan-Jansen  
Vanderbilt University

### Abstract

The freshman year of engineering continues to be one of the most critical components of undergraduate curriculum development for engineering schools. There is an ongoing challenge in developing an introductory engineering course that meets the needs of the school/college as well as the students in an effective manner. A major complaint of students is that there is no formal mechanism that helps students make an informed decision on their choice of major until well into their curriculum. Approximately 40% of the first-year engineering students at Vanderbilt University are unsure of their major upon entering the university. In addition, often parents and students complain of the lack of "real world" engineering in the first year curriculum, which is true of many engineering schools. As a result, the Vanderbilt University School of Engineering has initiated a series of changes that radically affect the freshman engineering curriculum to be more innovative, competitive, and challenging. The remodeled introductory course in engineering fosters early and informed student decision regarding their declared majors, brings real world engineering problems into the classroom, and anchors the curriculum in the context of engineering problem solving.

The first major change involves the development of a module-based freshman course in engineering. In this course, students take a common module focused on engineering problem solving and computing for seven weeks. The general module is taught in the context of data management/analysis using different software packages. Based on these skills, discipline-specific modules were created for each engineering major offered at the Vanderbilt School of Engineering (VUSE). The general module is followed by two self-selected four-week, discipline-specific modules that focused on a current event or area of research. Each discipline-specific module was designed in the context of problem based learning with a fundamental set of criteria and deliverables, which include a grand challenge statement, a culminating activity/deliverable, a minimum of 3 assignments that apply the concepts of problem solving learned in module 1, oral presentations, design and technical writing amongst others.

Assessment and evaluation will be facilitated by surveys conducted of students and instructors across all sections to obtain feedback on the progress and efficacy of the course. Student-based assessment shows that this course was beneficial toward student confidence in choice of major and working knowledge of current events within that discipline. Instructor-based assessments shows that several improvements have to be made to better achieve the learning objectives of the course.

## Introduction

In the past decade, the use of computers has exploded into 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 implementation. 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.

On the other hand, problem solving is a skill essential to all forms of engineering and the basics of problem solving, if learned early, can greatly improve student learning and effectiveness during subsequent years of their engineering degree. Since most students are competent in basic use of computers, our challenge becomes that of creating an environment where students can gain problem solving skills while using computing tools to reinforce the application of those skills. Thus we are striving to develop an engineering student who is technically competent while possessing sharp problem solving skills.

In 2001, the Vanderbilt University School of Engineering (VUSE) launched its wireless laptop initiative. This program is responsible for building a framework of consistent wireless network coverage within the Engineering School's facilities serving the undergraduate students using a wireless laptop computer. The ultimate goal of this program is to have every student on the wireless networks with their own machine, thus eliminating the need for large, overcrowded computer laboratories. The 2002 fall semester was the first class-wide rollout of this program. The redesign of the freshman introductory course provided the single largest wireless computing innovation for the School of Engineering. In the fall of 2003, all 10 sections of the introductory course (~320 students) were taught at the same class time with all first-year students using the various wireless networks within the School. The increased interaction among students and faculty showed an immediate improvement in communications and delivery of content. Courses such as this are no longer limited to being held in computer labs. Any classroom can essentially become its own wireless computer classroom, thus easing classroom and computer demands on the School's existing facilities.

With all students and faculty using identical systems, it is easier for the instructor to answer questions and provide instruction to the students. Using this new, innovative computing environment allows another goal of the introductory engineering course to be realized: learning what tools are appropriate to help solve specific problems. In real time, an instructor can provide an open-ended engineering problem; students can break the problem down, brainstorm possible methods of solving the problem, troubleshoot those methods through discussion and use of the computers in class, determine a best method for solving the problem, and then actually solve it. The experience gained by the students becomes interactive rather than observing an instructor

solving the problem at the front of the classroom. It is widely accepted that interactive learning is much more powerful than passive learning in a classroom setting. With an increasing number of engineering schools implementing a laptop initiative, this model can become more of a reality than theory.

Another key issue typically addressed via the introductory course is one that facilitates retention. Vanderbilt University has been more fortunate than many schools in having an above average retention rate for engineering; however, the statistics can always be improved. Engineering programs on a national scale are having major trouble recruiting and retaining talented and qualified students. Those students who do stay in engineering are very likely to change their major, often too late in their curriculum to permit a timely graduation and true satisfaction in their choice. Therefore, exposing students to engineering becomes slightly more complex. Students now need to know more than simply what engineering is; but about the various engineering disciplines, their interdependencies, and the various career opportunities for engineering graduates. In the past, VUSE has done little beyond standard coursework to actively engage students in self-discovery of their own talents and how they mesh with a specific engineering discipline. What was needed was an intense, interactive program that allows students to educate themselves with what the various fields of engineering are, their similarities and differences, and which of those areas are more closely aligned with their own interests. The introductory engineering course was selected as an ideal forum to implement this program.

In 1989, VUSE launched an innovative introductory course that focused on exposing students to computing tools that many had never seen at the high school level. Since user-friendly computing technology was relatively new, this major curriculum change was truly innovative. Over time, the course naturally evolved but maintained its focus on a skills-based approach to learning computing tools. In recent years, the course was divided into segments surrounding specific computing packages such as Excel, Matlab, and HTML programming. The course was satisfactory in instructing students in how to use the software, but was less effective in teaching the students how to apply the problem solving process and then use the computing tool as an aid in solving engineering problems. Now that technology has advanced to become more easily available to more people and that students are more technically competent, the need for the focus to change was realized. In the process of incorporating problem solving, educating on engineering disciplines, exposing students to real engineering issues, and computing proficiency, a new model was developed.

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<sup>8</sup>. Thus, combining all of these ideas, a new introductory engineering course was developed and implemented using challenge-based instruction.

Many researchers use problem oriented situations to facilitate learning<sup>1,2,3</sup> 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<sup>4</sup>. 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<sup>3</sup> and law<sup>5</sup>, and case-based reasoning<sup>6</sup>. These approaches give students authentic situations to explore course content while simultaneously allowing them to practice 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<sup>1</sup>, case-based reasoning, and project-based learning<sup>7</sup>. 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<sup>9</sup>.

## **New Course Description**

Three global goals were identified early in the redesign process. The goals listed below are essential in the construction of a comprehensive introductory engineering program.

### Global Goals for ES 130:

1. Educate students in their choice of engineering majors.
2. Educate students on what it means to be in engineering.
3. Provide students with essential tools for further study in engineering.

In developing any new course, past experience has taught us that the best approach starts with the development of firm learning objectives for the course – leading to the taxonomy for the course and therefore the course itself. Based on the primary goals for the course listed above the following learning objectives were formulated.

### Overall Learning Objectives for ES 130:

1. Apply the engineering problem solving process to solve basic engineering design and analysis problems.
2. Solve basic analytical (and design) problems using engineering tools, and be proficient and efficient in the use of these tools.
3. Choose appropriate tools to solve specific engineering problems.

In implementing these learning objectives, we expect the students to be able to:

1. Apply the general problem solving process and tools to introductory domain-specific problems.

2. Be able to identify necessary known and unknown information towards a solution and the process to be followed to arrive at a solution.
3. Work effectively in small groups through well-developed problem solving skills and be able to organize the group to optimize performance and results.

During the course of this learning process, we anticipate the affect of the redirection of the course to be that students will be able to:

1. Identify with what it means to be an Engineer and being a part of the engineering community (at Vanderbilt) through exposure to practicing engineers, engineering faculty, graduate students, and fellow undergraduate students
2. Understand the focus of each (selected) engineering major and then be able to make an informed choice.
3. Begin building professional relationships with faculty members within the student's department of interest.

Once these learning objectives were developed, it became evident that a traditional lecture-based course would be difficult to effectively implement and meet the stated objectives while creating a unique and rigorous course. Thus, a creative approach was necessary. In order to fully engage students in discipline-specific activities, they must be divided into discipline-specific groups; however, it becomes complicated when a large number of students are unsure or undecided on a major. The idea evolved of dividing the students up several times over the course of the semester to explore different disciplines where students' interests may lay, hence a module-based approach. Students were to meet in a general problem solving and computing module in order to gain fundamental knowledge with little application to a specific discipline. Once essential fundamental engineering concepts (i.e. problem solving) were introduced, students elected to take two modules in line with what they thought their interests were. Some guidelines that were followed in creating the course structure are listed below<sup>11</sup>.

Tools for Success:

- An *environment* that encourages shared experiences by those in class.
- A *structure* that allows exploratory, open-ended learning by teams.
- *Resources* that bring professional practice into the classroom.

These tools are the fundamental building blocks of the introductory engineering course. Shared experiences are realized when students bring together differing skill sets in each of the discipline-specific modules to work on new projects. The structure of the course is designed to begin with partial exploratory learning by forcing students to become proficient in computing and expand that learning to solve real-world engineering problems which may not have one right answer. Because the discipline-specific modules involve current engineering problems and/or current areas of research, the resources are built into the curriculum from the ground up.

Criteria for Resources:

- Make it accessible and understandable.
- Make it challenging and engaging.
- Material should be faculty independent.
- Incorporate breadth of methodologies.

- No "wrong answer" – weighted criteria (for evaluation).
- Make it real.
- Promote active learning.

These criteria for resources were necessary for course instructors to develop an engaging and independent module. Since the discipline-specific modules are stand-alone, new modules can be developed and replace older ones as the landscape of the specific field changes over time or as faculty members teaching the course change over time. Also, because the teaching faculty developed the module themselves, they retain autonomy over that component of the course material even though they are teaching according to an identical course syllabus. The benefits of having 10 sections teach the same material at the same time, and having 10 instructors with ownership over course material was realized using this model.

The idea became to create a course based on three modules consisting of a general engineering module and two discipline-specific modules that are designed to accomplish the various objectives, tools, and resources listed above. The purpose of the general engineering module was to introduce problem solving concepts and processes, teambuilding, and basic application of Excel and Matlab to solve engineering problems. The purpose of the discipline specific modules were to introduce the students to the disciplines of their choice in enough detail to give the students a basic understanding of the discipline in the context of engineering problem solving. The idea was that each accredited major engineering discipline in the School of Engineering creates a module that is contextualized around a current issue, event or area of research. A challenge-based approach was encouraged to maximize effectiveness and student engagement. Thus the three-module structure was distributed as shown below.

|           |   |
|-----------|---|
| Module 1: | 7 weeks<br>General problem solving, basic Excel, basic Matlab |
| Module 2: | 4 weeks<br>First discipline specific module                   |
| Module 3: | 4 weeks<br>Second discipline specific module                  |

Concepts such as networking/Internet material, engineering ethics, and advanced Matlab applications were not covered in this course. Topics such as teambuilding and technical writing were briefly introduced in the general module and reinforced in Modules 2 and 3 if time permitted.

Students select their top three choices of engineering disciplines that they would like to learn more about in the first 2 weeks of class. This typically included their declared major as one of their selections. Based on these selections and appropriate class sizes, students were placed in specific sections of the course where each student was assured of their top choice and the majority of the students were also assigned to their second choice discipline. Thus each student could have up to 3 instructors over the course of the semester. Average class sizes were

maintained at about 30 students per section and thus instructors were selected to maintain this number across all disciplinary modules.

Each degree-granting program (with the exception of Computer Science and Engineering Science) was required to develop a four-week module to be taught twice in the second half of the semester. The modules are Biomedical Engineering, Chemical Engineering, Civil & Environmental Engineering, Computer Engineering, Electrical Engineering, and Mechanical Engineering. Students made three choices of modules with their first choice being their declared major. 97% of the students were given their top two choices. Each student participated in the two two-week modules for the second half of the semester. Based on historical enrollment and several other factors, the following number of sections and disciplinary modules were offered. The chart below also indicates the teaching schedule for each instructor.

|          | Section 1 | Section 2 | Section 3 | Section 4 | Section 5 | Section 6 | Section 7 | Section 8 | Section 9 | Section 10 |
|----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|------------|
| Module 1 | General   | General   | General   | General   | General   | General   | General   | General   | General   | General    |
| Module 2 | BME       | BME       | BME       | ME        | ME        | CEE       | ChE       | EE        | CompE     | CEE        |
| Module 3 | BME       | BME       | BME       | ME        | ME        | CEE       | ChE       | EE        | CompE     | CEE        |

Thus each instructor was committed to teach for the entire semester wherein he or she would teach the general problem-solving module for the first 7 weeks. Each instructor would then teach the discipline specific module of his or her design consecutively for the two 4-week periods to two different cohorts of students. To allow for these logistics, all 10 sections of the course were taught simultaneously at the same time slot to facilitate this switching around of sections midway through the semester.

Various assessment activities were performed in order to gauge success in fulfilling the learning objectives defined. In addition to the course modules, a series of discipline-specific panel discussions were developed to provide exposure to various perspectives of each major. The panels consist of a practicing engineer (usually a VUSE alumnus), a faculty member, a graduate student, and a senior undergraduate student. Students were required to go to several panels of their choice throughout the semester based on their interests. Most students attended more than the required number of panel sessions.

### Module 1 Description

The general engineering module comprises the first half of the academic semester (7 weeks). The focus of this module is to get students to formulate problem-solving methodologies. The paradigm in this module shifts away from a skills-based approach as in previous years to a challenge-based approach. The latter approach engages students to determine the best way to solve a problem. Students use a specific thought process to break the problem down, figure out the analytical component, solve the analytical component through their own discovery using a selection of software and hardware tools, and present their findings in a report format. The How-to aspect of learning to use the software tools is one of self-discovery with the practical experience of solving problems in class using these tools serving as the basis. Support in the

form of online tutorials and help sessions is provided for the student's benefit. Class time is focused on underlying common mathematical and scientific theories governing the physical constraints of data rather than how to use Excel and Matlab, by using discipline specific problems as the framework. The learning objectives for the first module are shown below.

*Learning Objectives for Module 1:*

1. Employ the engineering problem solving process to solve basic engineering design and analysis problems regardless of the environment (on paper, computer, etc.).
2. Be proficient and efficient in the use of computer tools.
3. Demonstrate ability to represent, interpret, manipulate, analyze, and model data associated with various basic engineering problems.
4. Choose appropriate tools to solve specific engineering problems.
5. Work effectively in small groups through well-developed problem solving skills.
6. Identify with what it means to be an Engineer and being a part of the engineering community (at Vanderbilt).

In implementing the above objectives, by the end of Module 1, students will be able to:

1. Organize and present information on engineering paper to communicate with others to solve problems by hand (with calculator) as well as for engineering graphics; and use Cartesian, semi-log and log-log graph paper for data representation.
2. Solve basic analytical problems involving curve-fitting, regression, basic statistics (measures of central tendency, variable relationships, mathematical modeling), and symbolic mathematics.
3. Utilize multiple computing tools to set up, analyze, and solve engineering problems.
4. Employ techniques of data representation, interpretation, and analysis to solve basic engineering problems.
5. Efficiently work in a small group environment to solve basic engineering problems.
6. Demonstrate competency in solving basic problems using software tools such as Excel and Matlab (amongst others such as Word, PowerPoint, Browsers). For example:
  - a. Using Excel, students will be able to demonstrate how to use functions on two-dimensional data sets and plot the results. They will be able to organize a spreadsheet, use appropriate formulas/functions to represent numerical results, and select an appropriate graph style to represent the data in an appropriate amount of time.
  - b. Using Matlab, students will be able to demonstrate how to define variables, mathematically manipulate those variables, read data from files, write data to files, construct m-files, and appropriately display graphical and numerical data and results in an appropriate amount of time.
7. Work with matrices including basic matrix algebra. Solve basic matrix-based problems using computing tools such as Excel and Matlab. Analyze systems of equations by performing matrix algebra using tools such as Excel and Matlab.
8. Construct basic algorithms using *if..else*, *for*, and *while* loops; and conditional and logical operators in a Matlab environment.

Modalities used to demonstrate computational components include paper, Excel, and Matlab; however, the solutions require more in-depth modeling and analysis of more complex problems than in older versions of the curriculum. The course begins with having students solve problems on paper using a formal engineering problem-solving procedure. This segment of the course also includes the basic concepts of engineering graphics, an integral part of engineering problem solving. Excel is used to illustrate the simulation of least-squares method of curve-fitting, variable relationships, linear optimization of multi-dimensional parameters, and statistical modeling. Simple spreadsheet management and organization is no longer a part of this course as most students come in with the ability to perform this function. Matlab is used to perform matrix calculations, statistical modeling, polynomial curve fits, mathematical differentiation, and demonstrate constructs of scripts using both static data and user inputs.

Rather than using a traditional model of one problem set per week, homework assignments are assigned with a rolling due date such that 1-2 problems were due each class period. This allowed us to map the assigned problems with the material followed in class. Since the module was only seven weeks, this parallel processing encouraged the students to be proactive about learning and to organize a consistent amount of time spent on course-related work. Assigned problems were selected to encompass the different areas of engineering to emphasize the application of the problem solving process regardless of the type of problem.

In keeping with the computing aspect of the course, a main goal was for students to realize the attributes of the various computing packages available to aid them in solving problems efficiently. A common trajectory problem was assigned across several modules from solving the problem by hand through solving the same problem in Excel and Matlab. This type of problem provided 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.

The general module was interspaced with small group activities to expose students to teamwork and small group dynamics. The group activities were designed in order for the students to take a break from the typical analysis-driven class structure and work to solve open-ended engineering design problems. Examples of such activities include building a bridge in an allocated time using a limited amount of specified materials, building a paper airplane and experimenting on its time of flight and distance, etc.

A common mid-term was given to all 10 sections of the course. It should be noted that effort was made to maintain consistency in workload and taxonomy across all 10 sections, a common complaint in previous iterations of the course. This requires continuous discussions and agreement by all 10 instructors.

### Modules 2 & 3 Description

The student proficiencies at the end of module 1 (as described in the previous section) form the foundation in the development of the subsequent modules and are based on the problem-solving

methodology in a discipline-specific environment. The modules have a minimum set of requirements that had to be met by the instructor. Keeping the time constraints in mind (<4 weeks, 11 class sessions, 3 days/week), the objectives were:

- Must contain a grand challenge and at least two subchallenges
- Must contain a mechanism for students to give in-class presentations
- Must contain at least one major writing assignment (lab report, design report, etc.)
- Must contain at least three major homework assignments that incorporates concepts from Module 1

Within these minimal constraints, the instructors were given full reign in the development of these modules. The learning objectives for the discipline-specific modules that were initially agreed upon by the ES130 faculty are as follows:

1. Choose appropriate tools to solve domain-specific engineering problems
2. Apply general problem solving process and tools to domain-specific problems
3. Work effectively in small groups demonstrating well-developed problem solving skills
4. Communicate technical content effectively with peers (presentations, papers, etc.)
5. Identify what it means to be an Engineer and being a part of the engineering community (at Vanderbilt)

By the end of Modules 2/3, the students should be able to:

1. Resolve basic engineering issues surrounding a field within the discipline of interest by solving open-ended problems and/or design-based problems and identifying the critical factors that influence the solution.
2. Work in small groups in order to solve a basic discipline-specific engineering design and analysis problems.
3. Employ fundamental analytical techniques to model and simulate a basic engineering problem.
4. Discuss current professional engineering issues involving a specific problem area.
5. Make a more informed decision on their individual level of interest in a major.
6. Begin building a professional relationship with a faculty member in the chosen area of engineering.

The module topics were left to the individual instructor(s) and/or department faculties for that discipline. All of the instructors were encouraged to choose a topic that illustrated current societal issues and/or research activities within that area of engineering.

For example, the Biomedical Engineering module focused on brain imaging techniques. This module introduced the physics behind medical imaging modalities including X-ray Angiography, CT, MRI, PET, SPECT, DOT, and Ultrasound, as well as EEG techniques. Students were presented a grand challenge on Day 1 and brainstormed ideas on how to diagnose a brain dysfunction using the imaging techniques previously mentioned. For anatomy and physiology instruction, students performed brain dissections using adult sheep specimens. Students also participated in imaging activities demonstrating the physical theories behind the modalities. Main deliverables included technical presentations on 6 of the modalities listed and a

thresholding assignment involving programming and image processing using Matlab. Multiple expert perspectives were provided on a panel of neurosurgeons, engineers, and radiologists. Students presented their results in the form of a diagnostic report.

Another example is the Chemical Engineering module, which introduced the underlying concepts involving prototyping fuel cells and establishing a manufacturing process. The module addressed the fundamentals of process engineering, materials science research on new, cheaper materials used for manufacturing, engineering economics in the hydrogen economy, environmental issues and pollution calculations as a result of burning fossil fuels, safety measures and risk analyses of using hydrogen as a fuel source, and issues related to converting from a petroleum economy to a hydrogen economy. The students used a LabView-based tool for illustrating changes in emissions sources and their effect on the carbon cycle. The main deliverable was a comprehensive report theorizing reductions in global air pollution and the conversion to a hydrogen-based fuel economy.

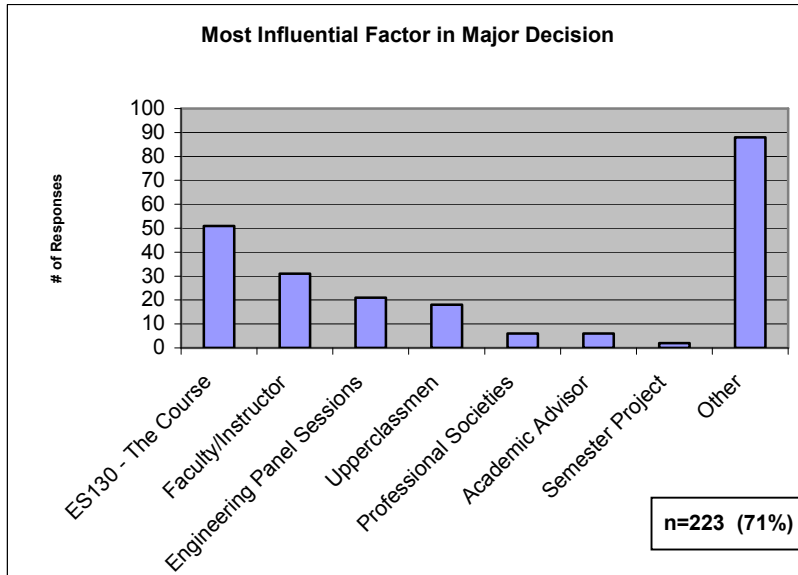
### **Assessment**

In order to assess the effectiveness in the new course format and to receive feedback on the new implementation of the course, students as well as instructors were surveyed both at the beginning as well as the end of the semester. Students were given a beginning-of-semester survey to obtain information about student background and knowledge baseline across all sections. The survey acquired data regarding students' backgrounds from the student perspective as well as preconceptions based on student opinion. Question topics include those about student major selection, knowledge about engineering, prior level of physics, math etc., and prior computer skills. In the last week of the semester, the student survey was modified and given to all students. Questions were modified to reflect change in the time line and assess student perspective of the course and their knowledge. The surveys were evaluated and compared both within and across all sections.

There was a 70.5% response to the post-course survey of the 316 freshmen that took ES130 in the fall semester. Based on the responses received, the results are shown below:

|   |     |
|---|-----|
| Changed engineering majors:             | 23% |
| Increased confidence in major decision: | 34% |
| Decreased confidence in major decision: | 13% |
| Intra-University Transfers out of VUSE: | ~4% |

The graphs below illustrate the order of influences on students' decisions in their choice of major. Each student was asked to identify his or her top three factors that had an influence over the decision or confirmation of the decision on a major.



Based on the graph above, 23% stated that the course was the most influential factor in their decision upon a major. Fourteen percent chose the Faculty/Instructor as their most influential factor and 9% stated that the weekly engineering panel discussions was their most influential factor in deciding upon a major. The course is also considered the second most influential factor in the students' decision making process with 27% of the students selecting this factor. The majority of respondents chose the engineering panel sessions as their third most influential factor in their decision upon a major (22%) with the instructor (21%) and the course (19%) the next two highest ranking factors.

The results of this comparison differ vastly from last year when students were asked the same question. The previous year's students stated that the engineering panel sessions were the most influential factor in deciding upon a major with the course being their second choice and the instructor being the third choice<sup>10</sup>. The most significant change between the two years was the implementation of the module-based course format, thus illustrating the impact of the course on student learning regarding the various engineering majors. With each student having at least two instructors for this course, the interaction between student and instructor more than doubles with most students having up to three instructors for the course. This evidence supports the student perception that the instructors had greater influence on their decision on an engineering major. The only aspect that did not change from the previous year and version of the course is the engineering panel sessions, further illustrating the impact of the change in course format. Given the feedback on the student perspective, there is significant evidence that the students are more educated on their choice of major and somewhat more confident in their choice.

The post-course survey had two sections specifically related to the discipline-specific modules. The responses are shown in the table below.

| Question   | Module 2 |     | Module 3 |     |
|--|----------|-----|----------|-----|
|  | YES      | NO  | YES      | NO  |
| Do you feel that this module was representative of the specific engineering discipline?  | 78%      | 22% | 94%      | 6%  |
| Do you feel more knowledgeable in some of the current research activities in that field? | 82%      | 18% | 94%      | 6%  |
| Did you change your major to this discipline because of this module?                     | 4%       | 96% | 10%      | 90% |
| Did you change your major from this discipline because of this module?                   | 7%       | 93% | 6%       | 94% |

The results of the above table indicates that the discipline-specific modules were effective in educating the students about their major and aided them in making their major selection. The above table also shows that there is a dramatic increase in student perception of how representative the modules were relative to the specific major as well as the awareness of current research activities in the field. This increase suggests that repeat instruction of the module enhances the effectiveness of the instructor as may be expected from practical experience. This increase also indicates the increase in student comfort level to the new modular format.

The questions relating to motivations for changing majors were included to satisfy a curiosity of the impact of specific modules towards student major selection. These results show that specific modules did significantly attract and discourage some students from a specific major indicating the importance of these modules towards student recruiting and retention, particularly in under-enrolled majors. These results evidenced the success of this modular format in achieving one of the primary goals of this course, which was to educate students in their choice of engineering majors.

In order to determine if Module 1 was effective in preparing students for subsequent modules, the percentages were slightly lower than expected. The discipline-specific modules were created given a set of objectives from Module 1 that the students should be able to achieve, thus allowing the instructors to develop material that would provide the most impact in presenting a quality module. However, students generally felt that Module 1 could have been constructed better considering nearly one-third of the respondents felt unprepared for the subsequent modules. Similarly, approximately 15% of the students felt that their instructors did not present the material that was necessary to complete the second and third modules. This point is of serious concern and reinforces the importance of all instructors enabling the students to achieve the deliverables set forth for Module 1.

Based on the survey results, the students overwhelmingly liked the module-based course format. They stated that it was unique and different over traditional lecture-based courses and felt like they learned more than they would have in a traditional course setting. The students largely liked the instructors and thought the discipline-specific modules were engaging and they enjoyed the class time. One significant outcome was that there were several comments that the students

felt like they knew more about what it was like to be an engineer than before taking the class. As this is one of the global goals for the course, these statements were refreshing. The drawbacks according to the students were as expected. They were very unhappy with the workload in Module 1 as it was significantly more challenging than in previous years this course was offered. As expected, they had heard much about the course from upperclassmen and were very surprised at the drastic change in format.

In addition to the student surveys, feedback was also obtained from the 10 instructors throughout the semester. The feedback culminated with a focused session at the end of the semester devoted to obtaining specific information from each instructor on what worked and what did not work from the instructor's perspective. This feedback is particularly important given the varied background of the instructors themselves and in the context of the first module and its impact on the instruction of modules 2 and 3. In general, each instructor taught two-thirds of the semester in an area of his or her expertise, thus increasing the instructor's comfort level, and thus effectiveness in presenting the material. Instructors also felt that the task of re-teaching the same module twice within the same semester gave them the opportunity to improve the organization and delivery of the module content. There was no significant change in student course evaluations across the instructors; certain instructors showed an increase in the overall effectiveness in the classroom.

This freshman course was formatted as a three-credit hour course and it was immediately apparent that the material developed for the course far exceeded the amount that could be conveyed in the 3 hours of contact with the student leaving little time for in-class problem solving activities. In addition, a set due date for specific problems in the homework across all 10 sections could not be followed as the pace of instruction for each instructor varied greatly, thus this aspect was quickly left to the discretion of the instructor.

It should be noted that the course material was developed independently by the authors and made available to all the instructors. However, instructors had the freedom to add to this material as necessary. While clearly all instructors were well-versed in problem solving, this aspect was found to be essential to accommodate for the varied expertise of the instructors themselves in the use of software tools such as Excel and Matlab. Since the focus of the course was on problem solving, the idea was to not spend valuable class time instructing students on how to use the features of the tools used. This decision implies that students need effective tutorials on the "how-to" aspect of these tools. While such tools were provided to the students via online tutorials, it was found that students did not avail themselves of these tutorials, for the most part, and did in fact expect the instructors to work with them on this. However, this leads back to the issue of limited contact hours. To address this issue, the next iteration of the course will incorporate out-of-class tutorial sessions to be held for all students, in addition to the online tutorials for each of these tools, with some level of mandatory attendance or credit for attendance incorporated in the course grade.

One of the critical issues identified was the need for every instructor to achieve the deliverables set forth for the course as this severely impacted student ability to succeed in the subsequent modules as indicated by student surveys. The discipline-specific modules were developed based on the assumption that students would be able to do each of the items listed under the

deliverables. However, not all instructors achieved these deliverables. For example, one of the sections spent a significant amount of class time on engineering graphics and thus did not accomplish more than just the rudiments of Matlab. On the other hand, students were required to use Matlab to solve specific problems in more than one discipline specific module. The students from that section of module 1 were severely handicapped as a result. While accommodations were made for this limitation, future implementation of this course will require that each instructor keep to every one of the listed deliverables. This is also directly related to instructors' awareness of the learning objectives of the course in general and in module 1 particularly during the course of instruction. The instructors' awareness extends to the need to emphasize how these objectives relate to the delivery of the course content.

It should be noted that in its current form, this course does not incorporate engineering design. This course is primarily focused on analytical problem solving as it applies to engineering. Prior assessment has clearly identified design as an important component of freshman engineering education. However, it has also been ascertained that it is not possible to allot appropriate emphasis to engineering design to this course in its current form. Freshman design will be incorporated in future iterations of this course as an independent 1-hour component that works in tandem with the course.

## **Conclusions.**

The Vanderbilt School of Engineering is evaluating a new approach to their freshman engineering curriculum 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 across the entire freshman class. The focus of the new format is to integrate engineering principles and engineering problem solving with real world problems to deliver instruction in a challenge based environment. In addition, discipline specific modules re-emphasized the concepts of engineering problem solving with the context of major-specific problems within the framework of a current event, issue or area of research. Results indicate that the new course format increases the awareness of these students about their major and helps them make an informed decision about their choice.

While it remains to be seen how the modifications to the course will affect student retention and career development, the renewed structure addresses some of the deficiencies and enhances the benefits of such an introductory engineering course. Thus based on initial responses from students as well as faculty, VUSE plans to maintain its new course using the modular approach with some modifications.

## **Bibliography**

1. Cognition and Technology Group at Vanderbilt. (1997). *The Jasper project: Lessons in curriculum, instruction, assessment, and professional development*. Mahwah, NJ: Erlbaum.

2. Adams, L., Kasserman, J., Yearwood, A., Perfetto, G., Bransford, J. & Franks, J. (1988). The effects of fact versus problem-oriented acquisition. *Memory & Cognition*, 16, 167-175.
3. Barrows, H. S. (1986). A taxonomy of problem-based learning methods. *Medical Education*, 20, 481-486.
4. Collins, A., Brown, J. S., & Holum, A. (1991). Cognitive apprenticeship: Making thinking visible. *American Educator*, 15(4), 6-46.
5. Williams, S. M. (1992). Putting case-based instruction into context: Examples from legal and medical education. *Journal of Learning Sciences*, 2, 367-427.
6. Kolodner, J. L. (1993). *Case based reasoning*. San Mateo, CA: Kaufmann.
7. Krajcik, J., Blumfeld, P., Marx, R., & Soloway, E. (1994). A collaborative model for helping middle school grade science teachers learn project based instruction. *The Elementary School Journal*, 94(5), 483-497.
8. Bransford J., Donovan, M., Pellegrino, J. (2000). *How People Learn*, National Academy Press.
9. Rowe, C., Mahadevan-Jansen, A., Crocetti, J., Brophy, S. *A Paradigm Shift in the Approach to Freshman Engineering Education*. Paper presented at ASEE Annual Conference. 22-25. June, 2003. Published in the Conference Proceedings.
10. Rowe, C., Mahadevan-Jansen, A. *Getting to Know Your Engineering Major*. Paper presented at ASEE Annual Conference. 22-25, June 2003. Published in the Conference Proceedings.
11. LITEE Workshop. Auburn University, Auburn, AL. October, 2001.

## **Biographical Information**

CHRISTOPHER ROWE received his Bachelor of Engineering degree in Biomedical Engineering and Master of Engineering degree in Management of Technology from Vanderbilt University in 1996 and 1998, respectively. He joined the Engineering faculty in January 2003. His research interests include technical program and project management and serves as the Director of the Freshman Year for the Engineering Dean's Office.

ANITA MAHADEVAN-JANSEN received her Master's and Doctoral degrees in Biomedical Engineering from the University of Texas at Austin and subsequently joined the Biomedical Engineering faculty at Vanderbilt University. Her research interests are in the area of optical spectroscopy and imaging for cancer detection. She is also a domain expert in Biomedical Optics in the VaNTH Engineering Research Center (ERC) for Bioengineering Education.