Session 3653

Assessing a Freshman Engineering Course

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Abstract

Assessment is arguably the most difficult activity in an engineering curriculum. An engineering school's first challenge is to align its incoming students with an area of study that appeals to their interests and will allow them to grow academically and ultimately embrace their profession. A secondary challenge is to provide the students with essential problem solving tools in an atmosphere that is engaging while accounting for their diverse educational backgrounds. The assessment tool thus must address these needs. In order to determine the effectiveness of the introductory engineering course, several assessment techniques were used. Initial assessment was performed using a pre-course survey in order to determine pre-conceptions and pre-existing knowledge. Innovative formative assessment used during the course includes using proprietary software permitting real-time, laptop-based student assessment in the classroom. Additional assessment techniques include a common mid-term exam; instructor evaluations for every module; post-module surveys; a post-course survey; and ultimately, student retention numbers.

Introduction

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 satisfies the course goals of fostering early and informed student decision regarding their declared majors, bringing real world engineering problems into the classroom, and anchoring the curriculum in the context of engineering problem solving.

Towards achieving these goals, learning objectives were defined and a model for implementation designed. The learning objectives are (1) to educate the students to apply the problem solving processes essential in solving both design and analytical problems, (2) to enable the students to solve these problems using engineering computing tools while continuing to use the process and (3) to allow them to make educated choices on the use of appropriate tools for the appropriate problems. A modular course implementation system was designed to accomplish both the global as well as specific goals for the students. The semester begins with a general module where basic computing and problem solving skills are developed and the problem solving process emphasized. This module encompasses the first half of the semester and is the driving force of the semester. 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 student proficiencies at the end of module 1 form the foundation in the development of the subsequent modules and are based on the problem-solving methodology in a discipline-specific environment. Thus, the second half of the semester consists of two self-selected four-week, discipline-specific modules focused on a current event or area of research. Each discipline-specific module is 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 three assignments that apply the concepts of problem solving learned in module 1, oral presentations, design and technical writing amongst others. The discipline-specific modules allow students to apply concepts of problem solving in an interesting and challenging setting during the second half of the semester.

The modular course approach is designed to increase student-faculty interaction and to optimize student interaction with faculty from the engineering departments of their choice. It is our expectation that the changes we have designed address students' needs and facilitates their academic goals. These changes provide students with the opportunity to 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, to understand the focus of each (selected) engineering major and then be able to make an informed choice and to begin building professional relationships with faculty members within the student's department of interest.

Assessment

Assessing student learning and understanding of core concepts taught in a classroom is a necessary but a continually difficult task for faculty. With the proliferation of computing technology available in the classroom including the mandatory student laptops, an additional daunting task for instructors is reworking their course in such a way to gather meaningful assessment data in order to determine student comprehension as well as to make effective pedagogical use of these technologies. With the changes implemented to the freshman curriculum, it becomes particularly important for instructors to obtain both formative as well as summative assessment data from the students in order to gain insight into the effectiveness of the new freshman model. Are we achieving our learning objectives? Are we addressing student needs appropriately? Are students actually benefiting from the new approach? Are the instructors adapting to the new learning environment? Do they consider this model to be an improvement from existing or previous practices? The assessment data will aid in answering these and other such questions as well as provide feedback in future implementation of this model. Assessment can be applied using many vehicles and in the initial phases, our focus has been on data acquired through self assessment using surveys. Other assessment data points are provided by analyzing course evaluations, student midterms (as compared to previous years) and in-class assessment instruments.

Methods of Assessment

A pre-course survey was given in order to determine preexisting knowledge and ideas. This survey requested information on major selection, confidence in major choice, knowledge of the chosen major, as well as questions on high school background, computer experience, and mathematical skill as they begin their first college year. This survey probes student perception and insight on what they know and what they think they know based on previous experience and second and third-hand information. At the end of Module 1, the students were asked to complete a mid-semester survey covering topics on computer experience and confidence in computer experience. Lastly, the students were asked to complete a post-course survey asking them to reflect on specific components of their experiences in the first-year course. Items of specific interest included whether a new major was selected and a summary of the selected major; confidence levels in problem solving, computer usage, and computer problem solving; and perceived skill levels in problem solving using the software packages presented. The trajectory of student responses allows us to obtain a measure of the effectiveness of the course from the students' perspective.

While the surveys formed the primary instrument of assessment that could be easily implemented in a large multi-section setting, other measures were also obtained. These include a common mid-term exam taken by all enrolled students regardless of instructor and declared major at the end of Module 1. In addition, students were asked to justify the vehicle (use of computing tool) as well as method of solution (process) applied in the midterm problems.

According to standard practices, instructors were evaluated at the end of each module using standard University evaluation forms. At the end of the semester, each instructor had three sets of evaluations – one general engineering module and two discipline-specific modules. Comparisons can be drawn to differences in style versus pedagogy and its effect on teaching interdisciplinary material versus teaching discipline-specific material in back-to-back modules. Other data include anecdotal information gathered from each faculty instructor on their perception of the effectiveness of the modular format, the implications from the discipline specific modules and the instructional value of challenge based learning.

Classroom Communication Systems (CCS) such as the Personal Response System have been shown to provide a wealth of data towards formative assessment as well as in creating a community in the classroom[1]. Since all freshmen at VUSE are equipped with laptops for school use, a form of CCS was developed for increased assessment and instructional functionality. The prototype system, Refero© allows for students to answer multiple choice, true/false, short answer, and essay questions to give instructors valuable assessment data, whereas traditional CCS systems only allow for multiple choice questions. This is a web-based system that can be implemented in many ways. The prototype system was tested in 2 of the 10 sections in module 1 of the course and 1 section during modules 2 and 3. This is a preliminary assessment of the effectiveness of the system to handle large, multi-section classes through the use of wireless communication. Refero© was implemented to (a) probe student preconception and preexisting knowledge on specific content, (b) reinforce concepts elucidated in class, (c) increase the environment of communication in the classroom, and (d) provide students with the opportunity for feedback, all within the curtain of anonymity of technology.

Results of Assessment Practices

All surveys were given across all 10 sections of the course regardless of the specific instructor and were mandatory in many of these sections. A summary of the yield in responses for all the surveys is given below:

Pre-course Survey Responses = 287 of 314 (91.4%)
Mid-course Survey Responses = 226 of 312 (72.4%)
Post-course Survey Responses = 256 of 307 (83.3%)

Thus the overall return in the responses to the questions asked was sufficient to allow some assertions to be made on student responses and their implications. Consistent through all three surveys were questions on self-assessed student level of competency in various computing tools. These include tools in word processing, presentation and publishing, math-based tools, etc. The most relevant tools which were the focus of module 1 (general module) were Excel and Matlab. While the survey questions did not target specific knowledge of software features and capabilities, students were asked to rate themselves in their general knowledge and familiarity with these tools.

Even though there is an increase in the early use of such tools as MS Word by students, the survey results show an increase in student perception of their knowledge using MS Word. The use of t-tests showed a statistically significant difference ($p \leq 0.0001$) in pre-course skill versus mid-course skill as well as mid-course skill versus post-course skill ($p \leq 0.0001$). Even though MS Word was neither taught nor addressed as class material, students were asked to use MS Word often for in-class and homework problems to describe and interpret solutions to problems. They were likely also using MS Word in other courses. These results are reasonable and it is clear that student skill and comfort level will increase with use, even if preexisting knowledge was high to begin.

While PowerPoint was not presented as class material in any module, students were required to give presentations in the discipline-specific modules. Pre-course survey results suggest students had some prior knowledge of PowerPoint; however, their knowledge increased significantly merely with experience ($p \leq 0.0001$). It is also possible students were gaining experience using PowerPoint outside of the introductory course through participation in freshman seminars and other courses.

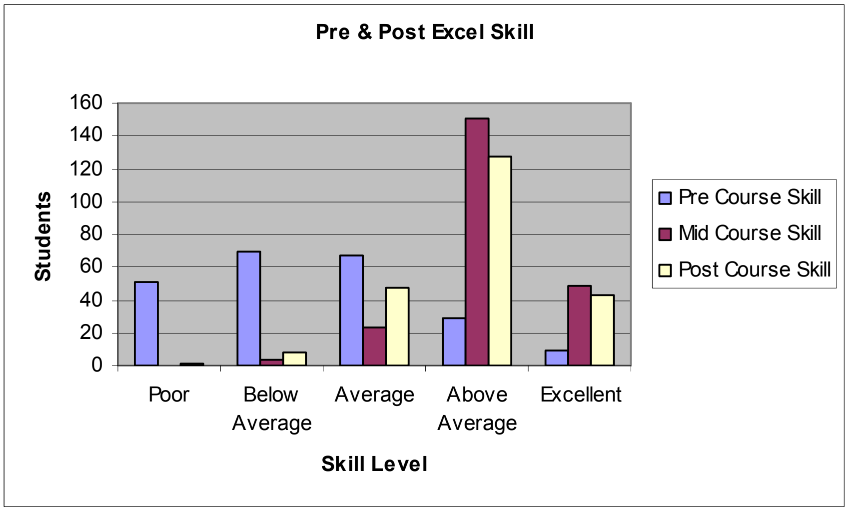

Figure 1: Pre vs. Post Excel Skill.

In analyzing the response to student competency in the use of MS Excel, the Figure 1 above shows a sharp increase in knowledge of using Excel to solve problems. Pre-course student knowledge was initially self-reported as centering on 'Below Average' and 'Average'. At mid-semester, students reported their own knowledge as being 'Above Average'. The results from the post-course survey show a small decrease in an 'Above Average' rating and an increase in an 'Average' rating. T-tests were used to compare results between the three surveys showing a significant difference ($p \leq 0.0001$) in response sets for pre- to mid-course. However, there was no significant difference in Excel skill for mid- to post-course. This suggests that through increased exposure to Excel's capabilities in the discipline-specific modules, students realized that there is more they do not know about problem solving in Excel, thus allowing the students to realize the extent of their own knowledge and accounting for the shift of scores from mid-course to post-course.

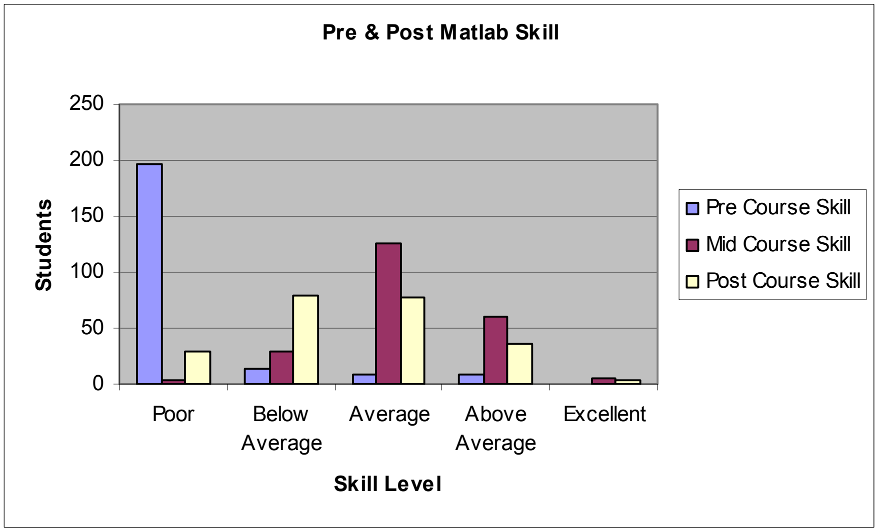

Figure 2: Pre vs. Post Matlab Skill.

As with most first-year engineering students, knowledge of problem solving in Matlab is nearly non-existent at the beginning of the first year. A vast majority of incoming engineering students had never heard of Matlab before completing the pre-course survey. A significant percentage of Module 1 was devoted to teaching problem solving using Matlab's capabilities. As seen in Figure 2, the growth of knowledge was much more gradual than with previous, more commonly used in high school software packages. However, the distribution in the mid-course results with a shift towards higher scores shows a significant increase in knowledge from pre- course results ($p \leq 0.0001$). Another observation in the above chart is that there is no significant change in Matlab skill from the mid-course survey to the post-course survey. Only three discipline-specific modules used Matlab more extensively than the other seven. The biomedical engineering module, for example, contained an assignment on image processing, thus the students had to expand their knowledge rapidly for a short amount of time. Students may have realized at the end of the course how little they actually know about Matlab and realized their knowledge is very limited, resulting in lower self-evaluations than previously provided at mid-course.

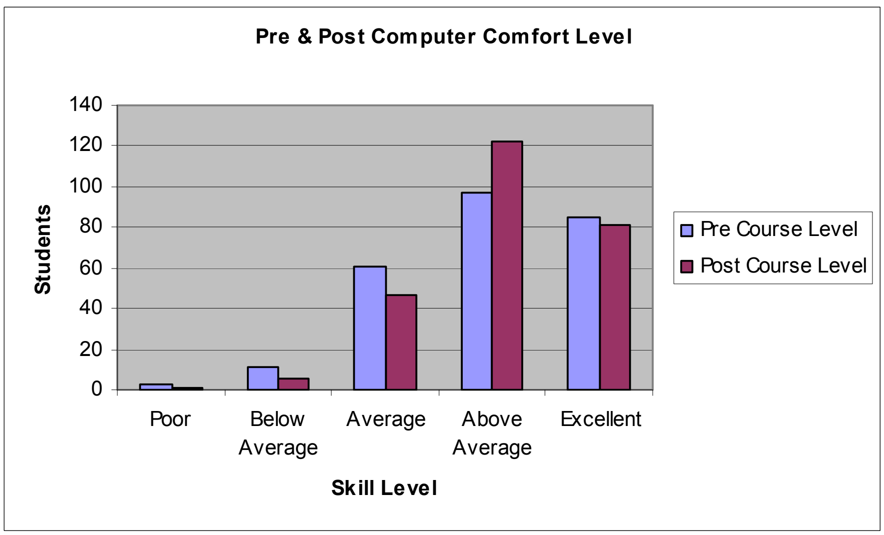

Figure 3: Pre vs. Post Computer Comfort Level.

One of the major goals of ES 140 is to allow students to gain knowledge and experience in problem solving using appropriate computing tools. All first-year engineering students receive a laptop upon entering the School of Engineering, thus significantly increasing their level of experience. However, students were initially much more comfortable using graphing calculators to solve problem than computers. Figure 3 illustrates that students' comfort levels increased significantly over the course of the semester ($p \leq 0.0032$).

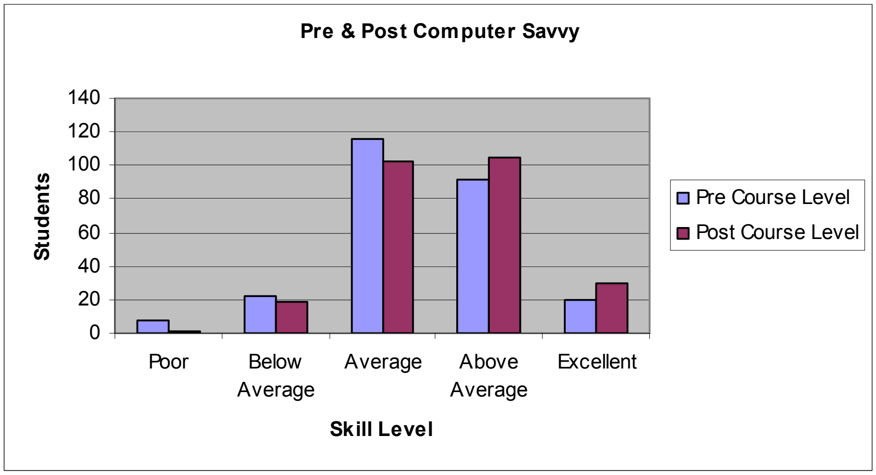

Figure 4: Computer Knowledge, Experience, and Confidence.

Assessing a student's increase in his or her ability to adapt his or her expertise is very important in determining the success of an academic program. We asked students to rate how "computer savvy" they felt they were when defining "savvy" as knowledgeable, experienced, and confident. As illustrated in Figure 4, the post-course survey results show a slightly flatter distribution centering between Average and Above Average as compared to the pre-course survey results which show a sharper and slightly steeper distribution centering more on an Average rating ($p \leq 0.0001$).

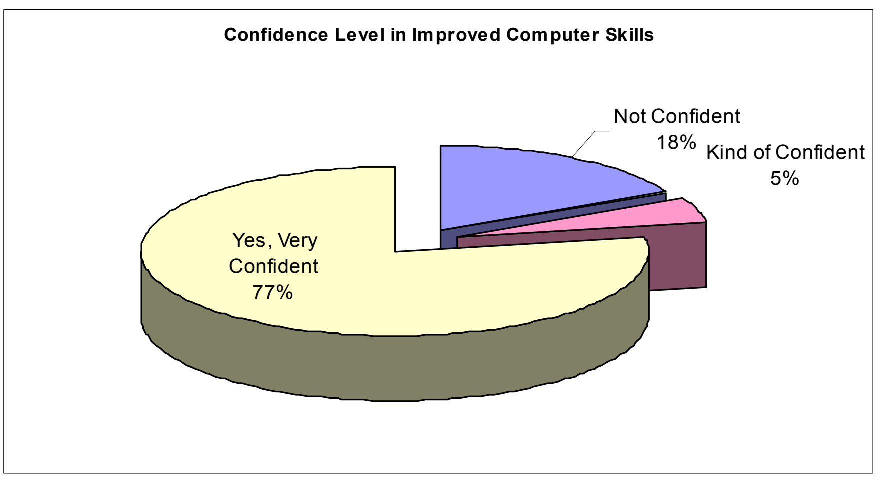

Figure 5: Computer Skill Confidence Level.

The post course result measuring increased confidence in computer skills is as expected, as illustrated in Figure 5. About 23% of the first year students stated they do not feel they have significantly increased confidence in their computer skills. Reasons for this feedback could be that few students really did not learn much new material because they had advanced computer skills upon arrival. Another argument is that some students still feel genuinely uncomfortable with solving problems using a computer even after one semester of coursework.

Anecdotal student feedback can be valuable when students provide specific examples in responses to open-ended questions. When asked about their opinions in using the formal problem solving method presented in class, the students' responses partially fell into the six main categories shown in Figure 6 below.

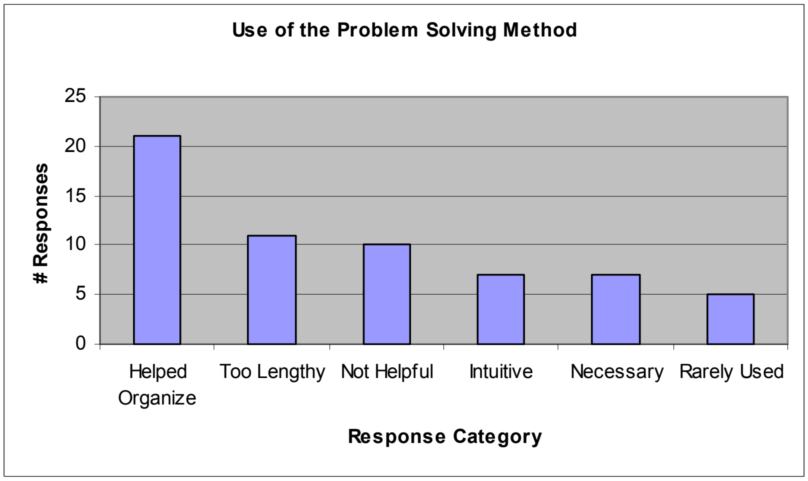

Figure 6: Anecdotal Responses to Use of Problem Solving Method.

About 10% of the students stated they thought using a formal problem solving method allowed them to organize their thoughts while problem solving. More students than expected reported that the process was too lengthy to use and that it was not very helpful. A smaller number of students reported that the process was intuitive and necessary for successful problem solving. While these results are not overly positive, they show that a significant number of students realize the importance of using a formal process to solve problems. Negative feedback could be a result of requiring all students to apply explicitly each step of the problem solving process in every homework assignment throughout the semester, thus making homework problems much longer to complete than if a process was used implicitly.

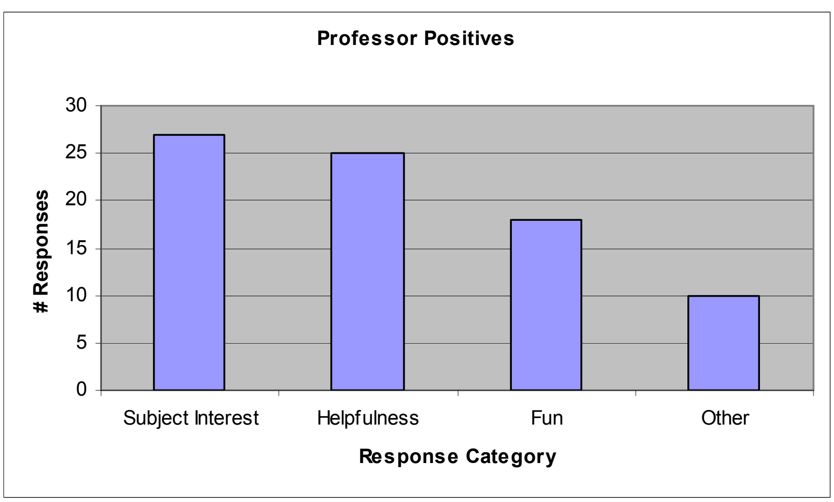

Figure 7: Feedback on Instructors.

In addition to standard University instructor evaluations, we asked the students to comment on what they liked about their instructors in ES 140. All students had at least two instructors and most students had three instructors for the course as they moved from module to module.

Resulting comments could be divided into three main categories – instructor's interest in the subject matter, instructor helpfulness in learning the material presented, and how engaging and entertaining the instructor was in class, as shown in Figure 7 above. The largest group of students commented on the interest level of the instructor in presenting class material. This response came largely from students' experiences in the discipline-specific modules.

An important metric for the School of Engineering in determining the success of the freshman program is the alignment of students with a major that appeals to their talents and interests in order to retain as many students as possible. Measuring the success of this goal is difficult and we rely heavily on student feedback and retention numbers.

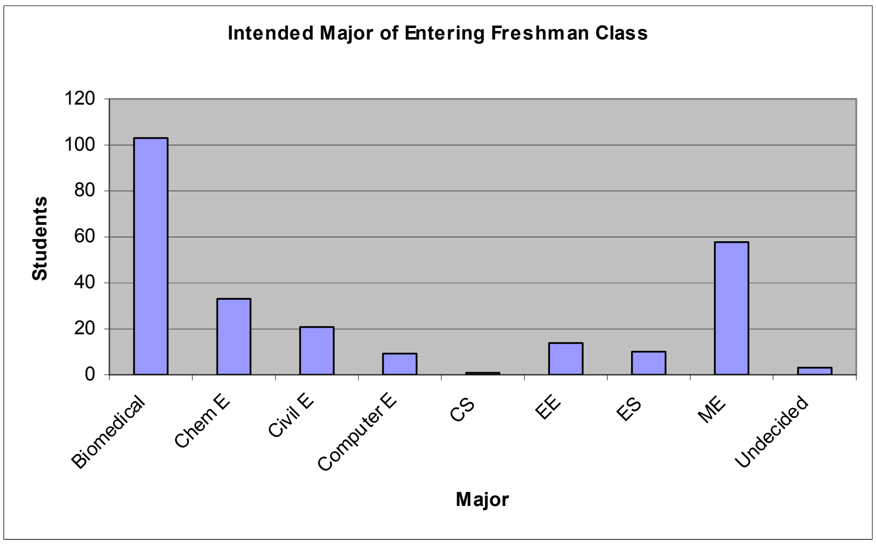

Figure 8: Entering Students' Intended Majors at Beginning of Semester.

Figure 8 shows the major choice of entering first-year students. Nearly one third of entering students declare biomedical engineering as their major followed by mechanical engineering. Our challenge is to educate students on the various engineering disciplines available to them and encourage them to explore other engineering major options. The current course format was created primarily to fulfill this goal. As a result, we are interested to know how many students are changing their major, to what discipline the change is being made, and why the change is being made. The following two charts show the percentage of students who stated they are interested in changing their major and to what program they are interested in changing.

The group of students interested in changing their major (15%) includes those students who are staying within engineering but choosing a new major and those planning on leaving engineering. We anticipate the latter will be extremely small keeping with historical trends. University policy says that freshmen are prohibited from changing Schools within the University until the completion of one full academic year; therefore, it will not be until the end of the upcoming academic semester before we see true retention numbers.

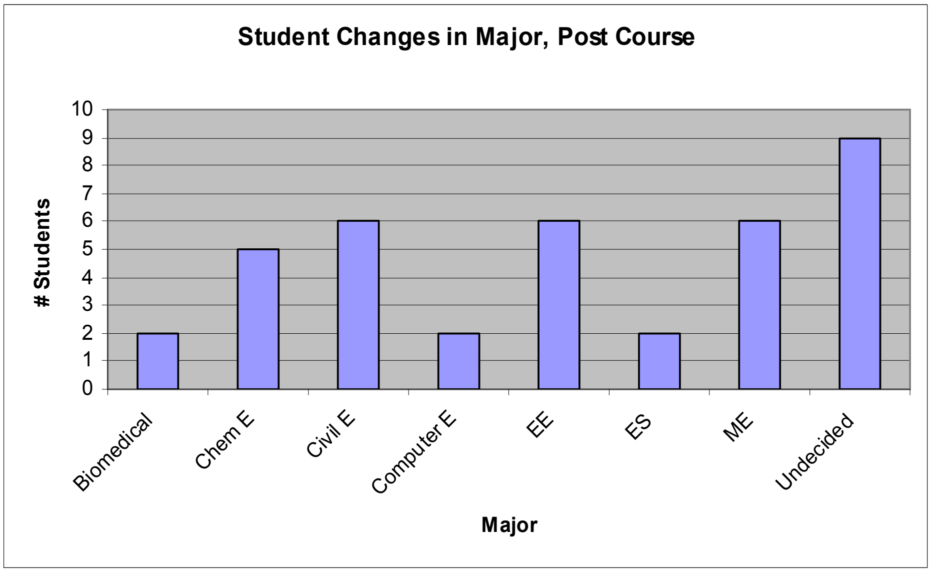

Figure 9: Post-Course Major Changes.

Figure 9 identifies disciplines into which students are changing. It is interesting to note the increase in the Undecided category. Upon applying to the University, students are strongly encouraged to declare a major. This selection is not necessarily binding to the student, thus giving a slightly skewed impression of freshman enrollment numbers. After a considerable amount of exposure to various engineering disciplines, it is clear that a small number of students are still trying to align themselves to an area of study that best suits them while others are making more confident decisions.

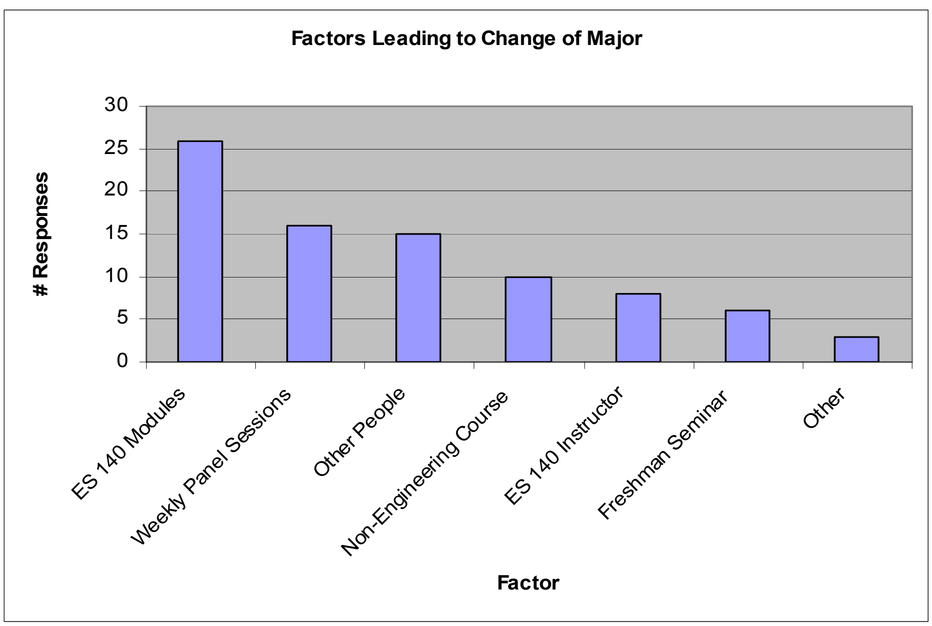

Figure 10: Factors Leading to Change of Major.

The reasons students stated for changing their majors are shown in Figure 10. ES 140 modules played a significant role in student decision-making, which is a reasonable result considering the major-specific modules were half of the content of the introductory course. An encouraging result is the secondary reason being the weekly panel sessions. These sessions comprise a series of panel discussions focusing on a specific engineering discipline each week. Each panel involves alumni, faculty, and current students; and showed greater attendance this year over past years with nearly every panel session filling a 120-seat lecture hall.

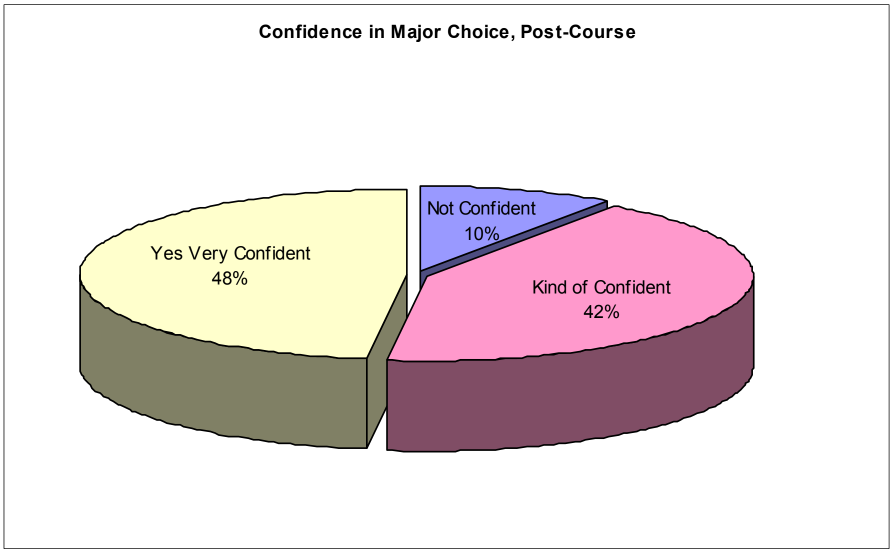

Figure 11: Post-Course Confidence in Major Choice.

Student confidence in major selection is critical to academic success in engineering school. Figure 11 shows that a large majority of the first-year students are confident in their choice of major with a small percentage (10%) not being confident at all. We expect that the 42% of the "Kind of confident" students will solidify their decisions in the second semester of their freshman year. The confidence levels reported in the pre-course survey have the Very Confident category at 40% - 8% less than the post-course survey results. The "Kind of Confident" category was 8% greater at 50%. The "Not Confident" category was unchanged.

These results suggest that some students became less confident in their major selection once they were exposed to other major options available to them. The results also suggest that it is difficult to achieve a significantly higher percentage of student confidence in the first semester based on only a few curricular modifications and a relatively short time of exposure to the major. Overall, there was a small increase in student confidence in major selection which fulfills one of the main goals of the course.

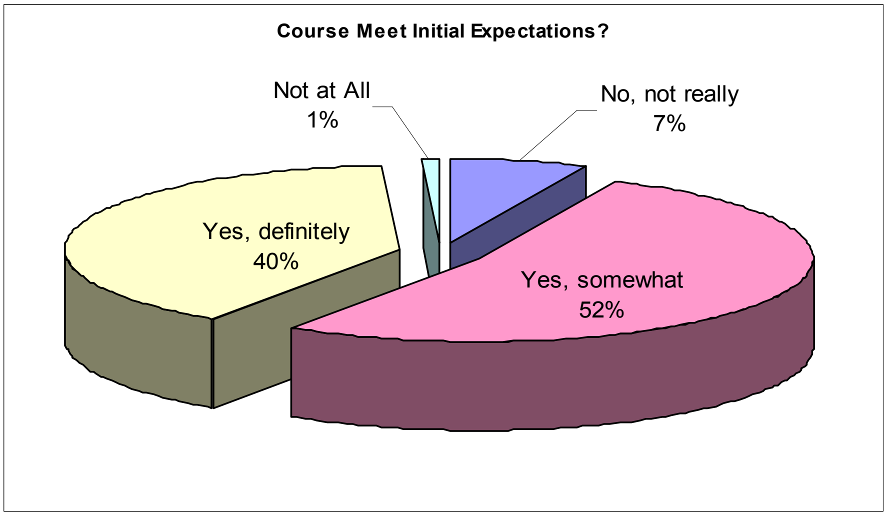

Figure 12: Accomplishment of Initial Expectations.

It is obvious the introductory course is a work in progress as introductory engineering programs should be at any engineering school. With only 8% of the students expressing true dissatisfaction, as seen in Figure 12, these results are encouraging to our efforts. They also show that we still have work to do.

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 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.

Due to early problems with the use of Refero®, much of the results presented in this report are qualitative and result from informal survey and observations. The effectiveness of such communication systems has been extensively reported in the literature although new avenues of implementation were identified as part of this study. We plan to develop assessment tools and rubrics that would allow us to quantify some of these parameters within the context of the intended use of such technology. As part of this study, we also applied Refero© for assessing student pre-conceptions. This use aided tremendously in presenting course content but required a fundamental shift in the method of instruction to increased flexibility in content focus as well as direction. An interesting observation was that the student wanted to discuss the basis for some of the pre-conceptions and its relationship to engineering principles. It was also observed that such preconceptions had to be addressed repeatedly before students were convinced to change their thought-processes.

Perhaps the most significant impact on instruction and classroom dynamics was the use of Refero© to increase student led discussion in the classroom. This use widely opened the path of communication between instructor and students as well as between students themselves. During the first day of the module with a new cohort of students, it was readily apparent that students showed an unwillingness to participate in class lending itself to poor faculty-student interaction. Using Refero©, however, resulted in near 100% response from the class, yielding numerous discussion points for enhanced communication. Two interesting observations were (1) despite the anonymity there was continued resistance from 2-3 students to such interaction and (2) half way into the module, student felt comfortable interacting verbally where previously they did not want to indicating the technology helps break the ice, but then becomes less essential for sustaining classroom dynamics.

In general, students indicated a willingness to use such technology, and, in fact, showed an expectation of seeing such pedagogical ideas in future courses. Most students agreed with using the laptop for assessment. Interestingly the majority of the students indicated that the use of such assessment was a measure of the level of caring of the instructor and made the instructor easier to approach as a result.

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. The results obtained from the survey clearly indicate an increase in the competency in the use of specific computing tools as well as a self recognition of how much more there is to learn. The results also indicate that the curricular changes empower student to make an informed decision about their major, thus achieving a primary goal for the freshman year. While the course and associated modifications in the curriculum have demonstrated to have had a significant impact on student learning as well as perception, the results also indicate areas of improvement. It is well recognized that use of the problem solving process, while time-consuming, aids in solving complex engineering problems and are key in subsequent year of engineering education. However, it is essential to impart these skills without frustrating the students. Thus modifications will have to be made to transition the use of the process in more effective ways. Implementation of more open-ended problems may emphasize the need for the process and facilitate their use.

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.

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Biographic Information

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ANITA MAHADEVAN-JANSEN received her Bachelor and Master of Science degrees in Physics from the University of Bombay, Bombay, India, her Master and Doctoral degrees in Biomedical Engineering from the University of Texas at Austin 1993 and 1996 respectively. She joined the BME faculty at Vanderbilt University in the fall of 1998. She is a domain expert in Biomedical Optics in the VaNTH Engineering Research Center (ERC) for Bioengineering Education.