Exploring Engineering at Bucknell University: a Seminar Approach to the First-Year Engineering Experience

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Abstract

Bucknell University requires all incoming engineering students to take an introductory engineering course. The course is typically taught by a team of six faculty and has an enrollment of over 200, while the size of a typical class at Bucknell is below 35. While this course has been successful at achieving its objectives in the past, it was felt that it could be improved in terms of class size and depth of coverage. This year the class was taught in four segments. The first segment was not altered – lectures were delivered to the whole class in the traditional manner, combined with smaller laboratory segments. Lectures included: engineering as a profession, the engineering design process, information on each engineering discipline, teamwork and learning styles. This was complemented by a team project in which students used the engineering design process to design a park. For the second and third segment, students were able to choose two of six quasi-major-specific seminars. Each three-week seminar had a class size around 33 students, a lab size of about 16 students, and featured a team-based hands-on project. Seminar titles included: Engineering Athletics, Programming a Computer, Green Engineering, Flinging Things, Pasta Towers and Digital Logic Design. Not only did these seminars allow a smaller classroom setting and more in-depth study, we found that it provided an opportunity for both students and faculty to take ownership of the course. The final section was also taught in the large classroom setting and centered on ethics and professional responsibility. This segment included laboratory discussions of ethics and discussions of books focused on engineering and society. It is our observation that this course structure resulted in a more optimal mix of breadth and depth, while giving students in a large course a small class experience.

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Introduction

Bucknell University is a primarily undergraduate university with a focus on undergraduate education. The College of Engineering consists of approximately 700 undergraduate students, currently divided among 5 major fields (Chemical, Civil and Environmental, Computer Science, Electrical, and Mechanical Engineering). Part of Bucknell's focus on undergraduate education is a commitment to small class sizes. Half of the classes at Bucknell have 18 students or fewer and courses with more than 35 students are typically split into two sections. However, there are several exceptions to this course-size rule, found primarily in first-year introductory classes.

Exploring Engineering is an introduction to engineering course taken by all 200 incoming first-year engineering students. The objectives of this course are given in Table 1.

Table 1: Course objectives for Exploring Engineering

Objective	ABET criterion 3[1]
1. Provide overview of basic engineering practice, including histories, impact on society, skills employed, and professional/ethical responsibilities	f, h
2. Provide instruction to knowledge bases, skills, problem types, and analysis techniques of the five engineering disciplines at Bucknell	
3. Develop skills for productively working in multifunctional teams, supported through guided practice and reflection	a, e
4. Develop strategies for addressing open-ended problems, and engage in design of systems intended to meet specific needs	d,
5. Develop technical communication skills	c, k
6. Provide knowledge and guidance allowing students to make an informed decision about choice of engineering major	g

This course is taught by six engineering faculty representing all the majors in the Engineering College. In the past, students would meet together three times a week for lectures on the various disciplines of engineering, problem solving, engineering as a profession, engineering ethics as well as lectures given by guest speakers. Once a week the students would meet in a smaller setting, supervised by one faculty member, for labs done in teams.

This previous format did fulfill the stated objectives in Table 1. However, it did not allow for the small lecture setting that Bucknell desires. It was difficult to hold the students accountable for their presence, and the course was not always successful at capturing the attention of the students. Additionally it was not possible to go into much depth about any one topic due to the limited time allotted to each major and the desire to provide information useful for all students, not just those considering the given major. Finally, because the lectures did not change much from year to year, there was little opportunity for faculty to contribute uniquely to the course. This format led to less faculty interest and enthusiasm.

The goal in re-developing this course was to maintain the objectives stated previously while addressing the issues of large class size, the need for more in-depth coverage, and greater faculty ownership. We feel that we accomplished this goal by adding faculty run “seminars” within the course. The students were able to participate in two out of six seminars that corresponded roughly to the five engineering majors. Each seminar contained 30-36 students, ran for slightly more than three weeks, and included three two-hour lab sessions. These seminars, along with the standard lectures at the beginning and end of the course, allowed the students to experience both the breadth and depth desired in this course.

Detailed description of course format

Exploring Engineering consists of three one-hour lectures per week as well as one two-hour lab per week (equivalent to a 4.0 credit course). The revised 15 week course was split into four segments (called modules) as summarized in the table below. The lectures in the first and last module were taught by various engineering faculty to large classes while each of the middle two modules were taught by one faculty to a smaller group of students in seminar format. Each module is described in more detail below.

Table 2: Layout of course timeline and goals.

Week #	Module description	Course objectives met	Lecture Class size	Lab Class size
1 – 5 ½	2.A. Engineering as a profession	1, 2, 3, 4, 5, 6	210	12-15
5 ½ - 9	2.B. Seminar #1	2, 3, 4, 5, 6	30-36	15-17
9 – 12 ½	2.C. Seminar #2	2, 3, 4, 5, 6	30-36	15-17
12 ½ - 15	2.D. Engineering and society	1, 5	210	10-11

2.A. Engineering as a profession:

The goals of the first module were to give students an overview of engineering as a profession as well as to expose them to the various engineering disciplines. The first module was very similar in format and content to the previous version of the class. The only significant change was that less emphasis was placed on discipline-specific problem solving, which was instead handled within the seminars.

In addition to the lectures, there was a team-based laboratory design component for the first module based upon designing a park for an unused 20-acre parcel of university property. Each three-student team was given a plot of land and asked to come up with a plan for the land using the engineering design process.[2] The expenses of their plan could not exceed a given financial constraint. They worked together as a team to develop and rank criteria for this plan and then used these criteria to evaluate their plan. This project culminated with a written report as well as an oral presentation. This project had been assigned in previous years, and was included here in compressed form (across three laboratory sessions rather than five). This project was also assigned early in the semester, rather than at the end as before, in order to get the students involved in teamwork without the need to first introduce many specific technical skills.

2.B. & 2.C. In-depth seminars

In these two segments ,the students opted to take two out of six seminars offered. The students were given a brief description of each seminar and asked to rank the seminars from 1-6. They were also asked to weight their choices with a dollar amount (for a sum of $100). All of the students received their first choice and 75% received their second choice. Although the majority of the students were accommodated by their first and second choices, there was a small but significant number (~20) who were assigned to both their first choice and their third, fourth, or fifth choice seminar.

While it was not the goal of the seminars to reflect a specific major, most of them are closely allied with the field of the professor leading the class. However, it should be noted that none of the seminars had the goal of introducing students equally to *all* of the sub-fields in a given major; rather, they were a more in-depth look at a particular project or area of engineering. Furthermore, it was communicated to the students that they should not feel that a given seminar was in any way *required* for entrance into a particular major. One of the seminars (Engineering Athletics) was deliberately not allied with a particular major.

The full description of each seminar is given below:

Engineering Athletics: Better, Faster, Stronger.

In this seminar, students looked at some specific examples of how engineering design has affected athletic gear and performance. While there are almost infinite examples to choose from, the seminar focused on three: gloves worn by soccer goalies, "fast" swimming pools, and sneaker design. The material was covered in a semi-project based format; that is, material covered in lecture was driven by the project underway in lab, with time in lecture allotted for team meetings to discuss lecture material and its application to the laboratory project.

The first topic, goalie gloves, was a one-day analysis done on the first day to introduce students to the intersection of engineering and athletics. Students calculated the force needed to break or sprain a finger, and then worked out the force which can be delivered by a professionally kicked soccer ball (breaks turn out to be unlikely, but sprains are quite possible). Students then reviewed the design of goalie gloves with a better understanding of the functions of each of the design elements.

The second and third topics revolved around laboratory experiences. In the first, students were challenged to design a "fast" pool; that is, a pool in which disturbances die out quickly. Teams were given a list of constraints, a model pool (a Rubbermaid under-bed storage box), and a large amount of raw material for pool modifications (Styrofoam blocks, clay, balsa wood, and tools). "Fast"-ness of the pool was assessed by the amount of time needed for a fishing bob to come to rest (shorter times were better). Students began their design by "trial-and-error," and then improved it based on lectures on fluid mechanics and energy conservation. Results were analyzed using digital video analysis and presented in the form of an oral report.

The final segment of the seminar was devoted to sneaker design. Lectures centered on biomechanics and the material properties of sneaker elements, while the laboratory component was for the student teams to determine which, out of three choices, was the "best" sneaker for a given athletic event. Teams were allowed to invent their own specific definition of the "best" sneaker, then to select from a menu of tests those which would aid them in selecting that "best" sneaker. The number of tests which could be performed was limited by cost (each test had a price, and the students were given a budget). During laboratory time, the teams performed the tests they had selected and then analyzed their results to determine the best sneaker.

While this seminar was not specifically allied with any major, concepts common to many fields (materials science, fluid mechanics, mechanics, and a little biomechanics) were covered. Care was taken to mention to which fields each given topic was relevant, so that the engineering majors would feel they were learning something which would be related to their future majors.

Programming a Computer

The objective of the computer science seminar was to give the students an introduction to computer programming, without duplicating the material in the Computer Science department's introductory course. Since the seminar was just three weeks long, covering the material in a meaningful way was a real challenge. Alice, a visual programming environment that is freely available from <http://alice.org> was used. Alice has the expressive power of languages such as C++ and Java, but because of its visual nature, the students are not burdened with syntax.

In just three weeks, we were able to cover many of the topics that appear in a traditional CS1 course. Students learned about objects, loops, Boolean expressions, conditional expressions, and concurrent programming. Students constructed 3D virtual worlds and placed objects in them. The visual representation of objects provided immediate feedback to the students, which enabled them to learn much more quickly than they would with a traditional programming language.

The laboratory component of the seminar consisted of exercises which reinforced the concepts covered in lecture. For example, one exercise was to program two horses to walk towards one another. To complete the exercise, the students needed to understand methods and parameters which had been covered in an earlier lecture.

Choosing a visual programming environment was the key in achieving the goals of this seminar in the time allotted. It enabled the students to learn the basics of object-oriented programming while having fun.

Green Engineering for the 21st Century

This seminar addressed the growing need to incorporate environmental (or "green") components to engineering design. The overarching theme of this seminar was use of life cycle assessment – a technique for quantifying the effect that a product or process has on the environment over the entire life cycle. Examples discussed in lecture included the use of paper versus plastic bags and improving the design of automobiles. In order to perform these assessments the students also needed to learn about environmental impacts such as toxicity of chemicals, global warming, and ozone depletion.

The lectures were complimented by the lab sessions where teams of students worked on five hands-on projects. All of the following labs involved analysis and decision making. They also forced the students to address some of the current environmental issues that engineers may face. 1) Electronic disposal: The students were given old computers and asked to dismantle them in order to recycle them. They were asked to identify the hazards involved and make suggestions as to improve the design of the computer to make it more easily recyclable. 2) Recycled paper: The students made a number of sheets of paper with varying recycled content. They then tested these sheets for quantitative (e.g. strength) and qualitative properties (e.g. ease of writing). They were asked to analyze and decide on the best formulation for a given application. 3) Energy Use: Students were given a wattmeter and asked to measure the energy use for various appliances provided. Most teams chose to compare the energy use during various functions of a desktop and laptop computer. Others focused on how to better supply this energy to the appliance. 4) Green Building design: The College of Engineering at Bucknell is building a new engineering building. The students were asked to re-design the building to minimize energy use. One of the main tools that they utilized was a software package called Energy 10. It was easy for the students to use and gave them a "feel" for the effect of various design criteria such as insulation and windows on total energy use. 5) Green Packaging: Students in this lab were asked to design the more environmentally friendly package that could protect an egg from a drop of 5 ft. They were given various packaging material as well as the price and environmental impact of each product (e.g. kg CO_2/dollar of material) and asked to analyze their packages to find the least environmentally intrusive.

During the first lab session, teams of students rotated through all the labs. For the second lab session, each team was assigned to one lab and asked to continue the work from the week before. This allowed each student to experience each lab, albeit some for a short time. During the final lab, teams of students presented their results to the rest of the class in a 20 minute oral presentation.

Flinging Things

This seminar was centered primarily on engineering analysis of a medieval siege weapon called a trebuchet. The students were asked to assume the role of consultants to a fictitious historical re-enactor, Albert the Hun, who would like to sell table-top trebuchets at his concession stand at the next renaissance fair. At the beginning of the seminar, each student team was provided with the major components of a simple trebuchet. By the end of the seminar, they were to provide Albert with recommendations for the optimal proportions for the various components, such as the throwing arm and the sling, as well as a design for a mechanism to release the projectile (a golf ball).

The lecture sessions were spent providing guidance on how to use a systems approach to design for this problem, how to use physical principles to predict the range of the trebuchet, and how to optimize its performance through a combination of analytical, computational, and experimental techniques. Each lecture was directly related to the problem at hand, but was also used as a brief introduction to a specific topic from mechanical engineering. For example, overviews were given of vector mechanics to analyze the projectile motion and kinetics, mechanics of materials to consider the stresses in the throwing arm, and fluid mechanics to estimate the effects of aerodynamic drag. Each team derived detailed analytical expressions of the motion of the trebuchet and the projectile. A major element of the final report was a detailed energy balance on the trebuchet in which the teams accounted for the observed performance of their final designs. In the first laboratory session, the students developed and experimented with a simulated trebuchet using Working Model®. The next week they performed field testing of their prototypes, which they videotaped. In the third session, they performed a frame-by-frame analysis of the videotape to determine the exchange of energy from the device to the projectile. A major emphasis throughout the seminar was on achieving not just long throws, but being able to use engineering methods to improve upon and account for the observed performance.

Most students found the seminar to be somewhat more mathematical than they expected, but were pleased with the outcomes of their efforts.

Pasta Towers: Whose cuisine will reign supreme?

The objective of this seminar was to explore engineering through the profession of a structural engineer. An overview of the process typically used to design large-scale structures, such as buildings and bridges, was initially provided. Students learned that successful designs are based on an understanding of three essential topics including design loads, available materials, and applicable structural forms. With this insight, three lectures were spent on each of these topics, which were further complimented by laboratory sessions and a project as described below.

The design load lectures included in-class exercises where students worked in pairs. One of these activities included the identification of different effects for which various types of structures are designed. The groups classified their design loads according to provided definitions of dead, live, and environmental loads. They then weighed samples of steel and concrete in order to develop an understanding of the approximate magnitude of dead loads in a typical office building. Using the weights of classmates, water, and instructional materials, such as books and computers, the students further estimated live and environmental loads that might be used in designing a college dormitory. Their estimated values were then compared with actual design loads provided in building codes. Basic concepts of wind and earthquake loads were also presented.

The next series of lectures presented the basic requirements of structural materials, such as steel, concrete, and timber. Strength and stiffness concepts were emphasized. Equipped with a fundamental knowledge of tension, compression, bending, and torsion, students participated in a three-part materials laboratory session. Tension tests on steel, cast iron, and aluminum were performed at the first station. Students gained an appreciation of ultimate strength, modulus of elasticity, and ductility by comparing the obtained stress-strain diagrams and failure modes.

Compression tests were then performed at the second station. By varying the length of aluminum columns of the same cross-section, students observed the corresponding impact on buckling strength. They also made comparisons with results obtained using Euler's equation. The third experimental station included a series of torsion tests where the stiffness of closed (tube) and open (tube with slit) sections were evaluated and compared.

With the students equipped with a basic understanding of design loads and the performance of construction materials, the remaining lectures focused on structural form. The basic behavior of beams, columns, trusses, arches, continuous beams, frames, and domes was explored. In-class exercises relied heavily on physical intuition since the students had not had a course in statics. For example, one class exercise included using visual inspection to determine tension and compression members within statically determinate trusses. Several real-world examples, ranging from those found in nature to ancient structures to modern buildings and bridges, were presented for each structural form.

Six homework assignments were given during the seminar. Each assignment consisted of reading a case study from the book *Why Buildings Fall Down – How Structures Fail* by Salvadori and Levy.[3] To assure that the reading was completed, students were required to submit a 500-word brief that described specific case details (i.e. when, where, what occurred, why, and who was responsible) and, just as important, their own personal reaction.

An outside-of-class design project also ran parallel to the lecture series. In the first laboratory session, students were presented with a project that consisted of designing, analyzing, constructing, and experimentally testing a scaled model of a water tower. These efforts were artificially intended to assist the city of Kobe, Japan, where in 1995 earthquake damage resulted in massive fires that destroyed a substantial portion of the city. Students worked in groups of three to construct 36-inch tall towers that could fit within a 14-inch square footprint. Building materials were strictly limited to 1 lb of spaghetti, 4.5 oz of quick-dry epoxy, and a 2 qt plastic bin. Students used basic intuition and the structural analysis program MASTAN2 to explore design alternatives. [4] The final laboratory session consisted of experimentally testing their pasta towers on a small-scale shake table. Using the actual Kobe earthquake signature, most of the towers could support between 10 and 18 pounds of weight.

Digital Logic Design and the Engineering of MP3s, DVDs, and Cell Phones

This seminar was centered around a team-based laboratory project on digital logic design, computer simulation, and hardware implementation. Students worked in teams during the first six lectures to learn digital logic design tools, including truth tables, Boolean algebra, Karnaugh maps, and state transition tables for sequential logic design. The final three lectures were used to introduce the basic principles of digital information processing, including sampling, quantization, and compression. Multimedia demonstrations and MP3 were used to illustrate these principles.

The laboratory project was to design an interface to a network of 15 motion sensors that surround a sensitive building to detect intruders. The sensors are arranged in three concentric rings around the building. The objective is to design and construct a digital logic circuit that monitors the sensors and displays the "level of threat" on a 7-segment display. If none of the sensors are active, then the 7-segment display is off. If the intruder is detected in the outermost ring of sensors, then "F" (for **F**ar) is displayed on the 7-segment display. If a sensor in the middle ring is active, then "C" (for **C**lose) is displayed. If the intruder is detected in the innermost ring of sensors, then "A" is displayed (for **A**larm) and an audible tone is sounded. In addition, the circuit remembers and displays the *highest* level of threat detected.

The design is partitioned into three subsystems: (1) an interface to the sensors, (2) memory to remember the highest intrusion, and (3) a driver for the 7-segment display. A complete system is developed by a group of three teams, where each team has three students. Each team is responsible to design, simulate, and implement in hardware one of the subsystems. Then one team plays the additional role of integrator to simulate and connect the overall system. The project contains several parameters that may be optimized, and students are asked to strive for the simplest hardware implementation. Each team presented their design to the class during lecture 6, and some teams achieved their goal using very simple circuits. Students wired their circuits outside of class, and the third laboratory session was devoted to debugging and demonstrating the circuits.

The seminar provided an introduction to two aspects of electrical and computer engineering: digital logic design and digital information processing. The digital logic topic was treated in considerably more depth, but the lab project helped to make the 0's and 1's that we discussed in the digital information processing segment a "bit" more tangible.

2.D. Engineering and Society

The final segment of the course was again similar to the previous version of the course, where students in the large lecture typically spent the last few weeks of the class learning about ethics and the relationship between engineering and society. The key difference was that this year the ethics section was made more *personalized* than in years past by using laboratory sections for discussion of specific ethical situations and writing about the ethical implications of a situation presented in a book.

The lecture segment of the course was used to introduce the students to the concept of professional (and specifically engineering) ethics, to demonstrate the applicability of ethics through a number of case studies (such as the Ford Pinto and the Citicorp building), and for guest speakers. These lectures gave students examples of engineers who made the right and wrong ethical decisions and showed them the implications of these decisions. The lectures were accompanied by one laboratory segment where the students reviewed and discussed a number of videotapes showing ethical dilemmas involving academic responsibility (e.g. cheating on a take-home exam, bringing data into a laboratory). [5] These videos not only taught students about academic responsibility at the University but gave them the opportunity to practice ethical decision making for immediately pertinent situations.

The remaining two laboratories of the semester were devoted to the discussion of the relationship between engineering and society as illustrated in a specific book. A faculty member in each of the five departments sponsored a book. While it was not required that each text specifically align with a major, most are tied closely to a particular engineering field. These books included: A Civil Action by Jonathon Harr (Chemical Engineering), The Johnston Flood by David McCullough (Civil and Environmental Engineering), Cuckoo's Egg: Tracking a Spy Through the Maze of Computer Espionage, by Clifford Stoll (Computer Science), Wireless Nation by James B. Murray (Electrical Engineering), The Biotech Century by Jeremy Rifkin (Biomedical Engineering). Students ranked their choices and were given their book choice during the 8th week of class. Approximately 85% of the students received their first choice of book. They were asked to read their chosen book and bring an outline of it to the first lab meeting. For the second lab meeting, the students were asked to write a brief two-page memo discussing the ethics situations presented in the book. During the laboratories, the students participated in various role playing activities in relationship to the book.

Instead of a final exam, students were asked to draw from the book content and explore the relationship between technology and society by attempting to answer the following questions. 1) Who is responsible for the development of technology? 2) Who should be responsible for the acceptance or rejection of technology? 3) Who should be responsible for monitoring the use and/or misuse of technology? In addition to drawing on specific examples and issues from the book, they were also asked to integrate perspectives from course lectures and seminars and/or personal experiences.

Assessment and Attendance

The table below shows the assessment used for the student's grades.

Table 3: Assessment used to calculate student grades

Module	Assignment	%
Engineering as a profession	Quizzes on engineering major lectures & Labs (computer and library)	10%
	Park project	15%
		(25%)
Seminar 1	Homework assignments and laboratory memos	2.5 – 10%
	Team project	7.5 – 12.5%
	Final quiz	7.5%
		(25%)
Seminar 2	Homework assignments and laboratory memos	2.5 – 10%
	Team project	7.5 – 12.5%
	Final quiz	7.5%
		(25%)
Engineering and Society	Book outline	5%
	Role playing memo	5%
	Final paper	15%
		(25%)

In order to maintain fairness across all the modules, we normalized the grades to a common mean.

We also maintained a strict attendance policy. An absence from a lecture resulted in 2% off the final grade while an absence from a laboratory resulted in 5% off the final grade. Students with excused absences (ranging from athletics to illness) could make up for the lecture absences with a two-page paper assigned by the professor in charge of the lecture.

Results and discussion

Quantitative data on student impressions of the course were assessed in three ways. First, on the last day of each seminar, a survey was given assessing the effectiveness of the seminar and the seminar professor (seminar survey). Second, an end-of-course survey was given to the entire class, assessing the effectiveness of the entire course (final survey). In both cases, students were asked to respond to a number of statements on a scale from “agree strongly” (value: 5) to “disagree strongly” (value: 1). Results were reported as an average value over all student responses. The final survey is perhaps the most valuable, because it provides a basis for comparison with previous class years, where many of the same questions were asked. The third survey was given to approximately 1/3 of the class and dealt with their reasons for choosing their particular seminars. It was administered at the end of the second seminar.

The primary goal of the redesign, reducing the class size, was clearly met by the introduction of the seminars. Students responded quite positively to this change, as indicated on the final survey, where “The size of the seminars was appropriate” scored 4.1, while “The size of the full-class lecture was appropriate” scored only 3.5. On the final evaluation the students were asked to rate the value of various aspects of the course. Students assigned the highest value (4.3) to the seminars while the discipline overviews scored 3.9 and ethics scored 3.6.

Two other benefits were realized by comparison to previous years. First, the course was overall considered to be more challenging, scoring a 4.0 when the average of the three previous years is a 3.5. This is likely attributable to the more in-depth nature of the seminars. The second, most satisfying finding is that the perceived value of the course as a whole has increased, to a value of 3.9 from a previous average of 3.3.

One question not addressed by the end of semester survey was: by what criteria had students chosen their seminars? This is a key question because it was assumed, by the faculty, that students would select seminars they thought would be interesting, rather than selecting seminars because they thought they were *required* for their major (even though it had been stated they were not). A survey was administered to 79 students in the class at the end of the second seminar. Students were asked about their seminar choices, and allowed to give several reasons for choosing their seminars. As was hoped, 80% of students responded that they had chosen their seminars on the basis that they “sounded cool,” while 70% said they had also chosen them “because they were in their intended major.” Additional factors found to be important were that students thought the instructor seemed interesting (32%) and that they wanted help in choosing between two majors (28%). This indicates that students are using the seminars as they were intended. A final question on this survey asked if students thought the format of the class was better in the "module" mode or in the "big lecture" mode. While most students claimed to prefer the seminars, a significant fraction (23%) said that they would prefer the class in continuous large-lecture format. This seems in conflict with data from the end of semester survey, which indicates that students strongly preferred the small class format, and found the seminars to be one of the most valuable experiences in the course. A possible reason for this apparent discrepancy is that the first survey was given immediately after the second seminar (as part of the final quiz), so students had not been in the large lecture for over a month. Perhaps after they returned to the large lecture and had some time to reflect on their experiences, they realized that the smaller classes were indeed preferable.

There were a number of perceived benefits to the course changes which were noted by the faculty. A primary benefit noted by several faculty was that the seminars, because they involved more in-depth calculation and analysis than the larger class, seemed to be effectively reinforcing the connections between other courses and engineering. For example, one professor noted that students in the sophomore year often stare blankly at the professor when asked to calculate work or torque, whereas the seminar class, was able to immediately calculate work and torque without prompting from the professor because they had just recently covered these topics in Physics. Similar cross-connections from calculus and physics lab were noted, where, for example, students could take derivatives and calculate standard deviations without being prompted on how to do so. It is our hope that this early exposure to the interconnected nature of math, science, and engineering courses will facilitate integration of this material in other classes as well.

The faculty who had previously been involved in the course reported a feeling of greater ownership, one of the goals of the redesign. They also felt greater satisfaction in the more personal student-faculty relationship. For example, faculty had the opportunity to learn the names of one third of the entering class. While it was felt that the course required more work than it had previously, this was seen to be an acceptable trade-off for depth of coverage, improved student interaction, and greater academic freedom.

While the reaction to the course redesign was positive overall, not every aspect of the class received total approbation. From an administrative viewpoint, the course (while it was never easy to run) was significantly more difficult to manage, and required more university resources than before. One major issue was scheduling: in order to insure that all seminars would be available to all students, all students had noon-5:00 pm on Monday completely blocked out on their schedule. Also, six classrooms were needed for the lecture period (noon M/W/F) and six separate laboratory spaces for the seminar and discussion sections. There were also some logistics issues involved with seminar and book selection, and insuring the maximum number of students received their choices. While most students were accommodated in their first and second seminar choices, several of those who did not receive their desired seminars were upset (a fact which showed up in the seminar survey, but *not* the final survey). We will work on this issue in the future, although it seems highly unlikely there will be any possible way to insure students are placed only in their top choices, as some of the seminars were more popular than others. While all of the course infrastructure required significant effort, it worked out well in the end, and will improve with experience.

An additional problem with the course which has already been resolved was that of instructor credit. Each instructor received the same credit for the course as they would have under the previous teaching method, although the preparation and contact hours required of each faculty member almost doubled. This was addressed by giving each instructor more credit in the up coming semester.

From the student perspective, comments on course evaluations point to three issues. The first was that the course had a longer than usual turn around time on grading of projects and exams. This was due to two factors, both of which were invisible to the students: first, the course redesign lead to more grading for each professor, something which had not been fully anticipated at the outset. Second, because five or six different people were grading supposedly equivalent assignments, extra time was required before grades were returned to discuss and normalize the grades. Because we are now familiar with these issues, the turn-around time should be better in the future. A second, related problem, voiced by a few students, was that some of the seminars were perceived to be more difficult (or at least, to require more work) than others. While most students did not perceive this to be a problem, several students felt very strongly that it was an issue. Unfortunately, the reviews do not mention which seminars the students were comparing, so it is difficult to validate this complaint. While some variation due to teaching style is unavoidable, great care was taken to insure that all seminars were requiring similar amounts of work, and that approximately equal weight was given by each seminar to each portion of that work. Attention will be paid to this issue in the future, but it is difficult to address at this time based upon lack of data.

The final student problem was with choosing majors. While the majority of incoming students have declared a major before the start of classes, approximately 25% of the students are undecided about their major or change majors. A traditional role of the class was to provide these students with a basis on which to choose their major before course registration, which is midway through the semester. By the semester's mid-point, the class had been exposed to the brief overview of each major, as well as their first seminar. However, many students were expecting to be able to compare their two seminars before making a decision, which did not turn out to be possible. In the seminar evaluation, it was clear that a significant minority of students were expecting more information/experience in order to select a major. Also, some of the students were disappointed that the seminars did not have a strict one-to-one correspondence with the possible majors. In the final course evaluations, this showed up again in written comments, but as a relatively minor point. In fact, it was approximately balanced by students voicing the opposite opinion, that the overviews were unnecessary for the students who knew their major, and ought to be replaced by more time in seminar. An additional fact which minimizes this concern is that, while students are required to choose a major in October, they can change that choice without penalty up to January 15 of the following year.

Conclusion

This paper detailed a major redesign of a general engineering first-year course. The goals of the redesign were to give students exposure to the small-class atmosphere, enhance depth of learning, and expand the sense of instructor ownership of the course. Based on both quantitative data and qualitative observation, we can say that the goals of the redesign were met without sacrificing any of the overall course goals. We feel that this paradigm for Exploring Engineering was implemented successfully, and we hope to improve upon it as we repeat the format in the future.

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