Introducing first-year students to engineering, economics, and social responsibility: ADA compliance as a first project

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Abstract

Exploring Engineering is a first semester required course for all 200 first-year engineering students at Bucknell University. Last year, the course was modified into a format consisting of four project-driven units, with the middle two being student-elected topical seminars of approximately 25 students, and the first and last being taught to the entire class as a large lecture. This paper describes the reworking of the first unit of the course to include a design project focused on making the university more accessible for persons using wheelchairs. The main learning objectives for this project were to have students 1) Use the engineering design process 2) Practice teamwork skills 3) Practice oral and written communication skills 4) Apply math skills 5) Relate economic and other social considerations to engineering design 6) Produce a design for a real customer and finally 7) Develop a greater sensitivity to transportation issues faced by wheelchair users. The Accessibility Project replaced a project in which students designed a park, which had been satisfactorily achieving goals 1-5 for several years. However, it was felt that student and faculty interest could be heightened by altering the project to one that would perform a useful service to the university community.

In the Accessibility Project, teams of three students were assigned two points on campus, at least one of which was known to be currently inaccessible to wheelchair. Students then generated at least four possible alternative accessible routes between those points, and suggested and priced all improvements required to make those routes accessible. Students were given background on the Americans with Disabilities Act (ADA), which specifies the characteristics of "accessible" paths, access to various measuring tools, and wheelchairs. At the end of the project, students presented their work in both oral and written form to the Bucknell ADA Committee, which will consider their suggestions for implementation on campus. According to student evaluations, the project was successful in achieving all of its goals, particularly in heightening student sensitivity to issues facing wheelchair users, scoring 4.7 on a Lickert 5-point scale.

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 6 major fields (Biomedical, Chemical, Civil and Environmental, Computer Science, Electrical, and Mechanical Engineering). *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 six 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 team-taught by eight engineering faculty representing all majors in the Engineering College. In the 2002-03 academic year, the course underwent a major revision, which shifted half the course hours out of large lecture format into a smaller, seminar-type format, more typical of other Bucknell courses[2]. The new format for the course, used again for the 2003-04 academic year, is summarized in Table 2. For a more complete description of the course structure and seminar content, please see Vigeant et al. 2003[2]. As with the 2002-03 course, the seminars (Table 2, items B and C) were found to be popular with students and faculty alike, and to have a high degree of perceived value, based upon student surveys (4.3/5 for 2002-03, rising to 4.4/5 for 2003-04).

Table 2: Layout of course timeline and goals.

Week #	Module description	Course objectives met	Lecture Class size	Lab Class size
1 – 6 ½	A. Engineering as a profession	1, 2, 3, 4, 5, 6	210	12-15
6 ½ - 10	B. Seminar #1	2, 3, 4, 5, 6	27	12-15
10 – 13 ½	C. Seminar #2	2, 3, 4, 5, 6	27	12-15
13 ½ - 15	D. Engineering and society	1, 5	210	21

We felt that significant improvements could be made to the first segment of the course, which was given a fairly low effectiveness rating by students in 2002-03 (3.5/5, 2002-03), and featured a project which was not enthusiastically embraced by all faculty. This paper describes the new first module, which revolves around a project in which students design facility improvements which will make the Bucknell campus more amenable to travel by persons using wheelchairs.

Background

The first module of the course had a number of goals. First, the module was to introduce students to the different engineering fields (Table 1, #2 and #6), highlight their similarities and differences, and give undecided students a preliminary basis on which to choose a major. This was accomplished through a series of lectures, in which a representative of each discipline gave two lectures highlighting their field, and was largely unchanged from previous years, as this seems to be an effective way of accomplishing this goal. Each of the other goals from Table 1 was addressed chiefly through use of a design project, which was the focus of laboratory work as well as several supporting class lectures. The specific goals of this project, and their relationship to the course goals, is given in Table 3. A further characteristic of this project was that, because it occurs early in the semester, it should be non-discipline specific and require no more than the math and physics skills the students have developed after 2-3 weeks in those courses.

Table 3: Module 1 Project Goals

Goal	Teaching medium	Course Goal (Table 1)	Assignment medium
Work on an ill defined, open ended problem	1 course lecture	4	Project assignment memo, project itself
Use “engineering design process”	1 course lecture	3 (and 1)	Structure of project; decision matrix required
Use teamwork	1 course lecture	4	Project done in teams of 3
Use Oral/written communication	Lab discussion	5	Presented as both oral and written report
Use graphical communication	Lab discussion	5	Graphics required in report
Use economic considerations	1 course lecture, lab discussion	1	Required to remain within budget

During the previous 10 years, a project based upon designing a park for an unused 20-acre parcel of university property was used within the course (the “Park Project”). 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.[3] 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 was an effective team-experience for the students, and also met each of the goals given in Table 3. However, there were several minor problems with the Park Project. First was a perception by some of the students that the project was solely a civil engineering design. Part of the faculty dissatisfaction stemmed from that, because all students were given the same piece of land to work with, the designs tended to be quite similar, and therefore somewhat tedious to grade. Presentations were quite repetitious, which lowered student interest in their peer’s work. More importantly, the project involved no quantitative measurement or calculation, aside from the economic consideration. There was no way to quantitatively determine why, say, a roller skating rink would be a better use of the land than a rock-climbing wall. Finally, there was some disappointment from the students that none of the designs would actually be considered for implementation by the university.

The goal for the 2003-04 year was to rework the module 1 project such that it still fulfilled all of the goals given in Table 3, while addressing the concerns listed above. Further, it was decided that any change ought to be one which would increase both faculty and student enthusiasm for the project. Considering a number of engineering projects currently assigned at all levels both within Bucknell and at other universities, it was determined that students seemed most motivated by projects with a "real" customer as in senior design courses at Bucknell, projects with broad impact, such as those which help a target group or result in an actual product, and projects which result in the production of a prototype. The new project also had to fit within the allotted time and sufficient resources needed to be available so that students would have a reasonable expectation of success. To avoid repetition and decrease the possibility of plagiarism, we desired a project in which each team might be given a slightly different task. Finally, it was also desired that there would be an element of measurement and calculation to the project, such that the ultimate decision on the "best" solution would rest on more quantitative grounds than had the Park Project.

A number of candidate projects were considered by faculty, including development of packaging for a delicate object, automobile accessory design, toy design, playground design, amusement park design, and assessing the handicapped accessibility of campus. Of these, the packaging and accessibility projects received in-depth consideration, as they showed the most promise in addressing all of the desired criteria. Only the packaging project had the possibility of producing a prototype in the allotted time; however, the accessibility project, while failing this criterion, had a real customer, a broader social impact, logical use of quantitative measures, and many easily accessible resources and therefore was selected.

A project involving making the campus more accessible to persons using wheelchairs is attractive for a number of reasons. First, it is a natural fit with each of the goals given in Table 3, which was our minimum criterion for acceptance. It also allows greater consideration of social impact and ethical responsibility (Table 1, item 1) than did the previous project. It was also hoped student enthusiasm would be increased by the socially beneficial aspects of the project, as well as the presence of a customer. Bucknell has, as required by law, a faculty and staff committee charged with insuring and improving access for disabled persons on campus. This group, the ADA Committee, agreed to act as our customer, attend student presentations, and to consider the possibility of implementing reasonable student suggestions.

The Americans with Disabilities Act (ADA) specifies designs which must be incorporated into new structures, as well as changes which should be implemented in older structures under renovation. While Bucknell University is fully ADA compliant, this does not mean that a person using a wheelchair can access all points on campus easily or at all. For example, a wheelchair user who we interviewed, who was working on campus, commented that while the newer dormitories had one "accessible" room per floor, all other rooms in the facility remained too small for her to maneuver within. She then pointed out that this would mean she, as opposed to walking students, would not be able to visit friends in their rooms, even in the most compliant dorms. There were other, older buildings which she could not access at all, because renovations of existing structures are not required by ADA. Also, as Bucknell is situated on a hill, the terrain presents challenges of its own which the university is not required to address. This means that, while the campus is in excellent legal standing, it is still a rich environment for students to find and address problems.

The existence of the ADA fulfilled the last desired criterion in a new project: easy access to information. The law itself, as well as numerous state and local regulations, precisely specify what types of structures are "compliant," and this information is readily available from a number of sources[4,5]. For example, door width, sidewalk width, hand-rail height, ramp and hill slopes are all specified. Prices for these improvements are readily estimated using the Means Cost Guide for ADA Compliance[6]. Costs for non-structural improvements (such as stair climbers or electric wheelchairs) can be readily found from a number of catalogs available on the Internet.

ADA project specifications and resources

The project assignment was straightforward; faculty, with help from the ADA committee, generated a list of origins and destinations on campus, where at least one end point from each set was known to be difficult or impossible to access in a wheelchair. These locations were randomly paired, and assigned to teams consisting of three students. The students were then charged, in a memo signed by the ADA committee chair, with identifying the route they would use to walk between the points, the current most compliant wheelchair route, and then using the engineering design process to propose four alternative routes, listing and determining the cost of all improvements required to create the alternatives. The students were then to use a decision matrix to determine which alternative was the superior one, and then "sell" that solution in both an oral and written report.

Final student projects included a walking route (which served as the benchmark time and distance against which to compare the optimum wheelchair route), the current wheelchair route, and four alternative routes. An "alternative route" was defined as one which had substantive differences, either because it followed a different path or added infrastructure, from both the existing route and the other alternatives. Total costs for each alternative were compiled, and a decision matrix was generated which compared all alternatives and the existing route. Students were required to quantitatively rate all five routes based on time, distance, and cost. However, teams were allowed to both add other, usually subjective, criteria (such as attractiveness, usefulness to non-wheelchair users, expected durability) and to choose the relative weights of the different categories.

Students had just over four weeks to work on the project. At the start, background aspects of the project were covered in three lectures given to the large class. Two important guest lectures were the highlights of this section. First, one of our associate deans who is an ADA expert and our university compliance officer, gave a talk on the legal aspects of the ADA, why it exists, how it works, and how the university defines "reasonable accommodation" as required by law. For example, he described how we are obligated to provide access to education for all, which encompasses classrooms but not, for example, fraternity parties. This was followed by a talk given by a local resident who is both a lawyer and a wheelchair user. He was able to give the students a first-hand appreciation for both the legal and personal aspects of ADA, and he reflected on how it is sometimes preferable to work outside of the legal system, using informal accommodations willingly provided rather than legal accommodations forced through a lawsuit. His talk left a very strong impression upon the students and gave them a chance to ask questions. We would highly recommend any other group undertaking this project to seek a similar speaker. Finally, an instructor described the project in detail and showed a demonstration route, which he had traveled with a friend using a wheelchair, and pointed out all of the aspects of the trip which had either inconvenienced or stopped her.

Table 4: Weekly project homework and assignments

Due date	Assignment (due in lab)	Notes
Homework (due prior to lab 1)	• Research and list a number of important ADA specifications. • Determine length of ramp needed to access the lecture hall stage	
Lab 1	• Generate typical walking route, measure distance and time • Generate current most compliant route, measure distance and time • List and describe areas needing improvement • Generate team contract	Available tools: tape measures, measuring wheels, digital levels, and wheelchairs used here and for Lab 2
Lab 2	• Develop preliminary criteria for assessment • Develop timeline for project • 5 minute update	
Lab 3	• Complete timing statistics for best route (in wheelchair) • Estimated times for improved routes • Complete cost estimates (all alternatives) • Complete decision matrix (all numbers) • 5 minute update	Cost estimates developed using the Means pricing guide[6]. Lab discussion of appropriate use of maps and descriptive graphics.
Lab 4	Final oral presentation	Presentations attended by Professor, classmates, and representative of ADA Committee
One week after Lab 4	Final written report	

After the large overview lectures, responsibility for the progress of the project shifted to the smaller laboratory sections, where students could more easily discuss design issues with classmates and a professor. To help the students maintain consistent progress towards the completed project, weekly assignments were due in lab (see Table 4). This kept student work, the majority of which was done outside of both class and lab, on track by forcing the students to complete all of the technical aspects of the project one week early, giving them sufficient time to compile the report.

Physical resources available to students to complete this project were extensive. Each team was provided with a measuring tape of their own, to be returned at the end of the project. Students were also given a poster-sized printout of a high-resolution aerial campus photograph, and access to the same as an electronic jpg. Further, 10 sets of the following tools were available for check-out through the library reserve desk for 3-hour blocks: a measuring wheel, a digital level, and an adult sized wheelchair. The measuring wheel was provided so students could measure the larger distances between their origin and destination more easily than with the measuring tape. The digital levels were capable of outputting the slope of a given area, and were extremely useful in assessing the compliance of the various hills and ramps around campus. Finally, it was absolutely critical that the students were able to use a wheelchair and to find for themselves the small bumps and curb cuts which would have passed unnoticed for walkers, but were very significant for a person using the chair. This also gave the students a feel for how difficult navigating even a compliant slope can be. Having access to the chairs was the second most highly rated aspect of the project (4.4/5).

Figure 1: Exploring Engineering Students testing their routes with wheelchairs and measuring wheels.

To insure return of tools and wheelchairs, the library assessed serious fines for each hour after its due time an object was returned. Students also signed a form promising to replace any damaged items. Finally, as there were concerns that students might engage in horseplay with the wheelchairs, and that this might be found offensive, students were strongly cautioned to be respectful, and were asked to sign a document promising they would use the wheelchairs only in the manner intended. Students were also explicitly forbidden to ask questions of persons they saw using wheelchairs on campus; as there are typically few wheelchair users here, we did not want anyone to be overrun with intrusive or possibly unwanted attention.

Results and discussion

In analyzing this project, all student teams passed with at least a C, demonstrating that the academic goals of the project were met satisfactorily by all students. In fact, many of the student projects were surprisingly good, showing technical competence, creativity, and an unexpected mastery of computer graphics. For example, one team photographed non-compliant areas, and then digitally added their projected improvements. A sample of a student route and analysis can be seen in Figure 2. As judged by a survey given at the end of the project, students largely also felt that they had met the goals of the project, giving their highest scores to "I used teamwork skills" (4.2/5), "I used oral presentation skills" (4.1/5), "I used graphics" (4.0/5), and "This project made clear the relevance of economic considerations" (4.2/5). Student comments generally reflect that the project was a positive experience and that they felt they had learned both about engineering and about the ADA and issues facing those in wheelchairs.

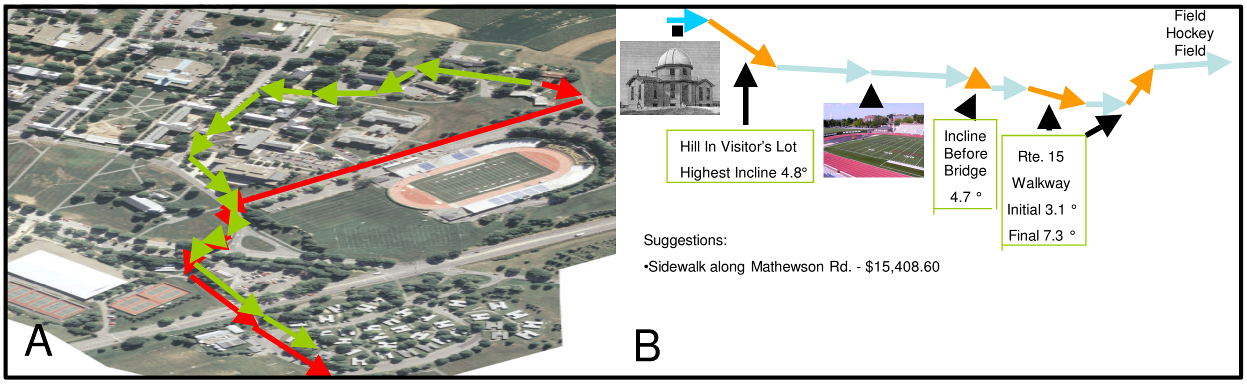

Figure 2: A: Aerial image of Bucknell, showing two alternate routes between the campus observatory and field hockey field. B: Elevation view of red path from A. Orange arrows indicate areas which are currently too steep. From the report of team OOO.

When students were asked to suggest improvements to the project, several pointed out that they would have appreciated a higher degree of organization and clarity from the project and the professors. This was also reflected in the relatively low score for "Instructions were delivered clearly" (3.5/5). This is largely due to the fact that project development by faculty was ongoing while students were working on the project, and should be much less of an issue next year. Amusingly, the next biggest student complaint was the size of the budget; $10,000 does not go very far for major landscaping projects, nor for the purchase of any electronic assistance devices. However, as this is the actual budget for ADA compliance, we feel justified in continuing to use it (and perhaps will in the future try to make it more clear that the students' budget frustrations should be directed elsewhere).

In summary, both the faculty and student reaction to the new project was positive. In the student survey given immediately after the project, students gave "This project was worthwhile" a rating of 3.9/5. On the final, overall course survey, a similar question "the wheelchair project was a valuable part of the course" scored 3.8/5. This is a significant improvement to the rating given the previous project in the 2002-03 school year of 3.5/5.

Overall we feel this was an excellent first-year project. It achieved all of our academic goals, and encouraged students to practice a number of skills which will be important to their future engineering careers. The perceived level of student and faculty enthusiasm about the project was much higher than in the previous year. The project was covered by local newspaper and television reporters, which gave an added boost to student motivation. In addition to the stated academic goals of the project, a number of other side benefits were also found. Students involved in this project are much more familiar with the campus than many of their peers (and even faculty), due to the extensive walking and route finding involved in their work, making this a good orientation exercise. Students uniformly expressed that they had developed a much greater appreciation for the issues facing wheelchair users (4.7 out of 5), a fact which will hopefully impact their future work and social lives. Finally, out of the 70 projects, several ideas were generated which are under active consideration for implementation by the ADA committee. We plan to re-use this project for several years to come. As the project is quite flexible, we can do so without worry of projects being copied from year to year. For example, we can maintain our focus on wheelchair accessibility, but change the set of origins and destinations. We are also looking into considering other aspects of ADA compliance besides wheelchair accessibility. For example, with many of the same tools and references purchased for the original project, we can look instead at accessibility for the visually or hearing impaired.

Finally, we feel this project is an excellent candidate for adoption for similar courses by other Universities. As the majority of campuses are within legal ADA compliance, but still lack universal access, there are a wealth of projects which can be found. Further, all universities should have an ADA committee or compliance assurance officer to act as "customer". Students are enthusiastic about the project, and, most importantly, improving access to our campuses for all is the right thing to do.

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Biographical Sketches

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