AC 2008-463: INTERDISCIPLINARY CAPSTONE DESIGN PROGRAM - A CASE STUDY

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Interdisciplinary Capstone Design Program
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Abstract

To advance interdisciplinary engineering, an all college multi-disciplinary senior design program was initiated. The initial project was a two year effort to design an automated transit system for the campus. The first semester was a planning stage to establish vehicle, route and infrastructure parameters. The planning semester was followed by three semesters of sequential design. Students enter the program at various stages of development and must complete defined portions of the overall project. The program places emphasis on documenting work, picking up work initiated by others and communicating design objectives and changes to the team in addition to completing the design elements. The teams orally presented their work to a panel of class selected evaluators. The program was presented to the top university administrators, including the president and vice presidents of facilities and research, plus several state legislators.

Institutionally, the program was designed to meet the various departmental senior design requirements. Students in the class were registered for between two and five credit hours. Depending on the major, the students had to either fabricate their design or develop detailed design drawings. The interaction between the vehicle design and infrastructure works required close interaction of the various disciplines.

The paper presents and assesses the project concept, discusses the professional involvement, institutional constraints, administrative support and the results of the five semesters work. Recommendations for improvements for implementation of similar projects at other institutions are included.

Introduction

Engineering projects are increasingly complex due to client needs, system integration efforts, advances in technology, and computer aided design tools. A common concern of national advisory boards is that students must function better in team projects and improve communication skills. This is reflected in ABET requirements for multidisciplinary senior design activities. In many situations, these objectives are met by defining "multidisciplinary" as using different skill sets within a major. For example, civil engineers may require students use structural and geotechnical skills in their project. The use of "interdisciplinary" in this paper is to suggest that a wide range of engineering studies are engaged in the program.

In 2001 the University of Wyoming appointed the first permanent H. T. Person Professor dedicated to improving undergraduate education. One objective for this professorship was to enhance engineering design activities into the college curriculum. The first three years were spent introducing design projects into the freshman Introduction to Engineering class. Once the freshman program was established, the operation of the program transferred to other full time faculty.[1] In 2005 attention shifted to development of an interdisciplinary senior design program.

Establishing an interdisciplinary senior design program required meeting the various departmental senior design curricula criteria, identifying a project, recruiting students, engaging external professionals, developing class organization, and establishing a presentation forum for the work. The remainder of this paper examines the first project and introduces the second project. It concludes with recommendations for initiation of similar programs at other institutions.

One caveat is offered at the outset of this paper. It is easy to suggest that Wyoming has only one four year university and that access to resources is easier than other locales. Such a suggestion misses the fact that there are only two civil engineering consulting engineering firms of any size in Laramie and that the nearest major manufacturing firms are in neighboring states. Thus, direct involvement of external resources requires a significant travel commitment by both the University and the outside professionals. On the positive side, involving local and state officials in the program is somewhat easier due to the support the University receives from elected officials.

Departmental Requirements

The College of Engineering and Applied Science has six departments containing ten programs: Atmospheric Science, Chemical and Petroleum Engineering, Civil and Architectural Engineering, Electrical and Computer Engineering, Mechanical Engineering, and Computer Science and Management Information Systems. Students from six programs may participate in the interdisciplinary program. They are civil engineering (CE), electrical engineering (EE), mechanical engineering (ME), chemical engineering (ChE), and computer science (COSC). Architectural Engineering and Computer Engineering programs opted out because faculty wanted students to focus on their own internal comprehensive senior design projects. In the first three years no Petroleum Engineering or Computer Science major elected to join the interdisciplinary project, so just the CE, EE, ME and ChE requirements needed to be satisfied. Each of these programs has different curricular requirements, summarized in Table 1. Meeting the various requirements was the first challenge of the program.

The solution to meeting the academic requirements required two components: organizational and administrative. The organizational component required each student to register for a separate section of their departmental senior design course. The EE and ME senior design courses had already been scheduled to meet at the same time to facilitate potential joint ME and EE projects. By creating a new section for each course, students in the interdisciplinary project could meet without creating new course conflicts within their own departments. This then required CE and ChE students to match the ME and EE schedule. The administrative advantage of this approach is that each student in the interdisciplinary course was registered for the course required by their major. This simple step significantly enhanced the degree check process required for graduation.

Identification of Project

Project identification considered three global requirements. First, the project must be adaptable to the actual composition of students who register for the class. Second, the project should be relevant to the students. Third, the project must be adaptable to departmental senior design requirements. These include a “paper design study” in CE and ChE and manufacturing requirements for ME and ECE.

Since the project is defined prior to the formation of the class, there must be some ability to adjust the objectives once the class is formed. For example, if the class has a disproportionate number of CE students, the project must be able to adapt to distribute the work evenly. The initial project for the class was to design an automated transit system for the campus. The project required considerable interaction between civil engineers conducting the traffic planning and passenger loads and the mechanical and electrical engineers designing vehicle size, frequency of service, and power demands. Underlying the entire project is the existing campus bus system, which served as a baseline for operational costs and level of service. Project objectives emerged to significantly improve service, improve environmental quality and reduce annual operating costs in response to a one time capital investment.

The selection of the automated transit system project addressed the second criteria – relevance to the students. Students “bought in” to the concept that such a system could improve campus life, enhance the campus image and provide a long-term solution to access on campus. They were able to envision themselves in both the process and the results. The transit project was equally well suited to meet the departmental requirements that the ME and ECE students should fabricate their design. As the design progressed, the transit system could be subdivided into components and groups of one to three students would fabricate individual components.

The transit project was conducted over a two year period. Semester one was devoted to traffic analysis, preliminary route layout and initial vehicle sizing. Semester two was dedicated to final route selection, initial guideway design, station conceptual design, and final vehicle concept and component fabrication. The guideway design used soil investigations for various buildings around campus to facilitate the foundation design and students developed a steel truss solution in conjunction with a local steel fabricator. Final vehicle design required integration of the guideway-vehicle interface. Semester three explored a prestressed concrete guideway alternative and vehicle automation systems. The automation system required construction of a 1/5 scale section of guideway and vehicle mock-up. The vehicle mockup required that the doors, with safety interlocks, cycle through opening and closing, followed by having vehicle progress to the next station using a linear induction motor system, stop, and again cycle the doors.

The 2007-08 project explores the development of a natural gas field in Pinedale, Wyoming to minimize environmental disruption. The development site is on a major large animal migration route and Sage Grouse habitat. With three major gas fields and over 18 trillion cubic feet of gas to be extracted over the next 30 years, the students understood the sensitivity of the project and the impact on the state. In addition to addressing problems specific to the actual sites, the students elected to participate in the Texas A&M Disappearing Roads Competition. This competition provided an external stimulus and added requirements to the project.

Student Recruitment

Each spring, just prior to advising week, a briefing session was held to provide an overview of the project. Invitations were emailed to all junior and senior students. The briefing was held at

5:00 PM to avoid class conflicts and food was provided. This briefing allows students to get a sense of the project. The class size is targeted at 15 to 25 students; however, there was no control on enrollment. Recruitment of Civil Engineering students competes with one or two other senior design projects offered each semester. These may be in specific areas such as water resources, environmental or geotechnical. ME ad ECE students have their departmental senior design class as an alternative.

In addition to open enrollment, specialty skills were recruited for each project. For the first year of the transit project a mobility impaired chemical engineering student was recruited. A campus advocate for mobility access, the student provided invaluable input on issues of mobility access and assured that the project was fully Americans with Disabilities Act (ADA) compliant. Thus, the student provided technical input on the chemical engineering component and ADA expertise.

For the gas field project one Environmental and Natural Resource major was recruited and given environmental veto power over any concept that was judged non-compliant. In addition to providing expertise to the program, her presence created very interesting class discussion.

Recruitment of students for the first year or the one year projects was about the same. The major fall off was recruitment of students for the second year of the two year project. The anecdotal conclusion is that students want to be involved in the project development but not the detailed conclusion.

Engaging External Professionals

A key element of the interdisciplinary senior design is engaging the students with other professionals. This proved to be a challenge to the program since there is no professional engineer in Laramie with direct expertise to assist the students. To compensate for this deficiency, a series of field trips were arranged. For the transit project the students visited the Denver International Airport (DIA), Six Flags Elitch Gardens and Rocky Mountain Prestress. At DIA students met with the airport operations staff for the airport automated transit system and studied the operation and maintenance of the system. They were further assisted by Log Plan Consultants, a consulting firm working on the baggage handling system at the airport. At Six Flags, they met with the engineers to examine how safety of small systems is maintained. One Six Flags engineer is a member of the ASTM committee on operation and maintenance of amusement rides and provided valuable insight to the issues they would face. Additionally, the students observed first-hand the benefits of involvement in professional societies. Lastly, Rocky Mountain Prestress discussed issues of prefabrication, construction and scheduling of complex projects.

Design and development of gas fields also used field trips to allow students to identify the problems they wanted to address. A three day trip took them to visit Halliburton, EnCana USA's Jonah Field, and the BLM office overseeing development of two of the fields near Pinedale, WY. Students were briefed on current best practices, and introduced to Environmental Impact Statements and Records of Decision. A second BLM tour examined a reclaimed gas field. Students received a thorough introduction to the issues to be resolved and met with the field engineers charged with the development.

Class Organization

Each class is organized to simulate a design office. Students are interviewed to determine their technical and career interests and their desire to be a manager or development engineer. Time commitments of each assignment are discussed, a class organization chart is developed, and contact information assembled. The contact information becomes critical with the interdisciplinary team because students often do not know their classmates from different majors.

Class objectives are developed in the first two weeks. These include the global expectations of the class, the interaction requirements, the need to define the project completion criteria, e.g., what do they expect to complete and when, where will they find the data needed to develop their design, and definition of the project deliverables. Development of each objective comes from a directed learning effort. Students are not accustomed to defining their class outcomes, especially within the time constraints of the academic year. While a Socratic Method best describes the intellectual effort of defining the class objectives and outcomes - pulling teeth better describes the actuality of the effort.

The class meets twice a week regardless of the number of credit hours. The first two to three weeks are spent in defining the project, field trips, scheduling and definition of term outcomes. About the fourth week, students begin presenting preliminary studies, design concepts, lead the team discussions, and update individual assignments. Separate meetings with the professor are used to equilibrate the required hours. In addition, the professor meets with the project managers weekly to keep the project on track, review individual performance and discuss possible task assignments. Other faculty members are involved where necessary. For example, the President of the university briefed the students on short and long range planning issues to assist in laying out transit options.

One important set of assignments is selecting the presentation coordinators. One student coordinator/editor prepares the term report and a second student coordinator organizes the oral presentation. Their tasks are to assemble, proof, and submit the term report and to organize, set speaking assignments, and compile the PowerPoint presentation. Examples of the reports and PowerPoint presentation can be found at http://wwweng.uwyo.edu/civil/Kester-Lab/ .

In addition to meeting with professional engineers, the second semester transit design class "hired" consultants to assist in the design. To improve the graphic presentation, a request for proposals was sent to the senior graphics arts design class. The graphics art class presented concepts in an evening class interview. The engineering students evaluated the presentations and selected features of each for further development. The graphics arts class led a campus wide focus group study to name the system and developed photomontages of the transit system, Fig. 1.

Presentation Forum

At the conclusion of each semester, the class presents their work in a public forum. The class selects their review panel and issues invitations. The second semester review panel for the transit system included the University of Wyoming president, vice president for research, vice president for facilities, all department heads, engineers from the field site visits, two state senators, city engineers and a representative from the Wyoming DOT. The invited panel participated in the discussion, and provided written evaluation of the technical and presentation quality of the project. The fourth semester presentation was conducted by the University television station.

The gas field development project invited members of BLM, six major oil and gas producing companies and the director of the School of Energy Resources in addition to university administrators. At the end of the first semester, the evaluators critiqued the progress to date and provided input for further development.

Academic Issues

The teaching load at Wyoming is typically two courses each semester. This was the case for all but the first semester of the gas field development when the teaching load was reduced to one course due to the demands of developing the project. The interdisciplinary design professor prepares and manages the design project and meets with the participating departments to assure that the objectives of each department are satisfied. In addition to the class professor, students had access to their own departmental senior design faculty members. Therefore, the interdisciplinary professor was not required to be knowledgeable in the technical details of each discipline.

The interdisciplinary class runs in parallel with the normal senior design projects. The class GPA was between 2.8 and 2.9 for the interdisciplinary classes. The mix of students varies each semester and is summarized in Table 2. Each year the ME and EE students are enrolled for both semesters while the CE student mix varies.

In the gas field project, approximately 30 percent of the senior mechanical engineering class opted for the interdisciplinary project instead of the departmental program. This raised a concern whether the interdisciplinary class was viewed as “an easier option” or if the draw was the relevance of the project. A comparison of the term reports suggested that the courses are comparable in rigor but very different in content. The interdisciplinary course required far more coordination and planning and less detailed design. The assessment of content is continuing.

Funding the field trips is a continuing issue. The transit field trips were funded by a discretionary fund available to the course professor. The gas field trip was funded by the University of Wyoming, School of Energy Resources. Once the project visibility increased, the oil and gas production companies offered to fund any additional visits.

Project leadership is perhaps the most critical issue because it requires the faculty member to address a broad range of design activities. The H. T. Person professor is a civil engineer with over 20 years of design experience. While some design experience is valuable to lead this type of project, it is more critical to have the ability to look at large picture concepts and interact with colleagues in other departments. The involvement of the Dean’s office was invaluable in providing support for the effort and minimizing the “push back” that came from “loosing” students to the interdisciplinary program.

Outcomes

The principle educational outcome of the project is the education of engineering students in the complexities of real interdisciplinary design. Based on student comments, this outcome has been achieved. There are, however, other possible outcomes of the work. The transit planning effort at the University of Wyoming was provided a copy of the student work. Some of the data developed by the students has been incorporated by the external planning consultants.

The success of the course is monitored by three sources of data; student evaluations, review comments at the presentations, and feedback from professionals. The student evaluations are generally positive with the major criticism being they did not anticipate the amount of work that was required to wrap up the project. The public presentation requested that each visitor complete an evaluation of the presentation. The evaluation criteria are given in Table 3 and include the ability to present the technical material, the oral presentation skills and the organization of the presentation. All responses are compiled and used in the grading rubric for the class. The fall 2007 presentation rated a combined score of 3.06 out of 4 and individual scores ranged from 2.8 to 3.6. Lastly, discussions with the engineers that participated in the field trips or visits were solicited. While anecdotal in nature all of the professional reviewers were of the opinion that the work was at a professional level.

A comparison with the "normal" project based senior design class is based on observation of the project presentations. In the first semester, the breadth of the interdisciplinary project is far greater than the project based courses and the technical depth is less. This results from the focus on identifying the project and developing design information. The second semester, the breadth is maintained and the detail of design is comparable to the project based courses.

The gas field development project is still in development. BLM has expressed interest in the concepts and is investigating whether some of the ideas should be incorporated in their requirements for the newest gas field development in Wyoming. Questar Production Inc. recommended that the students prepare a technical paper on their concepts and submit it to the American Association of Drilling Engineers. Three students are interested in writing these papers and the results will be reported in June. As of this writing, the team is one of no more than 10 selected nationally to qualify for the Disappearing Roads competition. The class final report will be submitted in March.

Conclusions and Recommendations

Overall, the interdisciplinary course succeeded in meeting may of the objectives of the Civil Engineering Body of Knowledge program[2]. Students participated in truly interdisciplinary teams, managed their own work, assembled data, identified problems, drew conclusions, prepared written and oral reports and interfaced with both professionals and the public.

The burden of leading the interdisciplinary class is large and requires considerable organization on the professors' part. The first semester of the project should be the only course taught by the professor. Time is needed to arrange and participate in the field trips and to organize the class once the student composition is known. The second semester is easier to manage because the major objectives are established.

The second year of the two year project was judged as less successful. Students were not as engaged as they were when the concept was first being developed. The class was much closer to the traditional fabrication of components mode rather than fully interactive with other disciplines. Therefore a one year project is recommended.

The merging of the gas field project with a national competition is seen as beneficial since it provided an added dimension to the project. Unfortunately, there are a limited number of such competitions in any given year. Furthermore, the competition has to be announced a year in advance in order to develop the course, recruit students, and develop contacts for field trips. Development of an annual interdisciplinary senior design project would greatly assist in focusing these efforts.

Bibliogrphy

1. Dolan, Charles W. David L. Whitman, Thomas V. Edgar "Introduction to Engineering Program at the University of Wyoming" *Proceedings of the 2005 American Society of Engineering Education Annual Conference & Exposition*, American Society of Engineering Education, June, 2005
2. *Chapter Seven, Engineering Education Reform*, Civil Engineering, November 2007, pg. 46-51.

Table 1 Departmental Senior Design Requirements

Department	**No. of Semesters**	**Credit hours/semester**	**Outcome**	**Writing Requirement**	**Oral Requirement**
Civil Eng.	1	3	Report and Plans	No	Yes
Mechanical Eng	2	2 3	Planning Fabricate project	Yes, with University oversight	No
Electrical and Computer Eng	2	2 3	Planning Fabricate project	No	Yes
Chemical Eng.	2	2 5	Planning Report and plans	Yes	Yes

Table 2 Class Population by Major

Semester	Fall 05	Spring 06	Fall 06	Spring 07	Fall 07	Spring 08
CE	5	6	5	12*	7	5
ME	6	6	3	3	15**	15**
EE	1	1	0	0	1	1
ChE	2	2	0	0	0	0
COSC	0	0	0	0	0	0

* Spring 2007 included in the guideway design in the prestressed concrete class. Integration with the ME students was limited to briefing requirements for the guideway.
** This represents approximately 30% of the ME senior design class

Table 3 Evaluation Criteria Sheet for External Reviewers

INSTRUCTIONS

You are asked to provide a grade of the students' presentation. The reverse side of this sheet has an evaluation form and lists the speakers in the order of their appearance. Check the box to indicate your participation in the review and fill out the sheet using the criteria below and place your grade sheet in the box by the exit.

Thank you.

If you want to add your name we would appreciate knowing who participates. If you are not on our distribution list and want to receive an invitation to the spring semester presentation then add your email address.

Grading	Each item is graded on a 1-4 scale with 1 being poor, 2 fair, 3 good and 4 excellent
Evaluation area	**Expectation for a grade of 4**
Organization	The concepts and designs are presented in a logical sequence with each point building on previous work
Clarity	Concepts and designs are presented in terms that are clear, well defined, free of jargon, and easily understood
Verbal	The presenter had good verbal skill including eye contact, voice projection, posture and poise
Response	The presenter was able to respond to questions in a clear concise manner.

HANDOUT SHEET

[ ] Faculty **[ ] Professional** **[ ] Guest or visitor** **[ ] Student**

INTERDISCIPLINARY ALL COLLEGE DESIGN PROJECT - EVALUATION SHEET Spring 2006 **Order of Presentation**	Organization	Clarity	Verbal	Response
OVERVIEW				
Students name listed in order of presentation				
First Student				
Second Student				

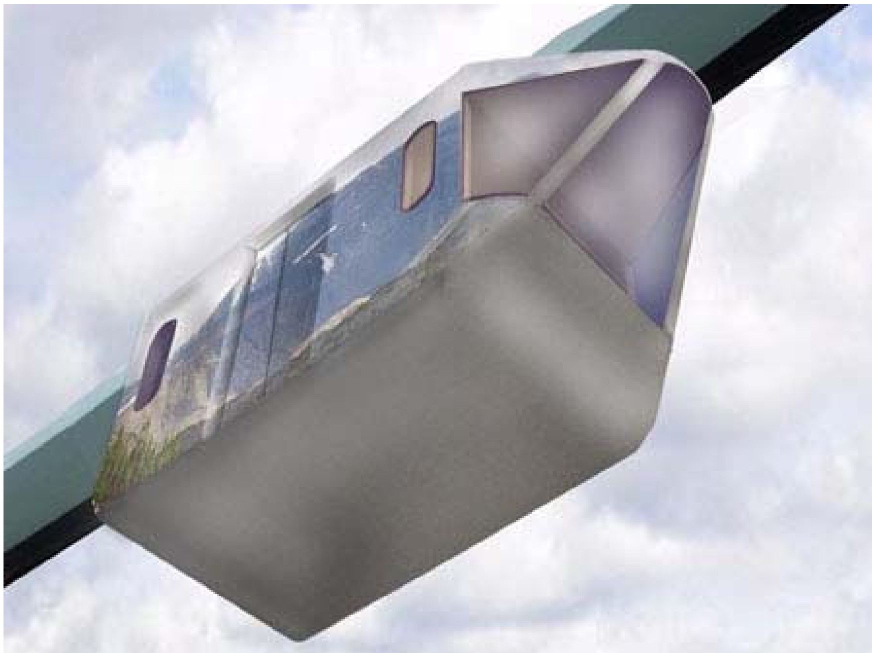

Figure 1 Photomontage of Student Designed Transit System Prepared by the Graphic Art Senior Design Class