2006-2295: PRACTITIONER DRIVEN SENIOR DESIGN CAPSTONE COURSE

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Practitioner Driven Senior Design Capstone Course

INTRODUCTION

The capstone design experience in an undergraduate engineering degree program is a course in which students draw upon various aspects of their undergraduate coursework to develop a comprehensive, engineered solution to an open-ended problem. Since Autumn Quarter 2000, the capstone senior design course in the Department of Civil and Environmental Engineering (CEE) at University of Cincinnati (UC) is executed as a three-quarter Integrated Design Sequence (IDS) course, offered in conjunction with a practicing professional engineer (client), and other practitioners and faculty members acting as mentors. IDS is an innovative and ambitious three-course series focusing on a single design theme with multiple components that encourage interaction among traditional CEE specialty areas (e.g., construction, environmental, geotechnical, structural, transportation, water resources). Students work in design teams, like a design firm, and submit feasibility, design and construction plans, and associated cost estimates for a real-world project. Students must interface with a "client" and a group (consisting of 6 to 8 members) of "industry advisors" or practitioners (who collectively act as owners) to gather data and information; the owners are also in the audience for final presentations. A specially Design Center houses all the teams. The whole experience stresses on communication and collaborative skills. This course is designed as a gateway to the profession. The deliverable each quarter is a set of plans with a written report. For the autumn quarter, the drawings show a conceptual plan. The product of the Winter Quarter is a set of design plans with details, specifications, quantities and a construction cost estimate, and the product of the Spring Quarter is a set of design plans simplified for better understanding by a non-technical audience. This paper describes four aspects to the IDS course: 1) description of the course goals and implementation; 2) a brief description of the projects executed; 3) grading process used; and 4) assessment of the project outcomes, objectives, and results. Hopefully, this documentation will help others in planning similar experiences for senior engineering students.

DESCRIPTION OF THREE-PHASE SENIOR DESIGN PROJECT

Course Goals. All CEE undergraduate students at UC are required to take Integrated Design I, II, and III. These courses were installed in the curriculum to provide a final, integrated engineering experience for the students and to meet the General Education requirements of the University. The courses are spread over three quarters to allow the students sufficient time to complete a significant project. The goals of the Integrated Design courses are:

1. To show students how engineering concepts, taught as individual subjects in disparate courses, are brought together in a project.
2. To demonstrate the interaction needed between CE sub-disciplines in a project.
3. To provide training and experience on teamwork and team building, essential for modern engineering practice.
4. To improve oral, written, and visual communication skills.
5. To force students to consider non-technical aspects of a project, such as:

i. Cost,
ii. ,Time schedules
iii. Political considerations,
iv. Social responsibility,
v. Ethical issues, and
vi. Diversity/Community values.

6. To introduce technical material not covered in coursework.

Selection of Design Teams and Management. The senior class is split into independent design teams (typically there are 6 to 7 students per team). Teams are encouraged to operate as an engineering consulting firm. Each team is led by a project manager and a deputy project manager who are responsible for the deliverables. An effort is made to have at least one student in each team from each of the specialty areas (structures, geotechnical, transportation, construction, and environmental). All students before the end of their junior year are required to complete an online form documenting their desired specialty area. Team members are expected to contribute in their area of "expertise" and also to develop an understanding of how all elements of the project fit together in the final design package. Project managers and deputy project managers are selected before the beginning of the school year at a combined meeting of faculty and industry mentors. Material available to aid the selection process has primarily been student resumes from co-op jobs with input from faculty and industry mentors based on personal knowledge of candidates as well as grade records. (The undergraduate engineering degree program at UC is a five-year program, and students complete six quarters of required co-op training before their senior year. The UC's Office of Professional Practice places students on co-op jobs. The Office of Professional Practice maintains updated student resumes which document their co-op experience and evaluations.) For the current year, a questionnaire was developed and sent out to all incoming seniors explaining the program and assessing interest of each individual to serve in a leadership position. This has reduced problems occurring when students with no interest in a leadership position were given such assignments. It has produced a significantly increased positive atmosphere in the IDS design center. The project manager (PM) is responsible for the team's performance and productivity, and the deputy project manager works with the PM and fill in for the PM when necessary. Each team has an assigned CEE faculty mentor who meets the team every week. Each team is supposed to meet at least three hours each week, and the attendance is recorded by the faculty mentor. The faculty mentor monitors the progress of the team to keep them on task, but provides advice and resources based on the request of the team members. If expert advice outside the area of expertise of the faculty member is requested, the faculty member arranges a meeting with an appropriate CEE faculty member to assist the design team. Thus, all CEE faculty members are available to the design teams for consultation, but they have to request for it.

The IDS experience follows a natural progression during the course of the senior year. During the Autumn Quarter, each design team prepares a written proposal including an SOQ (Statement of Qualifications) in response to an RFP (Request for Proposal) from the "client." In addition, at the end of the Autumn Quarter, each team presents a preliminary engineering report on the feasibility of the proposed project. During the Winter Quarter, each team progresses from conceptual ideas to near-final design. During the Spring Quarter, each team finalizes its proposed design and prepares a detailed cost estimate and bid package for construction. The IDS experience culminates with a formal presentation before an audience of CEE students, faculty mentors, project client, and an advising board of professional engineers. More details of the three distinct, but integrated, phases, I, II, and III, of the course are presented below.

Phase I – Autumn Quarter – Feasibility/Conceptual Planning Phase (CEE 504, 2 credit hours). The Autumn quarter introduces the class to the concept of an *"integrated,"* or interdisciplinary, type project which is representative of the *real* world. The principal goal of this phase is to develop and hone skills related to oral and written communication of technical ideas, working together productively in teams, encountering and addressing problems and situations that sometimes are "out of the box," group organization, project management, synthesizing existing technical information, and independent learning. Part of the learning experience is how to communicate and work with other disciplines to accomplish a project. The teams visit the project site during the second full week at a time when all students are free from other classes. The field visit is coordinated with the "client."

In Phase I, each team will prepare a conceptual plan for consideration by the "client." The "client" is a practitioner who identifies the IDS project and defines the deliverables. The "client" also provides all the required information (topographical maps, soil log data, permitting regulations followed by the region, etc.) for the project site or directs the design teams to the sources of the information. Each team's conceptual plan will demonstrate how it proposes to *"best"* organize and develop the site to satisfy all client requirements, meet all restrictions and address all regulatory issues, and provide an efficient circulation system to serve traffic movements within as well as to and from the site. The investigation must include the environmental and geotechnical ramifications of the proposed project as well as any drainage, runoff, and erosion issues that might be involved. Also to be included are constructability and structural ramifications. A transportation analysis must address not only circulation on the site, but also its operation within the project site's transportation system. In mid-quarter each team will present a *"proposal"* which shall include:

- The team's understanding of the project.
- The team's proposed approach to conducting the study, i.e., the scope of work.
- The team's schedule, identifying milestones and anticipated mid-term status when a review meeting will be held with the IDS Mentors' Group, and
- The team's estimated "cost," expressed in terms of person-hours, subdivided into major areas or tasks.

Mid-quarter presentation with the "client" and the industry advisory (practitioners) and faculty team (faculty mentors) is essentially a two-way discussion where team members bring in materials (progress reports, challenges encountered, drawings, list of questions, etc.) and initiate a dialogue with the mentors. The outcome provides guidance and support for the students and gives the mentors a basis for evaluating the team's performance at the mid-quarter point.

At the end of the quarter, each team will make a 20 minute PowerPoint presentation to the "client" and the industry advisory and faculty team to demonstrate why and how its conceptual plan is the *"best."* This presentation will be made as "consulting teams" presenting to an audience the results of their work. The presentations should include graphics, some of which would come from the deliverables, and handout material, or "leave-behinds." The purpose of the presentations is to explain to the "public" how the team arrived at its findings and recommendations, what factors were considered in the decision-making process, what alternatives were considered, what the team proposes and why it is the best, and exactly what the team proposes to accomplish in the Winter Quarter (Phase II). The presentations do not go into the technical aspects of the process beyond what is necessary for the audience to understand the final recommendations. The presentation time is limited to allow questions and discussion from the audience, so it is necessary that each team be thoroughly conversant with its work and be able to respond. Each team member must participate in preparing or giving the presentation.

Phase II – Winter Quarter – Design Phase (CEE 505, 3 credit hours). In Phase II, the design teams will be required to develop the site plans (contours and cross sections), drainage pipes and inlets, roadway plans for all components of the circulation system (plan/profiles, typical sections, intersection geometry and traffic design, and detail elevations for paving), utilities plan (sewer main, water lines, underground electrical, telephone, data, and gas), and right of way and set-back requirements for facilities. Each plan shall also include the significant structural design of a design element, such as a retaining wall, parking deck, small building or major component(s) of larger structures, etc. The plan must also include a cost-effective drainage system to accommodate the ultimate development of the site. "Green Facility" concepts should be considered in the design; drainage must incorporate environmental considerations. The proposed design should promote sustainable waste management by considering options for waste minimization and water re-use. At the end of the quarter, each team will make a 20 minute technical presentation augmented by appropriate handouts and visual aids, and submit a written report to the "client" and the industry advisory and faculty team. Each presentation is followed by a 10 minute question and answers session.

Phase III – Spring Quarter – Bid Package & Final Documents (CEE 506, 1 credit hour). In Phase III, each Design Team will add the documentation necessary to transform its plan into a bid document for receipt of proposals from contractors. Documentation will include elements such as specifications, general conditions, definition of bid items, quantities, and estimated construction cost. At the end of the quarter, each team will make a *"final"* 20 minute PowerPoint presentation augmented by appropriate handouts and visual aids oriented toward a non-technical, administrative, and corporate audience showing how the proposed development will best serve users' needs. Each presentation is followed by a 10 minute question and answers session. A written *"final report"* is also required to the submitted "client" and the industry advisory and faculty team. A suggested outline of the final report is presented in Table 1.

Seminar Series. As part of the IDS course a series of lectures is conducted in the Autumn Quarter on topics intended to guide students in their senior capstone design project and as they approach their transition from student to young engineers beginning a professional career. Expert practitioners, some of whom are part of the IDS industry advisory team, are invited to give one-hour seminars on following topics:

- Introduction to the IDS Project Selected
- Writing Reports and Giving Presentations
- Environmental and Permitting Aspects of the Project

Table 1. Suggested Outline for Final Report

- Title page with date
- Cover letter (from team to client)
- Acknowledgements
  - list all team members, their hometowns, and specific project responsibilities
  - list all engineering consultants, industrial mentors, and CEE faculty mentors
- Executive summary
- Table of Contents
- List of Figures
- List of Tables
- List of Notation

1.0 Background
2.0 Project Scope
3.0 Proposed Design
4.0 Preliminary Design
  4.1 Environmental
  4.2 Geotechnical
  4.3 Transportation
  4.4 Structures
  4.5 Water Resources
  4.6 Construction

EACH SECTION WILL INCLUDE:

4.x1 Field Investigation
4.x2 Data Analysis
4.x3 Findings
4.x4 Design Options (this will include the alternatives not selected and the reasons why they were not chosen)
4.x5 Recommended Option
5.0 Project Cost
6.0 References
7.0 Appendices (if bulky, appendices can be bound as a separate document)
  Drawings, maps, and photos
  Design calculations (each checked by other team members)
  Data from field or other sources
  Other relevant information (regulations/permits)
  Copy of Power Point slides

- Geotechnical Aspects of the Project
- Drainage and Erosion Control Aspects
- Structural Aspects of the Project
- Construction Aspects of the Project

To augment the above seminar series, the seniors also enroll in a separate one credit seminar series course on following topics:

- Building and Working as Teams
- Cost Estimating
- Value Engineering
- Ethics Issues for Projects
- Creativity in Design
- Construction Management
- Safety and Liability
- Construction Law

For each of the above seminars the student prepare a short paper summarizing what he/she experienced from, learned or received from, the presentation. This is a reflective writing and not just a repeat of the material presented in the class.

The seminars in Autumn Quarter reflect the basic disciplines to be addressed in the project – site design, structures, drainage, environmental, geotechnical, transportation, and construction. More detailed lecture series on 1) modeling and related computer software use (HEC-HMS and HEC-RAS) for drainage guidance and 2) preparation of bid package is provided in the Winter Quarter by CEE faculty members, each of two-hour duration. Sessions with the "client" are scheduled in both Autumn and Winter Quarters, and in Spring only if needed. Faculty and industry advisory mentors are available to come-in upon request if students are experiencing difficulties.

DESCRIPTION OF THE PROJECTS SELECTED

Restoration of the Historic Miami-Whitewater Canal in the Village of Cleves, Ohio. The project for the first two years (2000-2001 and 2001-2002) focused on a buried brick arch tunnel that carried the Whitewater Canal under US 50 years ago. The then-acting-department head and some faculty members had been working with the Village of Cleves to prevent the site from becoming a repository for fly ash. When the IDS program began, it was suggested that the tunnel could be an interesting, non-traditional multi-discipline project. In the first year, the student teams developed plans to preserve the canal tunnel, open up the end as a static display, and surround it by a small park with an amphitheater for educational purposes. The second year's project was the excavation of some of the tunnel in such a manner that it wouldn't collapse and to use it for a more dynamic site, employing bicycle and/or pedestrian routes through it.

Design of Solid Waste Transfer Station for Landfill Operation in Colerain Township, Ohio. Rumpke Landfill is considering the construction of a transfer station near its entrance to reduce the volume of traffic going back to the dumping site by transferring loads from smaller road vehicles into large on-site vehicles, thus reducing lost time for the many road vehicles as well as mud tracked out onto public roads – a long-festering problem in the community. Rumpke was willing to work with the IDS program, supplying valuable information and background data in return for "designs" that would look into many facets and alternatives of operation. Thus, over two years (2002-2003 and 2003-2004), eight IDS student teams developed eight variations of a transfer station on the landfill site. Students in the second year of the project did not see the results of the first year, although basic information and knowledge gained from the first year is shared with them by the lead professor, faculty, and industry mentors.

Design of the *Con*solidated *R*ent*a*l *C*ar (CONRAC) Facility for the Greater Cincinnati/Northern Kentucky International Airport. In the summer of 2004, the IDS lead professor spent considerable time meeting with the Director of Planning and Development for the Greater Cincinnati/Northern Kentucky International Airport to consider possibilities for an interesting, challenging multi-discipline project for the IDS program. They settled on the design of a consolidated rental car facility, a project that the airport hopes to build in the near future. In 2004-2005, five student teams generated plans for a CONRAC facility, and five more are working on it this year. As the airport's Director of Planning and Development has noted, no two of the ten are alike; each has some individual qualities, and all together provide a wealth of useful data to the "client." As with the Rumpke project, knowledge gained in the first year of design is shared with the second-year (2005-2006) teams, but the final products are not shared to avoid the temptations of copying previous work.

Involvement by the "client" is key to the success of the project. The first two years of the Whitewater Canal project were challenging to the students because there was no local, knowledgeable "client" to provide guidance. The project emanated from local civic enthusiasm and activism, but had not reached a point where technical people had become involved. That plus the very non-traditional nature of the project and the virtually unknown characteristics of historic brick arches were challenging. In the second project, the "client" in the first year was very much involved, and the students' interest reflected that. The "client" was not as involved in the second year, and the student interest and enthusiasm dropped considerably. The current airport project enjoys considerable support and enthusiasm from the airport's Director of Planning and Development, and the student interest and enthusiasm reflect that. One other element that has been part of all six years is a visit to the site at the beginning of the year. This visit gives the students an opportunity to see the site, visualize its characteristics, understand better the nature of the project, and ask questions of the "client." The visit also emphasizes the fact that the project is indeed "real," not contrived.

DESCRIPTION OF THE IDS DESIGN CENTER

In the IDS Design Center each design team has its own office style cubicle with a modern computer that has a full complement of software typically available in a real engineering office. All computers are networked to a high-speed printer (black/white and color) and a plotter that can produce full-size engineering drawings. The computer facilities provided in each cubicle and printing facilities provided in the Center duplicate a typical design office in a civil engineering firm. To assist teams during their planning sessions, the Center also has a conferencing area, complete with a 50 inch plasma screen Smart-Board. The CEE Department coordinated with the CEE Alumni Advisory Board's Facilities and Equipment Committee to raise $65,000 ($55,000 in cash and $10,000 in pledges) to establish this self-contained design and production laboratory. The lab was dedicated on October 9, 2003 by UC President Nancy Zimpher. The equipment and software provided in the Center are:

Hardware

- Five High-end Computer Workstations
- HP B/W Laserjet Printer
- HP Color Printer
- HP Large scale Design Plotter
- 50-inch Plasma with Smart-Board and multi-media hook-up.

Software

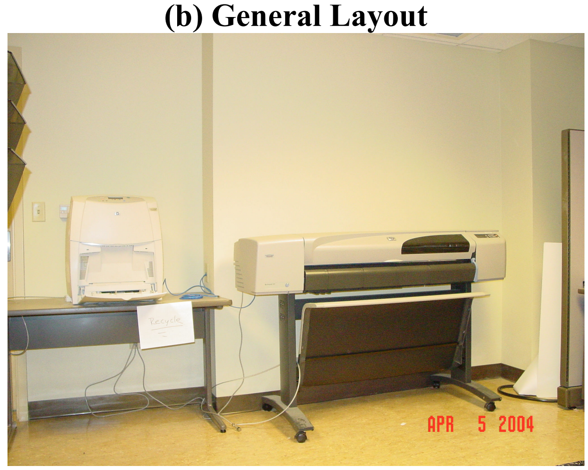
- AUTO-CAD (run from OCC license server) MICROSTATION
- HEC-HMS and HEC-RAS
- WaterCAD
- MS Office
- Wordperfect
- Visio
- Adobe Acrobat
- ArcView GIS

Figure 1 shows the layout of the work spaces and equipment provided in the Center.

(a) Conference Area with Smart-Board

(b) General Layout

(c) Typical Office Cubical for a Team



(d) Dedicated Plotter and Printer

Figure 1. A View of the IDS Design Center

GRADING PROCESS

The grade each quarter is based on a combination of individual performance as well as team performance. As mentioned earlier, each team is supposed to meet at least three hours each week, and the attendance is recorded by the faculty mentor. Thus a portion of the grade is assigned for attendance at these meetings. Quantity as well as quality of work is considered to assess mid-term and final reports. Both team performance assessments and individual performance in the presentations is part of the grade. The rating evaluation forms for each team mid-term and final-term presentations are shown in Table 2. A portion of the grade is also based on a peer evaluation where each team member grades the performance of each team member as well as his/her own. Finally, the project management team also evaluates each team member's performance and the faculty mentor assigned to each of the teams also evaluates the project teams. The final report each term is evaluated and graded by each faculty mentor and comments are also sought by the "client." These evaluations and comments are discussed in a meeting by the faculty mentors and the IDS instructor and a grade is assigned for the final report for each team member (note: each member of a team may or may not receive the same grade). The following grade distribution is used to assign the course grade for the quarter:

- Attendance: 25%
- Peer grading: 10%
- Mid-term Team Evaluations: 15%
- Presentations: 20%
  - Team: 10%
  - Individual: 10%
- Team Faculty Mentors' Evaluations: 15%
- Report: 15%

EVALUATIONS AND OUTCOMES

<u>Outcomes and Objectives</u>. For the undergraduate BS CE program at UC the outcomes selected correspond exactly to the program outcomes required by Criterion 3 of ABET EC 2000. Explicitly, the graduates of the Civil Engineering Program must demonstrate that they have:

(a) an ability to apply knowledge of mathematics, science, and engineering;
(b) an ability to design and conduct experiments, as well as to analyze and interpret data;
(c) an ability to design a system, component, or process to meet desired needs;
(d) an ability to function in multi-disciplinary teams;
(e) an ability to identify, formulate, and solve engineering problems;
(f) an understanding of professional and ethical responsibility;
(g) an ability to communicate effectively;
(h) the broad education necessary to understand the impact of engineering solutions in a global and societal context;
(i) a recognition of the need for, and an ability to engage in life-long learning;
(j) a knowledge of contemporary issues; and
(k) an ability to use techniques, skills, and modern engineering tools necessary for engineering practice.

Table 2. Presentation Rating Sheets

For Mid-Term Evaluations

Team _____ **Quarter _____**

Evaluation Criteria		Ratings									
Appearance (appropriate dress, name tag, engaged)		**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
Communication (clear & confident)		**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
Teamwork (displays cohesion, common voice)		**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
Progress (where it should be at this point)		**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
Concept Design (feasible, sound, innovative)		**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
Schedule (clear plan for taking project to end)		**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
Handout (appropriate)		**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
Asks Questions (seeks extra info or clarification)		**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
Design Team Total Score		<u>**Scoring Guidelines**</u> 1-2 Unacceptable, 3-4 Marginal, 5-6 Average 7-8 Very Good 9-10 Outstanding									

Comments: ____

____

Rated by: ____

For Final-Term Evaluations

Team _____ **Quarter _____**

Evaluation Criteria		Ratings									
Appearance (appropriate dress, name tag, engaged)		**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
Communications (clear & confident, use of graphics)		**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
Graphics (sufficiently large, clear and easy to understand)		**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
Presentation (logical order, coverage complete)		**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
Response to Questions (clear, direct & complete)		**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
Design (innovative, feasible, sound, complete)		**20**	**18**	**16**	**14**	**12**	**10**	**8**	**6**	**4**	**2**
Handouts (appropriate)		**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
Team Demeanor (relaxed, confident, enthusiastic)		**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
Teamwork (displays cohesion, common voice)		**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
Design Team Total Score		<u>**Scoring Guidelines**</u> **10-9** (20-18) *Outstanding* **8-7** (16-14) *Very Good* **6-5** (12-10) *Average* **4-3** (8-6) *Marginal* **2-1** (4-2) *Unacceptable*									

Comments: ____

____

Rated by: ____

The principal goal of IDS is to emulate the professional environment where teamwork is essential for collecting and analyzing diverse technical information needed to define and solve contemporary engineering problems. Under this umbrella, IDS has five educational objectives which are cross-listed with program outcomes in Table 3. The instruments used to assess IDS outcomes are described in Table 4. Results of assessment tools 2, 3 and 4 listed in Table 4 are summarized in Tables 5. In each case, the scale is 1 to 5, with 5 being the best. Over the years the assessment process has been developed and implemented in stages. So for certain quarters if the data was not available, it is indicated as NA.

In addition to quarterly reviews, two evaluations are performed on an annual basis: 1) the IDS external review; and 2) the senior exit interview. Recent results from both annual surveys are discussed below.

IDS External Review. The external review solicits written feedback from professional engineers who have served on the IDS industry advisory panel and assisted as reviewers. The Professional Engineers judge whether the graduating seniors meet eight desired educational outcomes and suggest ways to improve the capstone concept. As a sample, results are presented for the class of 2003 in Table 6. In 2002-2003 the IDS course feedback was used first time to make modifications for the following year; this is the reason for presenting results for this year. As can be seen from Table 6, seniors in the Class of 2003 were perceived as most capable in their ability to apply math and science with modern tools and techniques to formulate and solve engineering problems. By contrast, the two areas needing most improvement were communication skills and knowledge of professional and ethical responsibilities. The main suggestions for improving the IDS class focused on the perceived weak links. The external review panel recommended that some lecture time be devoted to reviewing the basics of effective communication skills and to discuss professional responsibilities and ethical issues. Discussions for these skill levels have since then been added in the senior seminar series.

Senior Exit Interview. CEE Seniors participate in an individual exit interview with the Department Head during the Spring Quarter to gather data on the overall quality of their undergraduate experience. Since IDS is a fresh experience for all seniors, they usually comment on it. Positive and negative comments from the Class of 2003 pertaining to IDS are summarized in Table 7, along with the number of students who raised an issue and the actions taken by the Department. On the positive side, many students understood and supported the rationale for IDS. Many comment that they most genuinely enjoyed the opportunity to work on a multidisciplinary (engineering) team. On the negative side, many students felt frustrated with a "lack of direction." To some degree, this outlook can be attributed to the open-ended nature of the capstone class. Nonetheless, the issue of organization was raised enough times to prompt the Department to re-examine and better define the expectations, deliverables, and schedule of the IDS class for the next academic year. Based on this assessment, following three recommendations were implemented:

1. Develop specific assessment tools to measure targeted IDS outcomes.
2. Track progression of design teams through the course of the year.
3. Provide students with a clearer picture of IDS expectations.

Table 3. Connection Between IDS Objectives and Program Outcomes

IDS Educational Objectives	Outcomes
1. Engage in continuous independent learning	e, i, j
2. Work together productively on interdisciplinary teams	d, g
3. Manage time and resources efficiently to complete a complex project	f, k
4. Apply technical information to make sound engineering recommendations	a, c, e
5. Develop and practice effective oral and written communication skills	g, k

Table 4. Instruments Used to Assess IDS Outcomes

No.	Assessment Instrument	Outcomes Addressed	When	By Whom+	Actions Taken
1	Project review meetings	a, c, e, g	Every quarter	FM, PE, PC	Intervene with design teams, as necessary
2	Team evaluation-1 (by peer group)	d, f	Every quarter	PG	Intervene with design teams, as necessary
3	Team evaluation-2 (by project mgrs)	d, f	Every quarter	PM	Intervene with design teams, as necessary
4	Student speaker evaluation	a, c, d, e, g, j, k	Every quarter	FM, PE, PC	Modify course delivery and content, as needed
5	Design report evaluation	a, c, d, e, g, j, k	Every quarter	FM, PC	Modify course delivery and content, as needed
6	IDS course evaluation	All	Every quarter	CEE Seniors	Modify course delivery and content, as needed
7	IDS external review	All	Every Spring	PE, PC	Implement suggested improvements
8	Senior exit interview	All	Every spring	CEE Dept Head	Modify course delivery and content, as needed.

+ Legend: FM = faculty mentors
PE = professional engineers
PC = project client
PG = peer group (student team members)
PM = project managers (elected student leaders)

Table 5. Evaluation Results

Team Member Evaluations by Student Project Managers				
CEE Seniors	**Autumn Qtr CEE 504**	**Winter Qtr CEE 505**	**Spring Qtr CEE 506**	**Class Size**
Class of 2001	4.67	NA	4.62	33
Class of 2002	4.55	4.38	NA	32
Class of 2003	4.53	4.15	4.50	36
Class of 2004	4.07	4.19	NA	35
Class of 2005	4.72	5	4.75	40
Team Member Evaluations by Student Peer Group				
CEE Seniors	**Autumn Qtr CEE 504**	**Winter Qtr CEE 505**	**Spring Qtr CEE 506**	**Class Size**
Class of 2001	4.66	NA	4.72	33
Class of 2002	4.56	4.72	4.74	32
Class of 2003	4.58	4.22	4.59	36
Class of 2004	4.32	4.59	NA	35
Class of 2005	4.44	4.53	4.73	40
Speaker Evaluations by Faculty Mentors and PE Advisors				
CEE Seniors	**Autumn Qtr CEE 504**	**Winter Qtr CEE 505**	**Spring Qtr CEE 506**	**Class Size**
Class of 2001	4.75	3.63	4.85	33
Class of 2002	4.41	4.40	NA	32
Class of 2003	4.58	NA	4.60	36
Class of 2004	4.50	4.12	NA	35
Class of 2005	4.34	4.72	4.52	40

Table 6. Assessment of Educational Outcomes Achieved by the Class of 2003 Judged by External Review Panel of Eight PEs

Rating[+]	Outcomes Achieved by CEE Graduates
4.75	Apply knowledge of mathematics, science, and engineering.
4.63	Design a system to meet desired needs.
4.63	Function on interdisciplinary teams.
4.75	Identify, formulate and solve engineering problems.
4.44	Understand professional and ethical responsibilities.
4.31	Communicate effectively.
4.63	Understand impact of engineering solutions in a global/societal context.
4.88	Use techniques, skills and modern tools needed for engineering practice.

[+] Note: 5 – strongly agree
4 – agree
3 – neutral
2 – disagree
1 – strongly disagree

Table 7. Strengths and Weaknesses of IDS as Perceived by CEE Class of 2003 (Sample Size N=27, 75% response rate)

Issues Raised by CEE Seniors	Number	Action Taken
Top 6 Positive Issues		
1. IDS helped me learn to work in teams	13	Reinforce importance of forming design teams
2. The idea behind IDS is excellent	7	Reinforce importance of participating in IDS
3. Having student group leaders is a good idea	3	Need to more strongly emphasize this aspect
4. Learned how a comprehensive project works	2	Need to better cultivate an appreciation for this aspect
5. Gained good experience in report writing	1	Need to better cultivate an appreciation for this aspect
6. IDS helped me become more persuasive	1	Need to better cultivate an appreciation for this aspect
Top 6 Negative Issues		
1. IDS lacks direction; needs more structure	14	Effort made to better define schedule and deliverables
2. Reduce IDS to a 2 quarter sequence	7	Issue will be considered by curriculum committee
3. Feedback from the client was slow	4	Instructor will encourage client to be responsive
4. Need more guidance from professors	3	Faculty mentors have been assigned to each team
5. Did not care for student leader concept	2	Allowed students to elect their leaders
6. Peer evaluations did not work	2	Modify evaluation process to assure anonymity

Evaluation for ABET Criterion 4. The ABET Criterion 4 states: "Students must be prepared for engineering practice through curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating engineering standards and realistic constraints that include most of the following considerations: economic, environmental, sustainability, manufacturability, ethical, health and safety, social, and political." To assess the satisfaction of Criterion 4 the following evaluations are planned to be conducted in 2005-2006 for the first time:

- A Student Opinion Scale Survey Form will be used to understand to what extent the students were able to meet the essence of ABET criterion 4. Student Opinion Scale Survey Forms are used to measure the motivation to learn a certain concept/topic/idea after completing a project or after taking the examination. For the IDS course the questions posed to the students in the form will include the following statements:
  - While working on this project, I understood the pertinent economic and sustainability issues that need to be considered in my design.

- While working on this project, I had a clear understanding of the pertinent environmental and health and safety issues that need to be considered in my design.
- While working on this project, I had a clear understanding of the pertinent ethical, social, and political issues that need to be considered in my design.
- My project presents a constructible solution to the problem that was given to us.

Students will respond to the above statements using a five-point Likert scale from 1 (Strongly Disagree) to 5 (Strongly Agree). This survey will be administered at the end of the course.

- Similarly, the faculty and industrial mentors will evaluate the student project reports and final presentations for the following statements:
  - While working on this project, the student team demonstrated that they understood the pertinent economic and sustainability issues that need to be considered for the project.
  - While working on this project, the student team demonstrated that they had a clear understanding of the pertinent environmental and health and safety issues that need to be considered for the project.
  - While working on this project, the student team demonstrated that they had a clear understanding of the pertinent ethical, social, and political issues that need to be considered for the project.
  - In this project the student team has presented a practical constructible solution to the problem.

CONCLUDING REMARKS

The Integrated Design Sequence for the CE Senior Class at UC occupies a unique niche in the CEE curriculum. Since its inception in autumn 2000, IDS has been quite successful in introducing CEE Seniors to a realistic open-ended design experience where teamwork, planning, and ingenuity are critical for defining and solving a contemporary engineering problem.