Educating Designers on Design via Distance Learning

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Abstract

This paper describes the experiences of the Department of Mechanical Engineering-Engineering Mechanics at Michigan Tech University in teaching conceptual capstone design to corporate designers, and it presents the challenges of adapting the traditional course delivery to students learning at a distance. This design course includes the integration of creativity with design; it simultaneously addresses a traditional on-campus population in a two-semester sequence and a group of corporate employees (100 to 200 students) at a remote location in a one-semester accelerated version. Differences are explored, ranging from cultural and logistical to the motivation of on-campus students versus off-campus designers in learning new methodologies. The challenges, logistics and organization, successes, failures, changes, and recommendations are discussed, based on experiences during Spring 2004 and Spring 2005.

Background and Challenges

The Designing Engineer Certificate (DEC) program was created by Michigan Tech in 2000 to meet the needs of a corporate distance learning client—its goal was to significantly enhance the skill and knowledge base of designers and engineers having diverse educational and experiential backgrounds. The program emphasizes the use of modern solid modeling tools to build a virtual model of a system, together with finite element programs for the evaluation of stress and deflection in the virtual model. The DEC core courses build on the fundamentals and encompass many of the mechanical design concepts included in the distance-learning Bachelor of Science in Engineering (BSE) degree program offered to people working in industry.[1] The capstone design project is the culmination in both the certificate course sequence and the on-campus course sequence. An important requirement by the client was that the distance-learning capstone design course must incorporate the same principles as the capstone course taught to on-campus students. This constraint represented a major challenge, not only because the distance-learning students had different educational backgrounds and experience levels, but because the content had to be delivered in one semester (e.g., Spring 2004), whereas the on-campus students had two semesters (e.g., Spring 2004 and Fall 2004) to complete their projects. Other challenging differences included project selection, team formation, team project monitoring and final course assessment. The instructional team also faced the challenges of integrating their teaching approaches and streamlining the topics and reading materials required of all students, while placing an increased emphasis on creative thinking and the development of new design concepts.

Evolution of Course Content and Objectives

Two professors with different perspectives and experiences in teaching design teamed up to teach the capstone design course for the academic periods designated "2004" (Spring 2004/Fall 2004) and "2005" (Spring 2005/Fall 2005). Professor Evensen's design background is in the area of "Design for X" (DFX), whereas Professor Lumsdaine has co-authored and taught conceptual design based on a creative problem solving model. The main texts used were *Engineering Design* by George Dieter[2] and *Creative Problem Solving and Engineering Design* by Edward Lumsdaine, Monika Lumsdaine and J. William Shelnutt.[3] To streamline the reading materials and substantially reduce the costs to the students for purchasing the books, a customized edition was produced at the suggestion of the McGraw-Hill campus representative; it is *Creative Problem Solving and Engineering Design 2* and combines all the material from Reference 3 with selected chapters from Reference 2 in the areas of information sources, ethics and DFX.[4] The course content traditionally taught at Michigan Tech during the first semester was retained, but the emphasis was shifted toward conceptual idea generation, development, and communication, as shown in Table 1.

Table 1 Capstone Design Course Syllabus and Sequence of Topics

Introduction	
1, 2	Course requirements, grading; project descriptions; need identification; design journals
Foundational Thinking Tools	
3, 4	Thinking styles model (HBDI); application to teamwork and communication
5	Creative problem solving: model overview; problem definition (*explorer* + *detective*)
6	Creative problem solving continued: idea generation (*artist*), creative idea evaluation (*engineer*), critical evaluation (*judge*), solution implementation (*producer*)
12	Overcoming mental blocks to creative thinking
Engineering Design and Project Management Tools	
7,8,18	Design documentation, formats; how to give an effective oral presentation
11	Project planning and scheduling charts (using CD templates in the textbook)
13, 14	The Pugh method for creative design concept evaluation and solution optimization
15	Information sources and patent searching
17	Economic decision making (using CD templates in the textbook)
19	QFD and design specifications (or other just-in-time topics needed by specific projects)
21	Prototyping and prototype testing
22, 23	Product liability; ethics
24–26	Design for X (DFX); design for manufacturability (DFM)
10	"Innovation in the Workplace"
Individual and Team Project Deliverables and Course Assessment	
9	Oral team presentation of project proposal; written proposal is submitted to sponsor
16	Oral and written team presentation of progress report to instructors and sponsor
20	Written exam on reading assignments and design concepts
27	Final oral team presentation and poster exhibition; design journals
28	Peer contribution rating form; course evaluation; final team project report.

Only three adjustments had to be made in the course syllabi between the campus students and the distance learning students to account for the major differences between the two groups:

1. <u>"Innovation in the Workplace" Lecture:</u> This topic was scheduled for the distance learning students while the on-campus students were on winter break. For the on-campus students, it was shifted to the second semester when they receive other materials commonly known by or provided to people working in industry, such as FMEA (failure modes and effects analysis) or support for patent applications.
2. <u>Project Reports:</u> The distance learning students had to have their projects completed and documented by the end of the semester, including prototyping and testing, whereas the on-campus students had a second semester to finish their projects. Thus the oral team progress report half-way into the first semester was a major presentation for the distance learning students, whereas the campus students were limited to a 3-minute briefing to their class and instructors. Both groups, however, were required to submit a complete written report. For the off-campus students, the final team project report was the last element in the course. On the other hand, for the on-campus students, the final team project report at the end of the first semester was an extensive progress, or "accomplishments to date," report, where all major decisions on the best design concept had been made. The second semester's work then consisted of detail design, building the prototype, analysis, testing, and preparing a final report that could include operating instructions and manuals if required by the sponsor.
3. <u>Use of the Herrmann Brain Dominance Instrument (HBDI):</u> At the beginning of the capstone design course, the on-campus students completed an on-line HBDI survey form to assess their thinking preferences.[5] The results were used to form mentally diverse teams which had at least one member with a strong preference for right-brain, conceptual thinking, together with members with dominant interpersonal, organizational, or analytical thinking modes as outlined in Table 2.[3,5,6] Although initial communication can be difficult in such "whole-brain" teams, the members learn to appreciate the contributions and perspectives their differences bring to the team, and the team is eventually able to achieve superior results.

Table 2 Thinking Characteristics and Behavioral Clues of the Herrmann Model

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A	D
Rational Financial	Visual Conceptual
Academic Quantitative	Futuristic Contextual
Mathematical Analytical	Risk-taking Synthesizing
Technical Critical Realistic	Holistic Playful Strategic
Authoritarian Logical Factual	Imaginative Spatial Artistic
LEFT	**RIGHT**
Dominant Organized Tactical	Expressive Symbolic Teaching
Risk-Avoiding Conservative	Interpersonal Communicator
Administrative Scheduled	Kinesthetic Value-based
Procedural Sequential	Intuitive Cooperative
Reliable Detailed	Supportive Sensing
B	C

LIMBIC

Since the distance-learning students were already in teams and assigned to specific projects before the start of the semester, they were not required to complete the HBDI survey, though some students did so on a voluntary basis at their own expense. All students, however, were introduced to the Herrmann model of thinking styles since it forms the basis of different thinking modes used at various steps in the creative problem solving process—the on-campus students received an additional ten minutes of lecture and a separate handout on the analysis of their class HBDI results.

Delivery Logistics

The lecture portion of the 2004 design course was taught in the University's studio classroom to an on-campus section of 63 students. Each "live" lecture was videotaped and then delivered to the corporate client with a set of all handouts, supplementary lecture notes, and hardcopy of all overhead transparencies used. The off-site schedule lagged behind the campus lectures by two weeks to allow the materials to be duplicated and delivered to the corporate client's sites. In 2005, the lecture portion was taught "live" to 50 on-campus students; it was then delivered to the corporate client with a two-week lag in delivery (one week after spring break).

<u>Team Formation and Project Assignment for On-campus Students</u>
In 2004, the HBDI consultant formed the required number of whole-brain teams based on the students' HBDI results—then the instructors assigned these teams to projects, based mostly on some of the technical/educational expertise present in the teams. In 2005, the process was modified. First, the students who were not mechanical engineering majors were assigned to the projects where their expertise would be of greatest benefit. Then each project was assigned one student with high quadrant C (interpersonal thinking) scores, one student with creative thinking preferences (quadrant D) and one student with organizational thinking preferences (quadrant B). The remaining slots were then filled with analytical thinkers (quadrant A), making sure that no team had more than one member who avoids quadrant C thinking (to prevent teams where members do not talk to each other). As much as was possible, the team assignments also took the students' interest in particular projects into account.

<u>Distance-Learning Students</u>
At least three months prior to the start of each distance learning course, the instructors spent several days at the corporate client's sites to set up the logistics for the course delivery. These students formed their own teams, depending on their location and work schedules, and then submitted project proposals to the instructors, after approval by their supervisors. In 2004, this proved to be a very time consuming process. Based on this experience, the procedure was streamlined and resulted in an increase in the number and quality of proposed projects for 2005.

The corporate client assigned a "sponsor" to each team—a high-level manager. In 2004, this sponsor was expected to contribute to the project assessment/grading. However, several sponsors did not want to become involved at such a detailed level due to time constraints. For 2005, each team was again assigned a sponsor—but the grading tasks were removed. Each team was also given a technical advisor. The course was being delivered at six sites, including five in Michigan and one in Canada. Each site had a moderator who set up the delivery of two tapes and associated handouts each Thursday afternoon. These moderators also collected assigned homework and reports and monitored the mid-term exam for the instructors.

Communication between the instructors and the distance learning students was conducted primarily by email and occasionally by telephone. It was found that some teams were very autonomous, whereas others required more detailed instruction and reassurance, especially when their supervising manager was unable or unwilling to be available on a regular basis. Face-to face contact between the course instructors (MTU faculty) and the distance learning teams was accomplished with site visits to the industrial client. The instructors traveled to each corporate site three times during the Spring 2004 semester, each time for two or three days. During each visit, they observed and evaluated the teams' progress from written reports and oral presentations, and they were also available to meet with individual teams at their request. All grading was done on-site because none of the generated materials (reports and journals) were allowed to leave the site due to the confidential or proprietary nature of the projects. For the Spring 2005 semester, four visits of three or more days were scheduled in response to demand—one visit approximately every four weeks. This was in addition to the official "rollout" meeting that took place two months before the start of each course. This meeting has proven absolutely essential for answering questions and discussing guidelines, so that supervisors and students would be able to form appropriate teams and select suitable project topics that could be approved by the instructors before the start of the course.

Experiences and Modifications

There was a noticeable difference in attitude between the on-campus and off-campus student populations. The on-campus traditional students were more willing to learn the structured design methodology and processes. Some of the distance learning students, on the other hand, continually questioned, "Why should I learn a new way—I already know the corporate way?" This attitude was an obstacle to successful team dynamics and project progress and had to be addressed very early in the semester. With very few exceptions, the instructors insisted that these students adhere to the "generic" structure and formats being taught—after all, these students do not have any guarantee of always working for the same employer. This difference in attitude caught the instructors by surprise—they had expected the experienced designers to be more aware of the need for change and flexibility for encouraging innovation in the industrial setting. Both the on-campus and off-campus industrial groups of students needed frequent reminders about taking some risks with new ideas, especially in the early phase of conceptual idea generation.

Cultural differences in the two distinct student populations were also observed with regard to the design journals. In 2004, the distant-learning design journals were very formal and structured and completed as a team, whereas the individually submitted on-campus journals were informal and at times rather sloppy documents. For 2005, the distance-learning students were required to complete individual journals, and the campus students were encouraged to develop a habit of making good journal entries.

Despite these differences and approaches to learning and "following the rules," the final products from the students in 2004 all incorporated a fine team effort, solid problem-solving, good design work, and for the most part, excellent presentations and reports. Thus, grades ranged from A to C for both the distance learning students and the on-campus students, with similar score and grade profiles in both groups. In 2004, many of the corporate advisors and sponsors in the distance-learning version would not execute their assigned assessment tasks; thus the evaluation scheme for the distance-learning students had to be revised. For 2005, the final grade for the distance-learning course was a composite of team performance (70%) and individual performance (30%), with evaluation being done by the instructional team (75%) and the students' peers (25%).

Table 3 Weight of Course Deliverables

Project Proposal, 5%	Project Poster, 15%
Progress Report, 5%	Written Exam, 10%
Final Team Oral Presentation, 20%	Design Journal, 10%
Final Team Written Project Report, 25%	Final Peer Contribution Rating, 10%

The Peer Contribution Rating Form[3] was first completed by each team member about five weeks into the semester to identify teams that may have problems with leadership or non-contributing members, or trouble emerging from the "storming" stage. Teams with problems were given advice on remedial actions, followed with a second form a few weeks later. Only the final form, submitted at the end of the course, contributed to the course grade.

The distance learning students had a "carrot and stick" motivation provided by their employer for succeeding in this course: if they did not pass, they risked losing their job; if they completed the course and obtained their certificate, they received a substantial bonus and pay raise.

Instructional Teamwork

The instructional team was intentionally diverse and was comprised of:

a. two instructors with overall responsibility for the course but with differing academic and industrial backgrounds as well as complementary thinking preferences,

b. a graduate teaching assistant to represent student viewpoints. Also, he had responsibility for record keeping and communication, as well as giving two lectures (project planning and economic analysis)—both of which involved the use of the CD-based templates furnished with the textbook, and

c. in 2004, a faculty associate who provided additional professional insights and several lectures. In 2005, this was a consultant (co-author of the textbook, HBDI-certified) who prepared many of the PowerPoint slides and presented four lectures in the area of thinking preferences, communication, teamwork, and the Pugh method.

All lectures and lecture materials were reviewed by the instructional team in a "dry run" conducted at least a day before delivery to the on-campus class and videotaping. As a result of this review, the lectures were modified as necessary and the handouts revised in time for classroom distribution and web posting. The lectures used overheads in 2004 but converted to PowerPoint in 2005. Communications with corporate and site moderators were conducted by email and telephone as needed. Mailings and web postings to the students were made through the university's Sponsored Educational Programs/Distance Learning (SEP) department. Contacts with corporate sponsors and travel coordination were also expedited through SEP.

Results and Recommendations

Teaching Load
The pilot distance learning class in 2003 had 25 students in five teams. All the teaching and administrative tasks were handled by a single instructor. This was a full load for one person and allowed only one on-site visit. Also, the textbook used at the time was not as "teachable" and did not provide the templates and communication formats which proved to be significant time savers in subsequent years. In 2004, the distance learning enrollment was 100 students in 20 teams with an additional 13 teams on campus. For Spring 2005, the distance learning enrollment was 180 students in 40 teams with an additional 12 teams on campus. Another group of approximately 100 distance learning students is expected for Summer 2005 to complete the DEC program with this particular corporate client. However, the instructors have found that the course improvements, including the streamlined syllabus and PowerPoint slides, have made this distance learning course exportable to other clients and sites. Some of the tapes are reusable "as is"—other topics can easily be customized and videotaped for different clients, thus reducing the preparation time for each lecture.

Site Visits to Off-Campus Students
Reviewing the design journals and oral presentations are the most time-consuming activities. The design journals cannot leave the corporate site due to proprietary concerns and thus can be processed only during a site visit. For this reason the two instructional tracks, on-campus and at the corporate client, must be staggered so that the heaviest grading workload and site visits occur in periods when the on-campus students either have a break or have completed their semester. In effect, this extends a typical semester's work for these instructors by two weeks. Also, it is important to allow for adequate commuting time and meal breaks between different sites, meetings, and work sessions and to streamline the process as much as possible.

Prevention of Dysfunctional Teams or Misdirected Projects
The instructors found that the combination of tools, from the four-quadrant thinking model and creative problem solving process to the project planning templates and the peer contribution rating form helped to prevent dysfunctional teams among the on-campus students. Also, having the structured information flow and design documentation through required formats and timely reports prevented teams from having project outcomes that did not meet the requirements or expectations of their sponsors. Several of the 2004 distance learning projects were submitted by the corporate sponsors for "value-added" awards. The results will be available by conference time. After the improvements made in more clearly organizing the syllabus for 2005, to address the major criticism from the 2004 student evaluations, the instructors have received very positive comments on the well-organized 12-step design process.

Instructional Staff
Although providing immediate answers to emailed questions from students was attempted, it was found that some delays could be beneficial. It enabled the instructors to be on the same wavelength when answering; it also gave students time to find their own answers, especially when the questions were very simplistic. In 2005, the instructors were careful not to include information geared only to on-campus students on the videotapes. This reduced student confusion at the distance learning sites. Whenever the two groups received slightly different instructions during the lecture, this was clearly identified in the slides and handouts.

Resources and Commitments Required
Support from the university administration, especially at the departmental level, and from high-level management in industry, is essential. There is no other way around it—teaching a capstone design course with a team project requires time and adequate staffing. It has been found that the distance learning design course is several times as labor-intensive as a regular distance learning course. It is also much more expensive than a traditional distance learning course that merely involves the delivery of a video-taped lecture.

What type of faculty members are best suited to teaching capstone design by distance learning? It is very time intensive and there are, for most institutions, no direct benefits in terms of tenure-track teaching and for promotion and tenure. Unfortunately, these constraints would most likely exclude young faculty trying to build their careers in research. On the other hand, engineering experience is a valuable asset. This type of teaching is a great opportunity for faculty who are not ready to retire and want to try something new—an enterprise that leaves room for new ways of doing things—in other words, an application of creative problem solving.

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