

Senior Design Classes: Teaming Engineers with Technical Documentation Specialists to Enhance Students' Learning Experiences

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“No single profession can hope any longer to equip . . . its practitioners with the knowledge and skill required to address the range of issues inherent in any complex project.” —Geisler, Rogers, & Haller (1998)

“In the ‘new organization,’ individual contributions will come as a result of understanding how one’s efforts coincide with others, how one’s objectives can be integrated with those of others, how one’s own point of view can be advanced” in the context of other points of view and “how multiple motives and energies can be focused on a single performance objective.” —Larson & LaFasto (1989)

Introduction

The most recent ABET evaluation of the mechanical and the industrial engineering programs at New Mexico State University (NMSU) highlighted the senior design class as an extremely successful and effective method for allowing students to learn by experiencing the realities of an industrial environment in the classroom. Our innovative method for teaching the senior design classes involves the formation of multidisciplinary teams of students from three programs: mechanical engineering, industrial engineering, and technical communications. The multidisciplinary teams work on designing products, product sub-assemblies, processes, or systems for various clients sponsoring the projects.

An integral component of this experience is the inclusion of technical communication students as full, participating members of the engineering design teams. This approach, modeled after cross-functional teams, is becoming increasingly more common in industry (Brown & Duguid 1998; Cole 1999; Farkas 1991; Finholt, Sproull, & Kiesler 1990; Grice 1991; Lave & Wenger 1993; Lay & Karis 1991). Another unique aspect is that faculty members from all three departments have collaboratively planned and designed all course materials. In addition, the faculty participate equally in delivering the class to students from all three disciplines in a shared classroom.

In this paper, we report on the mechanics, challenges, and rewards associated with creating and teaching a truly multidisciplinary, senior-level class. Drawing from our own critical assessment as well as student feedback, we also offer a number of strategies in a “course design checklist” for those who are considering the design of—or seeking to improve—multidisciplinary experiences in the classroom.

History of the Course

In part as a result of a survey of NMSU alumni, the two engineering programs joined forces with the technical communication program to provide students hands-on experience with realistic design projects sponsored by clients from the local, state, and national government and research communities. According to results from the NMSU Alumni Survey conducted by the College of Engineering, the top three skills required of a practicing engineer are 1) effective problem-solving skills, 2) communication skills, and 3) teaming skills (Riley & Pines, 2000). These three, interrelated aspects are also important for practicing technical communicators, making this type of collaborative enterprise valuable for students from all programs. Engineers and technical communicators alike are now spending more time on the job with multidisciplinary teams throughout the duration of workplace projects. Multidisciplinary teams are increasingly called upon for addressing complex problems and issues (Malone, 1991; Pieratti 1995; Schiappa 1995). Multidisciplinary endeavors, for instance, can ideally help address such problems by allowing collaborators to be introduced to alternative ways of thinking as well as different approaches to problem solving.

The joint effort between the College of Engineering and the College of Arts & Sciences allows students to work on multidisciplinary teams to create a design product for an actual client, such as Boeing, the Department of Energy, or smaller companies in our area. Students participating in this experience have worked on projects such as redesigning a manufacturing process for attaching a landing gear component to the internal wing spar of an airplane or replacing the current inspection of metallic tubes within generators using new radar technology. Several student teams have worked on competition projects such as BattleBots, Human-Powered Vehicles, and “Mini-Baja”—projects requiring the building of a product to compete with other such products from across the nation. In other cases, students redesign sub-assemblies of engines, audio speakers, or packaging for local companies or individual sponsors.

Students participate by signing up for a capstone course at the undergraduate or graduate level. Approximately 15 client projects are solicited each semester the course is offered, and students select the projects that interest them most. In addition to gaining multidisciplinary experience and learning to value expertise that other disciplines can bring to the table, students can benefit from learning to analyze a real client’s needs, researching alternatives to meet those needs, interacting effectively with one another and with the client, as well as designing and evaluating a solution in the form of a deliverable product or system. To supplement the design product, students also collaboratively produce a report documenting their processes and final product. At the semester’s end, they present their design solutions to the participating faculty as well as their own clients. All of these activities map onto the top strengths cited in the NMSU alumni survey: effective problem-solving skills, communication skills, and teaming skills.

This learning experience differs in significant ways from experiences in more traditional versions of our courses. In the traditional mechanical engineering capstone design course, for instance, only mechanical engineering students work in project teams. The major goal of the mechanical engineering (ME) capstone course is to utilize the

knowledge and skills acquired in earlier ME course work and to incorporate engineering standards and realistic constraints that include economics, sustainability, manufacturability, and so on. Yet to provide realistic and practical solutions to such problems, it is necessary to draw on multidisciplinary expertise. However, a complex and real-world project requires frequent and efficient communication within teams composed of people varied in expertise.

Similarly, in the traditional industrial engineering capstone design course, students focus on developing solutions that are entirely grounded in an industrial engineering context. Although this approach is a valid one for a sophomore or junior level course, it is unrealistic for a senior level course that is attempting to give students a realistic exposure to a working industrial environment. Typical problems that industrial engineers work on in industry are multidimensional and multifaceted in nature. Because the systems industrial engineers are most involved with are very large and extremely complex in nature, deriving a complete solution for solving these problems usually involves other engineering and other organizational disciplines.

The traditional senior-level technical communication course also differs in significant ways from the new, collaborative endeavor. While client projects are sometimes required in technical communication courses, the projects typically involve creating or revising text and graphics for a range of documents such as brochures, web sites, or user manuals. In these cases, the focus is often on the final product rather than on learning during the *process* of the experience; creating a deliverable; or using writing to plan, orchestrate the creation of, and document products designed with expertise from outside disciplines. In such cases, the documents are often constructed or revised in a vacuum, without the organizational or technical understanding necessary for a rhetorically appropriate document.

These more traditional projects often miss an introduction to ideas from external communities of practice, communities housing information that can prove critical to a successful project. As Beaufort (2000) states, a technical communicator, for instance, cannot help produce successful documentation without “understanding the bigger picture of both immediate and long-term social implications of a given document in relation to the discourse community's goals and values.” We would argue the same holds true for engineers designing products and systems: without understanding the bigger picture of short and long-term implications, their designs may fall short. In contrast, working on multidisciplinary teams typically leads to more questioning and rigor, since aspects that are immediately apparent to one community of practice may be misunderstood by those from other communities of practice. Providing explanations often leads to rethinking and re-visioning, as well as expanding exploration in breadth and depth within a project’s “problem space.”

The class is now in its third cycle of refinement. In our initial joint effort, students from mechanical engineering and industrial engineering were provided 15 client projects to choose from for the main component of the course. In contrast, the client project was one among many projects required of technical communication students, so the amount of

time available to work on the projects did not match the full attention required of the engineering students. In teams, students met outside of class time to plan, design, and revise their projects. The varied schedules of their classes prevented these students from meeting in person as much as their projects required, but students were still reportedly able to draw to some extent from one another's individual and disciplinary strengths.

In the second iteration of the course, faculty and students from all three disciplines worked much more closely, with the goal of overcoming the main difficulties noted during the initial effort (Riley & Pines, 2000; Dyke & Wojahn, 2000). During this iteration, the classes were more closely scheduled so that all students and faculty could meet in the same classroom once a week, sharing lectures and suggestions related to design processes and products. In this iteration, all 15 or so teams had at least one representative from each of the three disciplines. Yet because the technical communicators were scheduled for only half the amount of time the engineers were scheduled for, some time conflicts remained. Technical communication students were required to complete much more outside reading, and students still reported difficulties in understanding fully the importance of sharing expertise, learning about other disciplines, and so on.

Now in our third year, we are making even more changes. Based on student feedback and our own assessment, we are further redesigning the course and making efforts to bridge gaps between disciplines and to shape equivalent expectations.

Unique Features

With a focus on unique features of our collaboration, some of the key elements incorporated or modified in our third offering of the course are discussed below.

Premise

Our shared overarching goal continues to be to enhance student learning and experience. Originally motivated by ABET guidelines, our class was designed to address the outcomes of assuring our graduates could communicate effectively and participate successfully on multidisciplinary teams. As a change agent, ABET initially provided the framework and system of metrics enabling curriculum overhaul. Since that time, we have carefully tracked outcomes through student surveys, project logs, and meeting minutes; participant-observer notes, as well as student and faculty interviews. Feedback from students and clients alike document the improved learning experience for all involved.

The Faculty Perspective

The multidisciplinary course is offered in the Spring semester, however as faculty, we meet regularly, often weekly, throughout the year to plan and coordinate joint lectures and corresponding activities. Essentially this means that we are either meeting in conjunction with the specifics of an on-going class or preparing for the next offering of an upcoming class. While the class is underway, additional meetings with other team mentors, team leaders and student teams are held to discuss issues raised by teams over

the semester. This means getting immersed in one another's fields, acting as mediators and negotiating pedagogical practices.

After our initial semester, in which our classes met at separate times and in separate buildings, we have attempted to promote collaboration among disciplines by *modeling* a multidisciplinary endeavor ourselves. This entails careful scheduling so that overlap can occur and so that space is allocated for several full courses of students meeting together. It also entails substantial background work as we all attempt to learn to understand and value the various types of inquiry within each of our disciplines and to include multidisciplinary "takes" within the lectures we take turns presenting.

The class format focuses on various facets of the engineering and communication design process that relate to us all, including team dynamics; interpretation of client "needs statements"; client interviews; negotiating a "Statement of Work" agreement between client and student team; design conceptualization; feasibility assessments; objectives and specifications; design drawings; technical data packages/reports; design packages and reports; analysis and synthesis; designing for quality, reliability, and maintenance. Lectures are typically followed by a half-hour team exercise in which students apply the concepts and ideas related in the lectures. In the past, we also met with student team managers to preview the next steps and to review team progress.

In our third iteration, the course structure will work as follows: For a portion of the three-hour time slot on Mondays, we faculty will jointly present lectures on product and system design as well as the role of writing and communicating in both product and process. We will also provide a heads-up on where we expect the teams to be in the design process and field questions about individual problems related to the project, the client, or the teams themselves. These lectures will typically be followed by a team activity advancing the projects and reinforcing the lecture topics for the week. For the last portion of class, student teams may schedule meetings with a designated mentor (one of the participating faculty or other faculty who have agreed to serve as clients). Mentor meetings are to be scheduled for an hour or so each week. Students are encouraged to keep in close contact with any external client as well.

In the past, once a week, we went to what we called our "disciplinary corners," meeting in our own buildings and discussing issues related to our own disciplines in more depth. Students were additionally expected to meet weekly with their teams and, at times, their clients, outside of these scheduled time commitments.

In our third iteration, we are foregoing the separate meetings for students in their given disciplines; instead, we are making more class time available for team meetings, meetings with faculty, and meetings with mentors or clients. We are also strengthening coordination among ourselves and preparing course materials for delivery via WebCT. In our third iteration, we have also chosen two textbooks to be recommended to all of our students (one text from engineering and one from technical communication) and another text that we as faculty will draw from. We believe that providing students shared resources will provide a shared foundation as well as increase multidisciplinary

awareness and appreciation. For the first time, we have also scheduled courses exactly at the same times so students or teams can meet in class 6 hours per week, during which time some shared workshops and many shared lectures will be delivered.

Challenges

Not surprisingly, this type of endeavor presents challenges for students and faculty alike. As faculty, we have been coping with issues related to time—when courses (housed in different departments) are able to meet, how variable credits affect the timing of courses, and so on. During the first iteration, technical communication students received only partial credit for the multidisciplinary project, whereas for engineering students, the project was central to the course. As we approach our third iteration for Spring '02, we have allocated technical communication sufficient credit hours, and therefore times, to match the engineering students' class and lab times exactly.

Other logistical items have presented themselves, such as locating and reserving a shared classroom that can accommodate 80 or so students from across campus and departmental computer classroom permissions for students from outside departments.

Another key challenge has been locating committed clients that can provide and support a project (1) that can be completed in full or in part within the constraints of a semester and (2) that provides room to engage students from all three disciplines: mechanical engineering, industrial engineering, as well as technical communication.

Overseeing student teams is always a challenge, even more so when the teams consist of people with vastly different backgrounds. As much as possible, we tried to put together teams with members who expressed interest in a given project, and we tried to keep people apart if they explicitly requested those with whom they did not want to work. All teams were asked to report to and work with a team mentor (typically one of the participating faculty members) an hour per week, outside of class time. Nonetheless, despite leadership from designated team managers, some of the projects can “get away from” the students, particularly if parts aren't ordered on a timely basis, if communication among team members is poor, or if team members have different conceptual models in mind for their designs. A preliminary design review, scheduled for an hour and a half per team, was set to identify any glaring issues teams were (or would be) facing. This formal, preliminary review takes place with all participating faculty present to question the teams progress, materials to date, and schedule for completion.

Promoting effective working relationships also proves to be a perpetual challenge. In particular, one of the key challenges remains in prompting students to see the value of the multidisciplinary expertise made available from the three distinct disciplines, yet when this does occur, it proves to be a great reward. As one industrial engineering student stated, “This is what we need in engineering. [Otherwise,] everyone is taught the same way, taught to think the same way. [The technical communicator's] role here helped, as he'd have a totally different view [from the engineers' views].” Admittedly more

common during our first offering of the collaboration were student comments revealing misunderstandings or frustration, such as the following:

- “We just didn’t have a clear scope of what we were supposed to do with our technical writer.” - Engineering major
- “I had the feeling they would not consider me useful until it was time to put the report together, weeks later.” - English major

We expected and have seen a number of relationship problems surfacing, including misunderstandings based on discourse differences; varied goals priorities, and purposes; and varied or competing conceptualizations of the design’s target audience(s).

Given that academic institutions themselves divide disciplines, we do not find such comments surprising. After all, academia consists of distinct disciplines with scholars characterized by their differences (Russell 1997). Moreover, expertise is typically characterized by the resulting specialized knowledge and specific methods of investigation. Yet that approach results in knowledge being compartmentalized rather than shared and offered for use in other areas of an organization (Mahala & Swilky 1993). Brown & Duguid (1998) suggest that to solve this problem, many organizations attempt “cross-divisional synthesis,” though this does not necessarily produce the synergy made possible when cross-functional members or divisions actually work together. This aspect is key to our multidisciplinary endeavor, but has proven more difficult to overcome than simply putting mixing students from various disciplines into groups required to create a design and its documentation.

Such challenges suggest the need to provide students more space and time to work together, face-to-face, where they can ask questions as they arise, observe one another’s practices, and gain insight into the rationale behind the design decisions themselves. In our third iteration, we also plan to bring more attention to the importance of “boundary-spanning” objects that our students use, since such objects have been found to bring diverse team members to shared understanding. In our endeavor, such objects might include

- Group contracts
- Written minutes, notes, report drafts, schedules
- Plans, blueprints, prototypes, simulations

Ideally, we can encourage our students to use these boundary-spanning objects to articulate as well as negotiate their differences.

Rewards

Obviously, with the number of challenges we face in our collaboration, we see the rewards overshadowing any drawbacks. As faculty, we are joined by a shared sense of potential rewards, shaped by the following beliefs (discussed in more detail in Wojahn, Dyke, Riley, Hensel, & Brown 2001):

- **Multidisciplinary collaboration can provide students an enriched, challenging learning experience similar to situations they may face outside of**

school. Such collaboration is particularly useful “when diverse skills, judgments and experiences” are required to resolve a complex situation (Katzenbach and Smith 1996). Multidisciplinary teams in many organizations allow a project to draw from “expertise regardless of where it resides” (Finholt, Sproull, & Kiesler 1995).

- **Multidisciplinary collaboration can allow students to practice or strengthen skills they do not consider “their job.”** By working through problems with people outside their own disciplines, students can observe and practice new ways to approach and resolve issues.

Multidisciplinary projects can serve as a bridge between the academic and workplace worlds. Multidisciplinary, client-based projects can introduce students to the type of ill-defined, “messy” problems common to workplace settings, where no single “right” answer can be located and where expertise from many disciplines must be included.

Conclusion

Although the course presents many challenges for participating faculty and students across the various disciplines, in the end, students (1) understand design in ways they hadn’t before, (2) have experienced multidisciplinary design teaming, and (3) are able to showcase a real design product (and its surrounding documentation) developed for a true purpose. Most achieve the main goal of strengthening their awareness of their own disciplinary thinking as well as to broaden their—and our own—views to include alternative modes and approaches offered by other disciplines.

Another significant benefit is that many students learn to recognize, value, and take pride in what they themselves can offer, from an individual as well as disciplinary perspective. This awareness will be important as they walk out of our academic doors.

An in-depth, ethnographic study of an industry site suggests varied types of knowledge that those considered “expert” or seasoned employees possess: “discourse community knowledge, subject matter knowledge, genre knowledge, rhetorical knowledge, and task-specific procedural knowledge.” However, as Brown & Duguid (1998) state, “The key to organizational knowledge is to weave it all together.” As our experiences with multidisciplinary students have shown, and as research on organizations of all types suggests, this is much easier said than done.

We see our efforts as initial steps in a long process of helping new practitioners learn to seek out and identify important information, regardless of where it resides in an organization. Geisler, Rogers, & Haller (1998) make the case even more strongly, stating that “For multidisciplinary design to work, practitioners must be taught to seek out and respect the opinions of other affiliated professions, to know that other issues exist and are valid, and to know that others have the expertise to address them.” We see our projects as able to provide an effective, complex site for such learning; we see multidisciplinary teaming as a first step toward blurring artificial boundaries between disciplines.

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Checklist for Planning a Successful Multidisciplinary Class Project

Logistics	
1. Assure there is a room large enough to hold multiple classes.	<input type="checkbox"/>
2. Reserve the room in advance of class scheduling since there are very few room on a campus that can hold large classes.	<input type="checkbox"/>
3. Make provisions to assure there is multimedia equipment in the room for the various types of presentations that will be made over the course of the semester.	<input type="checkbox"/>
4. Arrange a common class time across the various departments and classes that will participate in the multidisciplinary experience.	<input type="checkbox"/>
5. Identify any course credit differences/class format differences (such as lab component), across the departments and plan a strategy to address these differences.	<input type="checkbox"/>
Working Relationships	
1. Identify a multidisciplinary faculty team that is comfortable working together and realizes that this type of class format will take at least 100% more time compared to teaching a discipline specific class.	<input type="checkbox"/>
2. Assure that the Department Head's of the respective departments support the individual faculty teaching the class.	<input type="checkbox"/>
3. Be prepared to spend a great deal of time working with the students on issues related to team dynamics, negotiations, leadership, conflict and team management.	<input type="checkbox"/>
4. Educate students from each discipline about the value of collaborative work.	<input type="checkbox"/>
Class Specifics	
1. Assign common textbooks and readings	<input type="checkbox"/>
2. Find good graduate students that have excellent communication and management skills as well as technical skills needed for the range of topics that will be covered. There should be at least one graduate student from each of the disciplines represented in the class.	<input type="checkbox"/>
3. Select a course management software product for the class.	<input type="checkbox"/>
4. If possible, find a web designer for the course material management for the class.	<input type="checkbox"/>
5. All faculty and graduate students associated with the class should have training in the course management software. (for example: WebCT)	<input type="checkbox"/>

6. Encourage students to take advantage of technological tools to aid collaboration.	<input type="checkbox"/>
Teaming Issues	
1. Prepare students for the project experience at the beginning of the semester by arranging teams and projects at the first week of classes.	<input type="checkbox"/>
2. Teach students to identify and market their individual abilities and potential disciplinary contributions.	<input type="checkbox"/>
3. Make teams small in size.	<input type="checkbox"/>
4. Assure that all disciplines are represented on each team.	<input type="checkbox"/>
5. Include a mix of more and less experienced students.	<input type="checkbox"/>
6. Frequently ask students to reflect on their teaming experiences.	<input type="checkbox"/>
Client Issues	
1. Involve project clients as part of the educational process.	<input type="checkbox"/>
2. Find projects that allow each team member to have a significant role in completing the project.	<input type="checkbox"/>
3. Spend time with project clients explaining the purpose and motivation behind multidisciplinary projects.	<input type="checkbox"/>