Undergraduate Collaborative Capstone Design Projects Using the Web

Michael B. Hailey, Jens E. Jorgensen, Ann M. Mescher and James L. Fridley

University of Washington
Seattle, WA 98195-2600

Abstract:
Design education and design project execution requires teamwork and collaborative efforts to be successful. In an academic setting this has typically been achieved by frequent 'face-to-face' meetings between the student design team, faculty consultants, and the project sponsors. Modern technology, via the Internet, has made the collaborative team efforts independent of the constraints of common meeting times and the need for geographical collocation.

This paper describes a prototype Computer Supported Collaborative Work (CSCW) and Virtual Project Management (VPM) system that has successfully been implemented in the undergraduate Mechanical Engineering design classroom at the University of Washington. This system employs the use of a commercially available World Wide Web-based software package that facilitates collaborative work while also providing for the Virtual Project Management needs of both the individual project teams and the course itself. Detailed descriptions of the software program, its implementation into the design classroom, and its use throughout the product design and development cycle are provided. Also presented are the results of surveys, taken by the students of several design courses using the CSCW and VPM software, which aim to discern the attitude of these students towards this prototype system.

I. Introduction

The emergence and proliferation of powerful computing and networking technology has been instrumental in both supporting and hastening a dramatic shift in the way in which Engineering work is done. Spurred in large part by the demand for ever-shortening product development cycle times, most organizations involved in product design and development have recognized the need to embrace and implement the Concurrent Engineering paradigm. At the same time, with increased globalization, many companies have also adopted the Distributed Engineering philosophy, which allows project teams and individual team members to work together despite geographical or temporal separation, resulting in more efficient and adaptable organizations.

With the widespread acceptance of these design and development philosophies has come the recognition that success within this new framework requires overcoming serious challenges. By far the most daunting of these challenges is that of communication [1,2]. Distributed and Concurrent Engineering practices have resulted in separation, with respect to both time and space, that necessitates the development and implementation of more effective means of communication. It is precisely these means of communication that the powerful networking and computing technology alluded to above can provide [3,4,5,6]. Indeed, this technology, and particularly the project management tools it has spawned, has supported the shift away from the slower and more costly Serial Engineering and Local design and development paradigm, resulting in generally more efficient, productive, and profitable organizations.

Concurrent Engineering practice places a premium on timely, accurate, and comprehensive communication *between* teams. Specifically, team members need to be able to communicate, evaluate data, negotiate features and specifications, and project and verify the effect of a given design change being considered by another group. These specialized teams are much more interdependent in the Concurrent Engineering model. They must to be able to discern and trust the veracity of each other's information, resolve differences and build consensus quickly, and in general, work together smoothly [7,8]. These are skills gained only with experience.

The separation of engineering teams and team members, both geographically and temporally, as seen in the Distributed Engineering model, also presents new challenges and a need for new skills. From a teaming perspective, these groups and individual members must learn to interact and cooperatively develop successful designs--often without the benefits of a single face-to-face meeting. They instead, through the various other forms of communication available to them, need to work a bit harder to build relationships and establish trust. They must be able to provide vivid, concise, and accurate descriptions of products and processes [9,10].

Additionally, these teams and individuals must learn a new project management discipline: digital documentation [11]. For example, sketches and doodles must be scanned and distributed, with careful and complete notation and descriptions. White-board scrawling, minutes from meetings with vendors and clients, CAD drawings, reports and presentations must be digitally documented, organized, and readily available to those who need the information. This new Virtual Project Management (VPM) [6] discipline requires development of additional skills, and these, too, are learned chiefly through experience.

II The Future: CSCW and VPM Applications

A variety of collaborative tools are both available and utilized in the industrial setting, (e.g., face-to-face meetings, video-conferences, tele-conferences, simple or sophisticated intranets, etc.) ranging from the very low-tech to the very new and cutting-edge. The purpose of these tools is to facilitate the transaction of ideas and information, and they accomplish this with varying degrees of effectiveness, particularly with regard to the aims of Concurrent and Distributed Engineering.

Perhaps the most promising of these collaborative tools being used in the engineering design and development industry are the Computer Supported Collaborative Work (CSCW) applications [12,13,14]. These are beginning to offer complete, comprehensive functionality as a solution to the challenges presented by both the Concurrent and Distributed Engineering practices. Specifically, these softwares have, in common, the capabilities to:

1) conduct discussions and multi-user real-time chat (including video chat),
2) post text messages with multiple attachments of any kind,
3) store, exchange, edit, and update documents,
4) grant variable levels of access to any computer connected to the WWW, and
5) organize and manage all of this information.

Significantly, these collaborative software are being developed for use on the WWW, which is easily accessible from all computer platforms, thus nearly eliminating issues of platform incompatibility seen with Operating System-specific software.

It seems certain that the use of Web-based CSCW will be featured heavily in the future of the Concurrent and Distributed Engineering environments of the engineering design and development industry. It is critical, then, that engineering students, if they are to receive a practical collaborative design experience, are given the opportunity to use, in a relevant and meaningful way, Web-based Computer Supported Collaborative Work software in the course of their undergraduate study [15].

III Teaching Collaborative Principles and Design Project Management

The importance of teaching collaborative principles and having students experience collaboration first-hand has largely been recognized and put into practice throughout most university engineering undergraduate curricula. However, the role that technology plays (and **is to** play [16]) in this field, particularly with respect to Web-based CSCW, has been largely neglected until recently [17,18]--though this could be due in large part to the relative infancy of this technology and, indeed, even of the WWW itself.

In general, instruction relating to collaboration has focused on issues of teaming and group co-operation, which are undoubtedly essential. However, most universities are not exposing their undergraduates to the CSCW types of software that are likely to be a part of their daily professional lives once they graduate. Even fewer engineering programs incorporate this type of software into real-world, industrially-sponsored and multi-disciplinary capstone design projects.

Some exceptions to this general observation include the Arizona State University’s Virtual Corporation [19], the Virtual Design Studio [18] project involving students and faculty from the University of Sydney, the University of British Columbia, MIT, the National University of Singapore, and ETH Zurich in Switzerland, and Stanford’s innovative SHAREd Web [20] program. Additionally, Kodkani [21] and others have described the development and use of a Web-based system that supports and facilitates collaborative product design to a degree, and some [22,23] have used the WWW on a more limited basis in similar applications.

IV Expectations for the Course and Software

In order to ensure that the senior-level industrial capstone design project provides a relevant experience, the engineering students would ideally be able to select and work on a real (i.e. an approved design project that could actually be implemented), multi-disciplinary engineering project from an identifiable client. Cross-functional teams are to be encouraged, with students acting as 'specialists' in a given area and responsible for certain tasks, thus introducing an element of Concurrent Engineering. (With a larger program, involving seniors from several departments, Concurrent Engineering practices occur more naturally). The teaching assistants and faculty should act as 'Managers,' encouraging the students, offering assistance, and evaluating their performance. Finally, the clients or project sponsors ought to serve the role of 'Customer' and should be willing to communicate with the project teams as much as is necessary. Most importantly, however, it is imperative that students in this senior-level industrial capstone design project use commercially available (or well-developed and tested academic variations) Web-based Computer Supported Collaborative Work software that incorporates, or can be used as, a robust Virtual Project Management System.

This software should fully and seamlessly integrate discussion groups, email, real-time chat (with multi-media capability), document uploading and downloading, and shared files. Additionally, this software must support all document and platform/operating system types, and be easy to learn and use. It also should be fully customizable, easy to organize and manage, and provide for partitioning and multiple levels of access. Through the use of such software, the students will learn to collaborate both synchronously and asynchronously with their fellow team members, and will also rapidly gain familiarity with how current technology succeeds and fails in providing adequate project management support for implementing Concurrent and Distributed Engineering principles.

V Responsibilities of Students, Instructors and Clients

In order that the students can indeed learn these new skills, they must be required to document their work digitally. This requires the scanning and posting of design journal entries and sketches, writing and posting briefs and summaries detailing communication with the client, vendors, teammates, and experts, posting the results of information searches (e.g. patent or paper abstracts, source URLs), and all major design decisions. They should be encouraged to practice Concurrent Engineering principles in the division of labor and tasks. Most importantly, the students must be committed to communicating the work that they produce in the design and development process. They should also be willing to take advantage of all of the collaborative Distributed Engineering enabling tools that are available for their use.

Several things are required of the faculty in such a course as well. The entire teaching staff must be fully comfortable with, and sold on the value of, instructing the students using Web-based collaborative software. This confidence should be achieved through adequate testing, iteration and improvement with respect to the integration and application of this software in the course. It is important to note that this collaborative software is simply a tool that will aid in Virtual Project Management; it is essential that conventional project management skills still be taught. Above all, the teaching staff must provide guidance through examples and assistance to students understand the importance of managing a design project well. They should meet with the student design teams on a regular basis face-to-face, but also monitor and provide input via the CSCW software.

When organizing the senior-level industrial capstone design project, the faculty should also require energetic client involvement as a requisite to project consideration. The client must be willing to spend time meeting with the team members, both through the use of Web-based VPM systems, as well as face-to-face meetings or teleconferences. At the beginning part of the student projects, the clients will need to provide prompt responses to the students' requests for information regarding the project, related processes or products, and other information with which the client may be most familiar. As the project progresses, the client is responsible for adequate and timely feedback with respect to the central design questions and issues that are posed by the student group.

VI Organization of the Capstone Design Sequence:

To facilitate a major capstone design project with a prototype deliverable we have found the 10 week quarter too short. A minimum of 20 weeks (two quarters) seemed to be a reasonable solution and we decided to use two existing courses Mechanical Engineering 395: "Introduction to Design," and ME-495: "Capstone Design," as the test bed for our approach. The objectives of the test program were to:

1) Initiate use of a a Collaborative web-based software tool
2) Provide students with training in the web-based software
3) Develop a system to effectively manage a large number of projects
4) Evaluate the effectiveness of our approach.

At the beginning of the first course (ME-395), students are presented with the descriptions of several potential projects (Requests for Proposal or RFPs). These projects have primarily been solicited by the instructional staff from companies around the metropolitan Seattle area and from the University of Washington design community. Additionally we sought projects from a few non-local industry contacts. The project descriptions (RFP’s) were posted on the Class Web-site for the students to peruse. Having studied all the RFPs, the students met the prospective clients at a ‘design kick-off’ fair. Immediately following the fair, they were able to submit their preference of three projects they would like to pursue and the final selection became a negotiation between the students and the instructional staff. Typically, we would have from 10 to 16 projects per two-quarter sequence.

The deliverable for the ME-395 class is a project proposal, which describes the completed design work of the past quarter and proposes work to be done in ME-495 resulting in hardware or a prototype. The proposal, of course, must be reviewed and accepted by the client before the proposed design progresses to ME-495, and often the goal, scope, and deliverables of the project need to be re-negotiated.

Capstone design courses present unique challenges for both the students and instructors involved. In an effort to offer a potential solution to some of these challenges, and to explore the application of internet-related technology towards the design process, the ME-395 and ME-495 students were introduced to a Web-based collaborative design tool for use in their project work during the 1998/99 and 1999/00 academic years. The introduction of such a tool was seen as an excellent opportunity to facilitate the exposure of these undergraduate students to the principles of both Concurrent and Distributed engineering. It is important to note, however, that this tool was only one—albeit the most critical one—part of a larger *system* that was developed to help manage student design projects.

Why a web board? The major stakeholders in the capstone design effort are the students, the clients, and the teaching staff. (See figure 1 below). They should at all times be able to communicate with one another regardless of time zone or geographic location. Clearly, the telephone, fax and email will satisfy some of these needs.

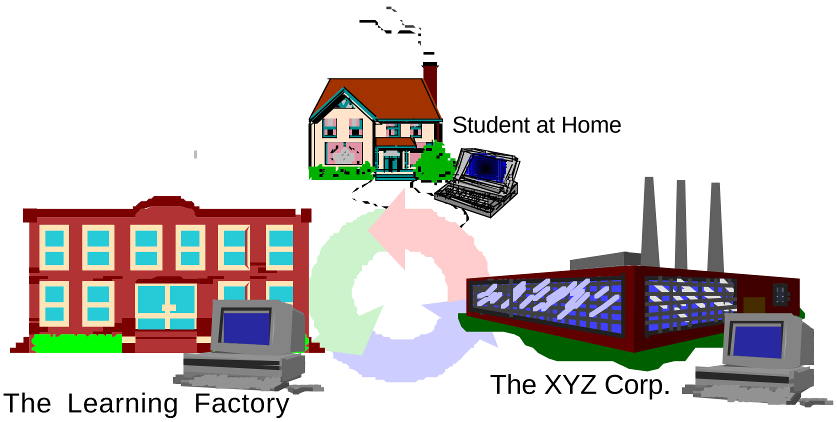

Figure 1: The Collaborative effort between the Stakeholders in the Capstone Design Activity

At the University of Washington the majority of the engineering students work and live off campus with long commuting distances. Likewise our project sponsors, the clients, are typically busy and often too far away to attend frequent (weekly) meetings on campus. The Web-based tool facilitates communication between the participants as well as joint composition, editing, and analysis of important team documents.

VII The WebBoard® Application: Description

The system that was developed employs the use of a commercially available World Wide Web-based software package[1] that facilitates Computer Supported Collaborative Work (CSCW) while also providing for the Virtual Project Management (VPM) needs of both the individual project teams and the course itself. As shown in figure 2, the system has four basic components: 1) a class portal web site, 2) a class instructional and communications web board, 3) web boards for each project and 4) links to the Request for Proposals (RFP's) submitted by the clients,

The Portal Web Site [2]: The Portal Web Site became the launching point for the students throughout the duration of the two-quarter sequence. From this site, they were easily able to access the Course WebBoard®, Sample Project WebBoard®, and their own Project WebBoard®s. Additionally, this Web Site became the home for archived Course and Project

[1] We used the web discussion board developed by WebBoard, Duke Engineering and O'Rielly Assoc., Inc., 1995, Email: Software@oreilly.com

[2] http://swhite.me.washington.edu/~dig/me495/

WebBoard®s, as well as archived RFP's. Both students and instructional staff were able to take advantage of the information found in the WebBoard®s from previous quarters. The Portal Web Site was a key feature of the Design Project Management system.

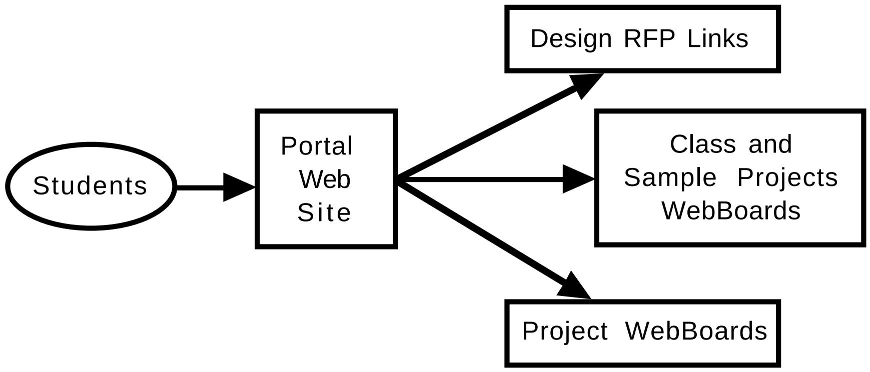

Figure 2: ME 395-ME495 Portal Web Site Organization

The Class Instructional Web Board: This web board provided communication with the students. Course syllabus, handouts and past design experiences (reports) were posted to this board as well as announcements, schedules and deadlines. In addition, it provided a place for the posting of their assignments, reports and poster presentations.

Individual Project Web Boards: The individual project web boards provide the work in progress communication, discussion, management and documentation of the project. One of the features of the web board is that certain parts can be made open to the general public while other parts are closed and only accessible by the students, client and the teaching staff. In this manner client specific proprietary information is protected if this is desired.

WebBoard®: The chosen Web-based collaborative design tool for use in the ME-395/ME-495 design course sequence is a product called "WebBoard®[3]". Developed by Duke Engineering and O'Reilly Software, the WebBoard® program has been used successfully by many corporate and governmental organizations[4] as an effective tool for communication among employees working and residing in different time zones. The challenge was to see if this particular product could be implemented in the undergraduate design project classroom setting, to aid both in the instruction of Concurrent and Distributed Engineering principles and to help organize and manage the course.

[3] This program was recommended by Prof. Joseph Heim, formerly of the UW Industrial Engineering Dept.
[4] See the WebBoard¤ site at http://webboard.oreilly.com/

Set-up of the WebBoard®, complete with various public and private Conferences is relatively simple. The manager or administrator's area allows for straightforward creating and manipulation of the conferences, including adding or deleting users (for private Conferences), modifying levels of access for a given user, or deleting a Conference once it is no longer needed.

In structure, the WebBoard® essentially mimics the 'electronic bulletin board' found commonly on the Internet. That is, having accessed the program, the user is presented, on the left-hand side of the Browser window, with different Conferences, each containing messages (or "Posts") relevant to a specific subject. A typical class WebBoard® is shown in figure 3.

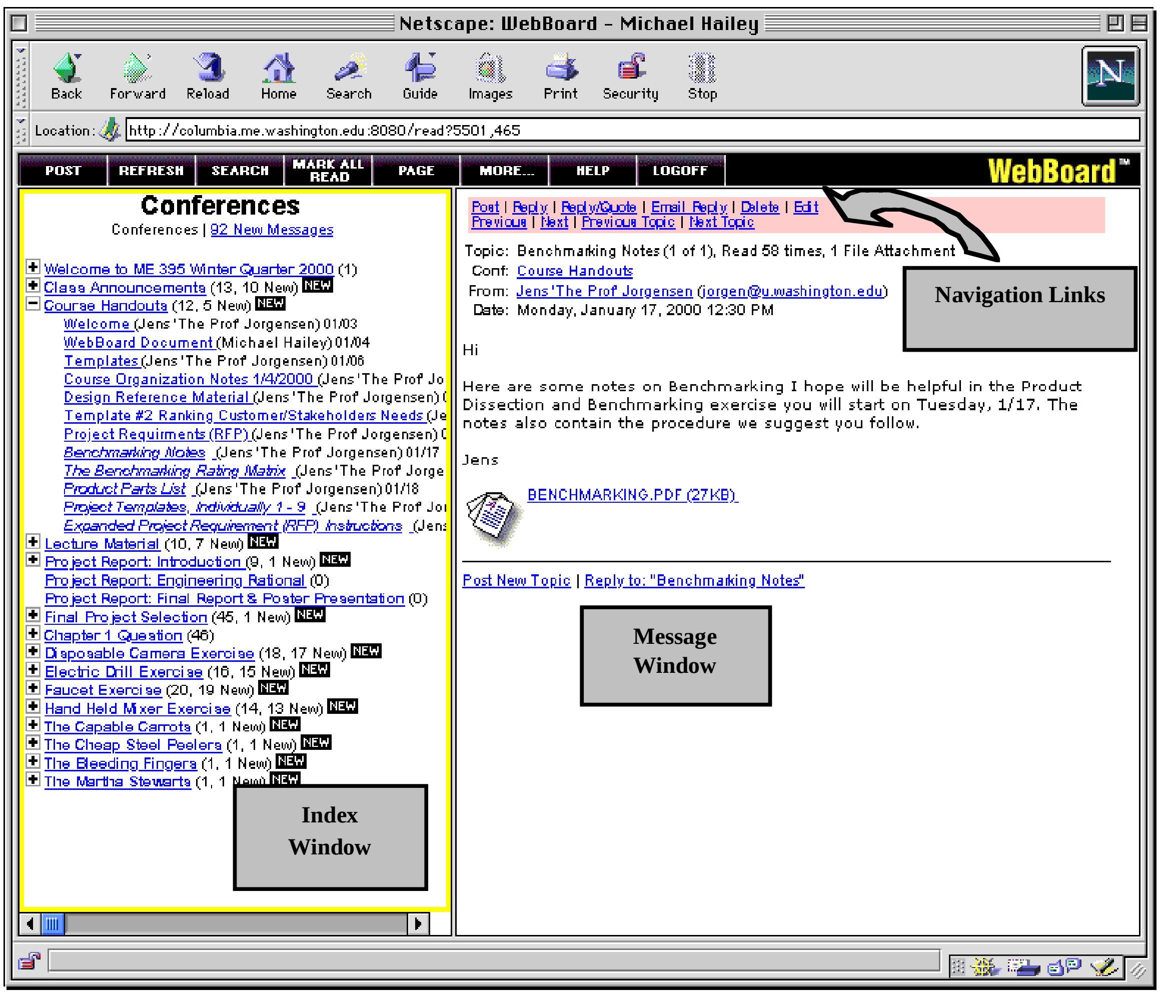

Figure 3: A Typical Class WebBoard®

In selecting a Conference (such as the Course Handout conference in figure 3), the user then is able to view a particular topic contained within that Conference; these topic headings are designated by the party posting the message. Selecting a Topic within a given Conference then reveals, on the right-hand side of the Browser window, the text of the given Posting. The user is able to view the posting date, name of the person submitting the message, and the body of the message. Also visible, at the bottom of the message area, are any attachments included with that particular posting. The user can quickly move between Topics and Conferences by using the Index on the left-hand side of the browser, or by using the navigation links ("Next," "Previous," "Next Topic" "Previous Topic") in the Message window, or even the Web Browser navigation buttons.

The WebBoard® program allows users to easily post new Topics within a given Conference, or to reply to messages already submitted; these new messages are organized and arranged hierarchically. Significantly, the WebBoard® also facilitates the use of attachments: it is relatively simple to include any kind and number of files (e.g. documents, pictures, executable programs, etc.) along with the text of a message. Additionally, the text box of the message area is HTML sensitive: URLs included in messages become active hyperlinks, and it is possible to directly post images and take advantage of other HTML-specific features.

The WebBoard® has several other very useful features, such as keeping track of which Conferences a given user has visited and which messages that user has read or posted. Secondly, the WebBoard® can be configured so that certain Conferences are accessible only to designated users; this provides managers or administrators with the ability to divide the WebBoard® into "public" Conferences viewed by all who log-on (or enter as Guests), and "private" Conferences, whose contents are visible only to specific users or groups of users. Finally, it offers the administrators a means by which to monitor WebBoard® activity: logins, postings, current users, etc.

VII Implementation of the WebBoard® in the Design Classroom

It took three quarters experience, and thus three design iterations, before a fairly robust procedure for successfully implementing the Web-based collaborative design tool into the undergraduate classroom was identified and implemented. This system for managing group design projects has been used with minor refinements, and has been found to be fairly effective in preparing undergraduate students for project management in a collaborative work place.

The design and development of this system, in which a CSCW and VPM program was to aid in the teaching and practical application of Concurrent and Distributed Engineering principles, was extremely challenging and yielded many key learnings. The primary set of realizations was that under any such system, if it is to be successful, the teaching staff must:

1) Allow each project team to manage its own significantly-partitioned virtual work space (i. e., a Project WebBoard®),

2) Provide a distinct Class WebBoard® for the administrative tasks associated with an undergraduate course,
3) Develop and provide an introductory WebBoard® user's manual,
4) Develop and reference a "model" Sample Project WebBoard®,
5) Develop and provide Templates to be used for documenting design activities digitally, and
6) Provide a Portal Web Site to use as a Portal to the above WebBoards®

The chief result of the iterative design work was the recognition that each project group required its own WebBoard®. In order to effectively organize, manage, and analyze the large amounts of information being transferred as part of the design process, it was necessary that each team be able to access, modify and create multiple directories (or Conferences). These partitions enabled the teams to create private work areas, public "Display Cases," and other topic-specific regions (e.g. "Questions for the Client," "Brainstorming for Component X," etc.) It is important to note that the student teams were truly responsible for the set-up, management and maintenance of their WebBoard®s: apart from a minimum set of standard Conferences common to all teams (see Sample Class WebBoard®, in Figure 4 below), the groups were free to structure their WebBoard®s as they saw fit.

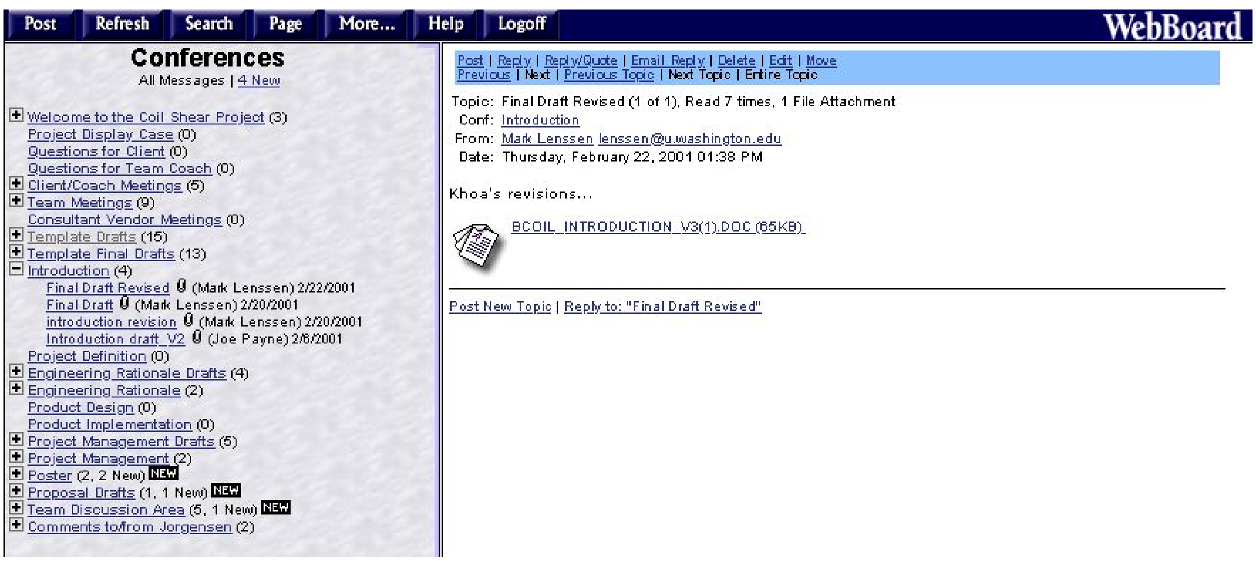

Figure 4: A Typical Project WebBoard®

Paralleling the recognition that each team needed its own WebBoard® was the realization that, in order to function efficiently, it was necessary that the instructional staff have its own WebBoard®, too. It is in this Course WebBoard®'s various partitions that class announcements are posted (in the "Class Announcements" Conference, naturally), that handouts and other documents are made available, that groups deposit assignments and receive comments, that deadlines are posted, and so on. If multiple instructors are involved in the course, it is possible here also to create private Conferences in which they can discuss various aspects of the class, such as grading schemes, upcoming lectures, or discussions. The creation of this Course WebBoard® greatly improved the ease with which the instructors collected and critiqued assignments, and also greatly facilitated the distribution of templates and handouts.

In order to ensure that both the instructional staff and the students would feel comfortable (or at least be capable of) setting-up, modifying and managing their own WebBoard®s, it became clear that it was important to develop a brief, introductory user's manual to the WebBoard®. This reference text was aimed at quickly familiarizing new users with elementary WebBoard® functions (posting, attaching documents, downloading items, etc.) as well as more advanced features, such as creating and editing Conferences. At the beginning of each quarter, an orientation session was conducted, during which time the manual was distributed and the basic WebBoard® operating procedures were discussed. An additional reference text was developed for the instructional staff that described the creation and configuring of new WebBoard®.

In order to provide some guidance in the organization and structure of the group Project WebBoard®s, a Sample Project WebBoard® was created. Viewable to all in the class, this WebBoard® outlined a skeletal frame from which the students could construct a manageable series of Conferences. The students were of course allowed to add relevant Conferences of their own, and many did so, but the minimum common content and structure allowed both the industrial clients and the teaching staff to more quickly and easily find important material within the Project WebBoard®s.

The development and inclusion of the Templates[5] in this Project Management system arose because of several factors. These Templates were designed to encourage the students to formalize their design thinking, particularly in the early problem definition stage of the project. They also aided in the digital documentation of the work, and allowed students to organize information in a way that facilitated both Concurrent and Distributed Engineering practices. The content of the Templates[6] was tied closely to the textbook[6] and was to contribute heavily to the final deliverable report as well.
A Portal Web Site was also a vital part of this Design Project Management system. It was to this site that the students regularly pointed their web browsers. The Portal Web Site acted as a portal to the class WebBoard®, the Sample WebBoard®, and their own individual Project WebBoard®s. Additionally, other course material (the RFPs, for example) and previous, archived WebBoard®s were also accessible via this Portal Web Site.

---

[5] The development of the Templates was largely the work of Prof. Joyce Cooper, to whom we are indebted.
[6] We used Ulrich and Eppinger s Product Design and Development, 2nd Ed., McGraw-Hill (2000).

Use of the WebBoard® The WebBoard®s were used extensively throughout each quarter. Class material such as lecture notes handouts, sample reports and presentations as well as announcements were made available exclusively on the Class WebBoard®. The instructors used a computer video projector to display information—lecture material, for example—downloaded from the WebBoard®. The student groups posted drafts of their deliverables, like sections of their reports, drafts of their presentations, and other assignments, to the appropriate Conferences on the Class WebBoard®. This material was then downloaded, reviewed and evaluated by the instructors. Comments were then either included on a version posted to the individual project WebBoard®, or were shared directly with the groups during the weekly meetings. Additionally, the Class WebBoard® was used for group work that was conducted outside of the normal project teams, like product dissection and other design exercises. Special Conferences were created for this purpose. The WebBoard® program was a particularly effective tool with respect to managing the administrative aspects of the ME-395 and ME-495 design courses.

The individual Project WebBoard®s were also used quite heavily. Having structured their WebBoard® based off of the Sample Project WebBoard, each Project WebBoard® contained Conferences that related directly to the design work that they were conducting; this was a key element of the software's VPM capability. Thus, meeting notes relating to conversations with the client, the teaching staff, vendors, or within the group were posted to the appropriate Conferences. The Project WebBoard®'s organization provided Conferences that were to contain completed templates, design concepts, and various draft sections of the final report. Many groups, having divided up assignments into various parts, used the Conferences in their Project WebBoard® to submit their work in pieces, to be compiled later into one final draft. Several groups completed brainstorming sessions, started in class, via postings to their respective WebBoard®s--or conducted them entirely through this CSCW application. The students also created Conferences in their Project WebBoard®s dedicated to researching technologies or components, for communicating directly with the teaching staff, for asking the client specific questions, and for chatting about more mundane (but nevertheless, important) issues such as meeting times and schedules.

Additionally, design materials, such as concept sketches or calculations, were often scanned from design notebooks and then attached to a message posted in the appropriate Conference, to be shared with and evaluated by the team. Some groups, having found relevant information, such as prospective vendors or components, at a particular Web site, then included that site's URL address into the text of their postings. The WebBoard® program instantly turned the URL address into a hyperlink that could be followed by the other team members. The instructors and clients, posting messages of their own, commented frequently on the student's work and also answered questions. Clearly, the WebBoard facilitated both Concurrent and Distributed Engineering practices.

IX WebBoard® Evaluation Questionnaire

In order to gain a more complete understanding of how the students viewed both the practical application of Concurrent and Distributed Engineering principles, and the specific CSCW and VPM software program whose use was at the heart of this effort, a WebBoard® Evaluation Questionnaire was developed[7]. At the end of each quarter [Autumn 1998, Winter 1999, Autumn 1999, and Winter 2000], the ME-395[8] students were asked to fill out this survey that was designed to evaluate the WebBoard® as a Web-based collaborative design tool, and to offer suggestions for improving its implementation into the design classroom.

The results of the survey are generally quite positive in favor of both the WebBoard® program and its implementation into the University of Washington's capstone design sequence. Below is a listing of the major findings:

1) Over 75% of the students indicated that the ME-395 course would have been more difficult without the use of the WebBoard®, 89% indicated that it was more helpful than painful.
2) Nearly 90% of the students would recommend the WebBoard® or other CSCW and VPM program to a future distributed design group.
3) The average time to "feel comfortable" using the WebBoard® was less than 10 days; 88% of the student respondents felt that they could teach the WebBoard® to a new user.
4) Most students agreed that the WebBoard® program was successful in providing a significant amount of geographic and temporal flexibility (5 out of a possible 7).

The students were asked rate the WebBoard® for the following categories relating to ease of use:

[Scale: 1 = difficult, arduous; 7 = simple, fast]:

Question	Average Response
WebBoard® "User Friendliness":	5.1
WebBoard® Ease of Posting:	5.9
WebBoard® Ease of Attaching Files:	5.5
WebBoard® Ease of Downloading Files:	5.3
WebBoard® Ease of Organizing Conferences:	4.3

Figure 4: WebBoard® Evaluation Questionnaire Results

7 Visit the 2000 ASEE Journal Paper Conference on the Product Design Endcuation WebBoard at : http://columbia.me.washington.edu:8080/~ProdDesEd and Login as a Guest.

8 Reasons for not including the ME-495 students *WebBoard¤ Evaluation Questionnaire* results were several, though this was done primarily due to the significant differences in course structure between ME-395 and ME-495, and the fact that very often, professors teaching the ME-495 course were different from those teaching ME-395 and were unfamiliar with the implementation and use of the WebBoard¤. Interestingly, many project groups in this situation requested that they be allowed to continue using the WebBoard¤ for their project in ME-495 even though it was not a requirement for that course.

X Evaluation of the WebBoard® Application

In general, it was apparent that the students found the WebBoard® program, and the implementation of this CSCW and VPM tool into their coursework, to be quite satisfactory. They responded that it was simple to learn, use, and configure; and relatively easy to modify and maintain. The use of the WebBoard®, as part of a larger project management system, clearly facilitated both concurrent and distributed design activities within their project groups, and also allowed the clients and instructional staff flexibility in the ways in which they communicated with the teams. In short, the WebBoard® successfully met the functional objectives we had set for the test project.

There were some drawbacks to this particular CSCW and VPM software, however. From the results of the *WebBoard® Evaluation Questionnaire* and conversations with the students (and, indeed, the experience of the instructional staff), the chief complaint was that it was difficult to organize the contents of a Conference, once messages had already been posted there. The WebBoard®'s document upload and download methodology also caused some headaches.

Although these problems and limitations in the WebBoard® application were sometimes troublesome, in no way did they overshadow the tremendous advantages and opportunities that the core functionality of this CSCW and VPM program provided. In general, the WebBoard® was found to is a very effective part of the group design project management system that was developed and implemented in the undergraduate ME-395 and ME-495 courses.

XI Improving Implementation into the Design Classroom

While the results of the *WebBoard® Evaluation Questionnaire* indicate that the WebBoard® application was implemented and integrated fairly well into the structure of the design course, the instructional staff has definitely been able to look back over the previous experience and identify many areas of potential improvement. Fortunately, a good number of these areas were recognized relatively early on, and resulted in modifications for subsequent course.

A significant area of improvement involves the integration and use of the Templates in the undergraduate design course. Ideally, the Templates that were adapted and put into use would be general enough to work with any textbook and for any design activity, yet specific enough to help draw out relevant and meaningful content. In practice, though, the Templates were in fact tied to the textbook (which actually had some distinct and compelling teaching advantages) and were not all terribly applicable to the broadest range of design activities (i. e., ranging from design of a totally new product, to redesign of an existing system, to the development of a customized control law).

A given CSCW and VPM tool could be better integrated, too, if the students are made more aware of the shift, alluded to earlier, towards Concurrent and Distributed Engineering practices. It should be made clear that the use of such a program in their design courses is not simply an academic exercise that makes use of a new technology for technology's sake; but rather, that this experience is a foretaste of the industrial environment in which they will be working.

Students are not the only ones who need to be reminded of the importance of using such a tool: clients and faculty must also understand the great benefit that a truly concurrent and distributed design experience can provide to the undergraduate student. This means that prospective project sponsors must be committed to using the Web-based CSCW and VPM tools on a regular basis, as well as interacting and communicating with the student groups using conventional means.

Finally, the implementation of a Web-based collaborative design tool into the undergraduate classroom should be done with a good deal of potential flexibility. The nature of capstone design courses is such that a strict, regimented program most likely will not work extremely well for all of the project groups—there is simply too much variation in the type of industrially-sponsored projects that are undertaken.

These suggestions for improving the implementation of a computer supported collaborative work (CSCW) and virtual project management (VPM) tool into the undergraduate classroom are steps toward a more realistic, relevant, meaningful and effective way to introduce students to the principles of Concurrent and Distributed Engineering. The continued development and use of such a system is highly recommended.

XII Further Research

The primary area in need of further research is the identification and evaluation of competing Web-based CSCW and VPM software programs. There are a growing number of commercially available collaborative design tools that use the WWW[9] and would seem to be quite appropriate. Such applications could be selected, ordered (many offer trial versions for free), set-up and then implemented on an experimental, small scale, basis in the design classroom. Benchmark tests and performance evaluation could then be conducted for these applications with respect to the WebBoard®.

---

[9]For example, ActiveProject¤ from Framework Technologies and Virtual Project Management Intranet (VPMi), available at www.frametech.com and www.vcsonline.com, respectively, appear to be promising. candidates for such a comparison. Another such product is Synchronicity¤ (available at www.syncinc.com) which has been quite popular in the IC industry. There are many others, both commercially available and developed within academia, that are worth investigating.

The Templates are another area of potential future research. The underlying motivation for having Templates is of course to help facilitate and formalize the development of design content. What is difficult is creating a set of Templates that makes sense to the instructional staff, corresponds to and complements the course textbook, and is broad enough to be useful for a wide range of design activities without being so universal that the results are meaningless. This clearly is difficult—as is creating a set of Templates whose value and usefulness are readily apparent to skeptical and less motivated students.

Finally, another area of related research would be to evaluate how the use of a Web-based CSCW and VPM tool in the undergraduate design classroom affects both team performance and group dynamics. The results of the *WebBoard® Evaluation Questionnaire* (see Appendix B1), suggest that the students held mixed opinions regarding whether using the WebBoard® program had a positive or negative effect on their team dynamics (4.2 out of 7). It would be interesting to pursue this further, examining how interactions (with the other team members, the client, and the instructional staff) and performance (creativity, productivity, quality and efficiency) were effected by the use of a Web-based collaborative design tool.

Acknowledgements Funding for this project was provided in part by NSF Award #DMI 9726178. The help of Ms. Dongmei Gui in setting up and maintaining the WebBoard® was appreciated. The WebBoard® server was provided by a gift/grant from the Hewlett Packard Corp.

Bibliography:

1 Sonnewald, D., (1996) "Communication Roles that Support Collaboration During the Design Process." *Design Studies*, Vol.17, No.3, pp.277-301.

2 Gammack, J., & Poon, S., (1999) “Communication Media for Supporting Distributed Engineering Design.” Proc. Of 1999 32nd Annual Hawaii International Conference on System Sciences, Jan 5-8, 1999, p.18.

3 Lange, L., (1997) “Tools Enable Virtual Design Over Web.” *Electronic Engineering Times*, May 12, 1997. p.16 (1).

4 Pahng, GD. F., Bae, S., & Wallace, D., (1998) “Web-based Collaborative Design Modeling Environment.” Proc. Workshop on Enabling Technologies: Infrastructure for Collaborative Enterprises, WET ICE June 17-19, 1998, pp.161-167.

5 Lange, L., (1996) “Net Tools Target Collaborative Design.” *Electronic Engineering Times*, Nov. 25, 1996. p.1(2).

6 Montplaisir, L., (1997) "An Integrated CSCW Architecture for Distributed Project Planning." Proc., 6th Industrial Engineering Research Conference, pp.364-368.
7 Pena-Mora, F., & Hussein, K., (1999) "Interaction Dynamics in Collaborative Design Discourse." *Computer-Aided Civil and Infrastructure Engineering*, Vol.14, No.3, pp.171-185.
8 McNeese, M., Zaff, B. S., Brown, C. E., Citera, M., & Wellens, A. R., (1992) "Role of a Group-Centered Approach in the Development of Computer Supported Collaborative Design Technologies." Proc. Human Factors Society, Vol.2, Oct 12-16, 1992, pp.867-871.
9 Sheldon, D., Conner, J., Williams, J., & Pena-Mora, F., (1997) "Collaborative Design Studio @ MIT." *1997 Computing in Civil Engineering*, pp.403-410.
10 Maher, M. L., (1997). "Model for Synchronous Collaborative Design Using CAD and Database Management." *Research in Engineeering Design-Theory, Applications, and Concurrent Engineering*, Vol.9, No.2, pp.85-98.
11 Nagy, R. L., & Ullman, D. G., (1991) "Knowledge Base Data Representation for Collaborative Mechanical Design." *ASME Design Engineering Division*, Vol.31, pp.69-76.
12 Wilson, J. L., & Shi, C., (1996) "Computational Support for Distributed and Concurrent Design Teams." *Computing in Civil Engineering*, 1996, pp.544-550.
13 Wilbur, S., (1994) "Computer Support for Cooperative Teams: Applications in Concurrent Design." Proc. Of IEE Colloquium on Current Developments in Concurrent Engineering—Methodologies and Tools, Jun 2, 1994, pp.8/1-8/8.
14 Merabti, M., & Carew, M., (1994) "A Distributed Support Environment for Concurrent Engineering." Proc. 2nd Biennial European Conference on Engineering Systems Design and Analysis, Vol.64, No.5, pp.97-102.
15. Hailey, M. B., Jorgensen, J. E., Fridley, J. L., & Heim, J. A., (1999) "Web-Based Design Experiences in Undergraduate Education." Proc. IEEE, Ostrava Prague, August 1999.
16. Baecker, R., (1993) "Readings in Groupware and Computer Supported Collaborative Work." Morgan Kaufmann, San Mateo, CA.
17. Turns, J., Guzdial M., Mistree F., Allen J.K., & Rosen, D., (1995) "I Wish I had Understood This at the Beginning: Dilemmas in Research, Teaching, and the Introduction of Technology in Engineering Design Courses." Proceedings from Frontiers in Education Conference 1995, New York, NY, USA.
18 Maher, M. L., (1996) "Technology Potential and Limitations in a Virtual Design Studio." *Computing in Civil Engineering*, pp.8-14.
19. Shah, J., Sadowsky, J., Macia, N., Woodfill, M., & Wilson, A., (1995) "Virtual Corporation: Simulating Real World Collaborative Design in a University Setting." *ASME Design Engineering Division*, Vol.83 No.2, pp.507-515.
20. Kumar, V., Glicksman, J., & Kramer, G., (1994, April 17-19) "SHAREd Web to Support Design Teams." Proceedings of the 3rd Workshop on Enabling Technologies: Infrastructure for Collaborative Enterprises, pp.178-182.

21. Kodkani, S. S., (1996) “Development and Implementation of a Collaborative Product Design Environment using Web Tools.” M. S. Thesis, Syracuse University, Syracuse, NY.
22 Hong, J., Toye, G., Leifer, L., (1995) “Using the WWW for a Team-Based Engineering Design Class.” Electronic Proc. Of the 2nd WWW Conference, Chicago, IL, Oct 1994. http://www.ncsa.uiuc.edu/SDG/IT94/Proceedings/Educ/hong/hong.html
23. Uptal, R., (1998). "Preparing Engineers for a Future with Collaborative Technology." *Computer Applications in Engineering Education*, Vol.6, No.2, pp.99-104.
24. Hailey, M. B. (2000) “Design of a Web-Based System for Managing Group Desing Projects”, M. S. Thesis, University of Washington, Seattle, WA, April 2000

Michael B. Hailey

NOKIA UK, managing product development, currently employs Michael Hailey in a new business unit. He received his B.S. in Mechanical Engineering (1998) from Stanford University, in Palo Alto and his M.S. in Mechanical Engineering (2000) from the University of Washington in Seattle. Michael previously held a product development role in Nike, Inc.'s Advanced Technology Exploration department in Beaverton, Oregon.

Jens E. Jorgensen

Jens E. Jorgensen is professor in Mechanical Engineering at the University of Washington. He also holds joint appointments with Industrial Engineering and the Forest Engineering Program in the College of Forest resources. Her has been active in both teaching and reseat in the areas of System Dynamics, control systems and Design. Since 1994 he has been involved in the development of the Integrated Learning Factory, Capstone Design projects and collaborative design activities using the World Wide Web.

Ann M. Mescher

Ann M. Mescher is an assistant professor in the Department of Mechanical Engineering at the University of Washington. Dr. Mescher joined the University of Washington in 1996 and has been involved in jointly developing and teaching the capstone design sequence since 1998. She also advises design teams comprised of undergraduate and graduate students in applied research projects sponsored by industry. Dr. Mescher received a B.S. degree in Engineering Physics in 1988 and a Ph.D. in Mechanical Engineering in 1995, both at the Ohio State University.

James L. Fridley

Jim Fridley is a Professor of Forest Resources and a Professor of Mechanical Engineering at the University of Washington in Seattle. He is a registered Professional Engineer in the State of

Washington and is actively involved in engineering design service learning involving local industry. Prior to joining the faculty at the University of Washington, Professor Fridley was on the faculty of Agricultural Engineering at Auburn University in Auburn, Alabama. Professor Fridley received a B.S. degree in Forest Engineering from the University of California at Davis in 1979, a M.S. degree in Agricultural Engineering from Michigan State University in 1980 and a Ph.D. in Mechanical Engineering from the University of Washington in 1984.