Total Studio: Collaborative Design for Engineering and Architecture

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Abstract

This paper describes an interdisciplinary design studio that utilizes concepts and methodologies intended to create a comprehensive approach to the organization of building design through the merger of several techniques. These techniques include 1) collaborative learning and design, 2) interdisciplinary team teaching, and 3) hypertext courseware and learning modules utilizing multi-tasking workstations. The studio merges the preceding teaching paradigms, building on current research and the experience of the faculty. The studio establishes the premise that architectural design studio and engineering laboratories (structural and mechanical) need to be organized across departmental boundaries as team oriented activities. The learning modules are being developed initially in a multimedia format (analog video and hypertext). They will be finalized in an entirely hypertext format using digital video and browsers, allowing latitude for the development of additional material in the future. The paper discusses the continual shift between synthetic and analytic processes in the context of problem solving, methods of representation, design assignments, methods and process.

The Problem

Architects and engineers, who need to interact during their professional career in order to build any kind of complex building, are educated entirely separately. “Over the past century, increased movement toward concentration within an academic discipline has taken charge of the curriculum, as well as serving to compartmentalize the professoriate and the institution.”[1] The vertical separation of disciplines occurs in most universities. This suggests a need for modification of the curriculum, the delivery of course material and teaching methods. Fortunately, this comes during a period of reflection in schools of architecture when, as Mitgang suggests, there are “growing doubts over whether the traditional educational environment is preparing students for a rapidly changing world outside.” While “schools remain wedded to shopworn traditions” there seems to be a growing malaise about the role of design as the centerpiece of architectural education.[2] Recognition of the problem also comes at a time when new teaching methods are emerging.

The major effort in trying to refine elements in the curriculum (particularly in different departments) depends upon what might be termed “changing the culture” of the curriculum. To create these changes architectural design studio and engineering laboratories need to be organized comprehensively, across departmental boundaries. In the course of these revisions they will also need to be changed from independently organized activities to team oriented activities.

The problem with the vertical separation between disciplines is that students from each discipline learn to solve their part of the problem independently. This separation discourages them from understanding the relationship among the problem components. The students can complete their projects without having the opportunity to gain insight to the trade-offs required for an optimal solution. While courses in each department include information about the other disciplines, each is taught in a manner which tends to diminish the importance of integration. Moreover, the ultimate professional relationship among the disciplines, which in the building industry consists of teams, is downplayed by the students working as individuals in their classroom experience. Research outside of the architectural and engineering professions suggest that "future work situations are likely to use a complex mixture of different information channels, including video conferencing, e-mail, small group work, and on-line searches." [3] In other words, information systems are being developed which rely on an awareness of the necessity for human interaction intertwining with the social and technological aspects of the design process. These are the conceptual underpinnings of the development of a new approach.

Designing the Solution

The hypothesis is that a concurrent and collaborative design environment will add to the problem-recognition and problem-solving abilities of the engineering and architecture students. In most workplaces in the building industry, problems solving and design require collaboration among members of a group. These activities require that people share information and coordinate their activities in a setting that allows for immediate interaction[4]. Although the design and production of buildings traditionally requires collaboration, the work is done serially, with drawings passing among the professions and each adding their information and recycling through the process until the project is completed. No methods of optimization are applied because of the way the design process is structured. Optimal solution spaces are closed off by the time each new part of the process is introduced. Therefore, the focus of the studio is around the activities in which the students can engage to help construct a comprehensive knowledge base necessary to design, optimize and build complex structures.

The potential impact of the studio is to improve the education, professional behavior and attitude of students as they prepare for various aspects of the building industry. The students have the opportunity to understand how the separate courses they have taken in architecture, structural engineering, and building performance are integrated. They comprehend that contemporary construction is not a simple separate, sequential process, but rather a system characterized by integration and a search for optimal solutions. When design is objectively considered as an iterative, multifaceted process, and a series of problem solving sequences, a significant paradigm shift can occur. Thinking this way, we discovered, is imperative because the way engineering and architecture students learn is different.

The project goal is to create a completely computer mediated environment, where students will work on their designs and problems, communicate with each other (both locally and at a distance), and receive courseware and criticism at the workstation. The innovative aspect of TOTAL STUDIO is that it is interdisciplinary, and has been designed from the beginning to provide the format for the perpetuation, replication and dissemination of the studio in a continually upgradeable hypertext format. This focus is away from the traditional piecemeal architectural methods.

The Underlying Pedagogy

The study of building design must be rooted in a general theory of building science in which architectural space and form, structure, and the effects of the bounding envelope for moderating the environment are considered inseparably. Optimization of building systems is a complex problem to solve. “In architecture, aesthetics deals with the way buildings look: the skin, form, site, and overall image within the culture to which they belong. In engineering, technology is informed by modern science and is systems and process oriented. Controlling building environments (both actively and passively) can produce more insightful architecture when understanding that the aesthetics of the relatively static building envelope is coupled with the dynamic technology of the building systems.”[5] Therefore, the studio focuses on the development of structural, energy and spatial intuitions and the relationship among them. These needs suggest the study of indeterminate structures for understanding building frame design.[6] They also suggest analysis of a skin-dominated building for energy analysis and building performance so that relationship of form to energy flow can be considered. One goal of the faculty is to identify projects at the appropriate scale to study these relationships. We are currently using an elementary school project which seems to have the requisite components.

Collaboration and the matrix of studio organization

Collaborative design—thus collaborative learning about a project—is a relatively new concept for students in the studio. A very serious introduction is required to get the students working collaboratively. Collaborative learning is “...a learning process that emphasizes group or cooperative efforts among faculty and students, active participation and interaction on the part of both students and instructors, and new knowledge that emerges from an active dialog among those who are sharing ideas and information.”[7] While group criticism and group research is a normal activity in the design studio, designing together is not. Turoff, is his years of development of computer-mediated environments at NJIT concludes that “in many learning situations it has been observed that two people working together at a computer learn more working together than either one separately. It is this ability to share the actual interactive process of “creating the painting” that this approach entails.”[8] This suggests, as Feisel points out, that “we need to design an educational process that involves students in one another’s learning and rewards mutual accomplishment.” [9] Our project adapts these concepts, and builds on them,

To facilitate the collaborative idea of teaching and learning, the studio is organized around a matrix of teams and groups. Teams are defined as a number of students assembled to apply techniques and complete a design task. Groups are defined as a number of students organized to develop techniques and learn a particular set of the task. Each student is a member of one team and one group. The sets of teams and groups act as support clusters for each student. It also generates various ways of learning cooperation. In recent semesters, the four by four matrix of teams and groups worked as theorized. The team organization depends heavily on the mix of students. The teams and groups for the first part of the semester were four member each. When the major design project began the teams of four were divided into teams of two. This afforded the opportunity to modify teams to improve interpersonal relationships among the members.

The Learning Groups

The learning groups are divided among the three disciplines involved in the project: architectural design, structural design, and mechanical design. Each learning group is led by an instructor who is responsible for the development of the educational modules associated with that discipline. The members of each learning group are responsible for learning the software packages associated with specific segments of the problem but encouraged to share their knowledge. As the experiment evolves, different uses of learning groups will emerge. For example, last semester project research assignments were made by the learning groups; this semester software instruction is carried on in learning groups. While the concept of learning groups and design teams seems rigid, we have allowed a certain degree of flexibility to accommodate the differences in instructional modes and components of the project.

The Design Teams

The design teams develop the building design as a whole. During their sessions with the design instructor they work together on the development of the project, each member looking at, and engaging, the design from the perspective of their learning group and/or discipline. Architecture students and engineering students work together on the design, each naturally contributing from the point of view of their background. This year we have divided the project by semester in order to be able to concentrate energy on a particular aspect of the design. The goal is that the whole experience be compressed into one semester. While it is intended that contributions are made to the design across disciplines, there has been a tendency for the engineering students to wait for the architecture students to finalize their designs before contributing. This is one of the attitudes toward design the project has been developed to change.

The Laboratory

The studio is held in an advanced computer graphics laboratory with video equipment available for both local viewing, editing and broadcasting. In 1996 the laboratory had its equipment augmented through funding from the National Science Foundation (NSF) for the project titled *Development of Interdisciplinary Courses and Laboratory Facilities* [10] The primary computer workstations available are Silicon Graphics (SGI) Indy models. The full complement of equipment is eleven workstations, the fastest of which is an Indigo Impact, with 128 MB of RAM. The UNIX based workstations are extremely flexible and able to accommodate simultaneous access to local and remote software. The computers are networked with adjacent computer laboratories and the Internet. Access to additional computer facilities (such as Sun workstations) for other tasks takes the pressure of the laboratory because we cannot provide a workstation for every student. The workstations are also linked together through a hardware and software system called Comweb which allows control of all, or groups of, workstations for the purpose of software instructions, group critiques, and other demonstrations. In addition to email, there is also audio communications software available on the machines useful for remote collaboration.

Furthermore, the Laboratory is adjacent to the Multimedia Internet Delivery and Production Studio (MIDPS) which is part of the New Jersey Center for Multimedia Research (NJCMR). This provides the faculty with a set of authoring tools, and other equipment to aid in the development of the courseware. Combined with our existing video equipment, MIDPS augments our facilities to provide webcasting.

The Four Modes of Representation

One important idea in the studio is to dampen the use of the computer as the central tool. The computer needs to be on equal footing with all the tools in the toolbox. This is accomplished directly through the assignments which emphasize the four modes of representing architecture. The notion of multiple representations of information is central to the course and is discussed thoroughly with the students at the beginning of the semester. Narrative descriptions of initial and final concepts are required, as are short written reports on field trips and research issues. Building class site models and chipboard study models in the traditional way—especially as a comparison to the 3D computer models—is emphasized. Students learn to study their work simultaneously via the computer models and via physical models and sketches to augment their visual perception and other cognitive skills. Research suggests that students relate to what they see on the screen better if they can relate it to previous experiences.[11] Our experience suggests that the shifting from one mode of representation to another, while difficult for some, offers the opportunity to broaden the perceptual understanding of the design problem and its solutions while preventing students from getting mentally fatigued by working on the project, either from one point of view or using one mode of representation. Each design team establishes a mode of internal communication that seems appropriate.

Final projects are presented in two ways. For an oral presentation of the project before a group of critics, they are presented on traditional "boards" which allows computer work to be communicated traditionally. This also gives the students the opportunity to mix their media, drawing on strengths and skills they may have previously acquired. Project are also represented on the Internet both as images and as VRML[12] models. We have experimented with webcasting the final review both as a means of organizing the work and disseminating innovative methods. The first webcast was a window into the studio without special effort to understand the change in media. This semester we are more prepared to modify our methods of presentation to meet the challenge and limitations of the new media.

Preliminary Results

The studio is presently being supported through funding from the National Science Foundation under Grant No. DUE 9752459 entitled *An Interdisciplinary Virtual Laboratory for Engineering and Architecture.* The studio has been offered in the academic year of 1996 and the spring of 1997 as a pilot effort, and is operating in academic year 1998-99 as a "proof of concept". The following items have been implemented: 1) collaborative learning and design, 2) computer mediated environment, and 3) interdisciplinary teaching, coursework and design. Deep within this seemingly complex learning environment are elements of the traditional studio. The semester is divided into an analysis phase and the design phase with a few short research assignments interspersed. The current two semester sequence is designed to emphasize structural issues in the fall semester and building performance issues in the spring. Development of a preliminary syllabi quickly dispatched the idea that such a holistic approach could be accomplished in one semester until some experience has been gained in the development of the delivery system. The organization of the three academic units strongly suggests implementing the course in one semester. The course fits best in all units in the spring semester.

Collaborative learning

From the faculty point of view dividing the class into teams has two major effects: 1) it increases management time to continually monitor the interpersonal problems which occur as people adjust to working together; 2) it reduces the number of critiques and increases the time available for each critique. In addition, it increases the students' effective working time because they need to manage each other and spend time in the studio discussing the problem and working together. The students report that they learn to verbalize their design ideas and make more objective design decisions.

The computer-mediated environment

The multimedia material is currently under development. The computer-mediated environment works as follows: Course material created on the word processor is converted to HTML, edited to add dynamic elements, stored on the server, accessed, displayed and disseminated through the browser. This provides the student and others continual access to all of the course material as it is posted and modified. Remote access and email allow the team members to work at a distance and to communicate with the instructors. The NJIT library catalog is also available through the workstation so that references to books and articles can be located immediately by the student.[13]

We have found that it is imperative that faculty take a hands on approach to imparting computer skills. Comments from the students indicate they are more confident in the instructors who are hands on and display their skills directly rather than those who are more aloof and directive in their approach. The experience of the last two semesters suggests that teaching small groups of students detailed methods of access to the computer systems diffuse information among the students more rapidly than imparting the information to the whole class in a formal setting. The students learn more quickly in informal settings in which they are able to communicate directly with their peers. Research by Roberts et al also suggest that of the critical variables for productive learning, "the most important is the faculty's pedagogical style in their direct teaching and the student interest in the subject. The faculty must be sensitive to both the need to empower students exploration by providing them with the skills they need to explore... through direct teaching as well as allowing and encouraging students to do their own exploring."[14]

Problems

The development of TOTAL STUDIO is an evolving effort. The imprimatur of NSF has been a great aid to fostering collaboration among the departments. The funding has provided the leverage of outside support against the internal politics in the various departments. A review of the four semesters of experience have yielded the following findings: 1) students are slow to conceptualize the multitasking potential of their workstations, and therefore under utilize the potential of the UNIX environment, 2) there are only a finite number of teaching hours in a studio and having to spend time teaching software subtracts from the time used for teaching principles of design, and giving individual design criticism, and 3) engineering students and architecture organize their work and their thought processes in an entirely different manner which will require further analysis and adjustment on the part of the faculty.

While working on teams is generally not part of the studio culture, most of the teams operated successfully in recent semesters. The reason for lack of success in teamwork seems to be based on the conflict in personality, differences in work ethic and habits, the lack of experience in

working on teams, and a mismatch in skill levels between team members. In anonymous evaluations, the students commented that "I liked the team thing as an idea. It didn't work out for me though because I had a hard time with my partners. I do think in the future, team design is a good idea." Or "Groups of peopled helped but caused many disagreements which slowed down progress. Although the thought of putting people together was a good one." The extended history of the studio as a collaborative one aids in the development of teamwork because it generally excludes students who are determined to undermine the concept.

Conclusion

The metaphor, changing the culture of the curriculum, may seem slightly pedantic; however, methods of teaching have been passed from generation to generation in the most unquestioning manner. New technologies, as precursors of changing methods, are often resisted. The efforts to change, sometimes abetted by the layers of accrediting organizations, are held back by the 'viscosity' in the organization. Creating a change that evolves, rather than changes abruptly, gives the results an opportunity to become integral to the culture and reaffirmed by the tradition. Our team of faculty has received criticism from our colleagues, and expect criticism from professional organizations with long standing paradigms and vocabularies holding antithetical views, and even from the students. We are abetted by the support of outside funding, which adds an imprimatur to our efforts. At the core of our activity is the goal of helping to "lead the professional to a future of greater relevance and responsibility."[15]

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Endnotes

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[11] Roberts, N., Blakeslee, G. and Barowy, W. "The Dynamics of Learning in a Computer Simulation Environment", *Journal of Science Teacher Education*, Vol. 7, Kluwer Academic Publishers.

[12] Virtual Reality Markup Language. The modeling software which we use, Alias/Wavefront, provides conversion directly to the VRML model. This allows an internet viewer to be able to view the model from all angles.

[13] The website can be observed starting the home page of the Simulation, Animation and Modeling Laboratory (SAML) at http://www-ec.njit.edu/ec_info/image1/text_files/hp_1a.html. It is a dynamic place, continually changing as courseware is posted and modified, and student work is added.

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