The Development of TOTAL Studio: A Comprehensive Computer-Mediated Studio Environment for Architecture and Engineering

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THE PROBLEM

Architects and engineers, who need to interact during their professional careers in order to build any kind of complex building, are educated entirely separately. This vertical separation of disciplines occurs in most universities across the nation. The two excuses offered for the vertical organizations are 1) accrediting organizations and 2) the need to hoard the university currency: FTEF—Full-Time-Equivalent Faculty. This suggests a need for modification of the curriculum, the delivery of course material and teaching methods. The major effort in trying to reform elements in the curriculum (particularly in different departments) depends upon what might be termed "changing the culture" of the curriculum. Architectural design studio and structural engineering laboratories will need to be organized comprehensively, across departmental boundaries. They will also need to be changed from an independently organized activity to a team oriented activity.

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-off 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 downplay 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. The design parameters of information systems—intelligent software agents, decisions about access to the information highway, and the appropriateness of databases to regional projects—rely on an awareness of how the social and technological aspects of human interaction intertwine." (Kilker and Gay) These are the conceptual underpinnings of the development of a new approach.

DESIGNING THE SOLUTION

The first step in developing the new studio format was to recruit a team of interested faculty and secure the support of the superimposing academic units. The disciplines represented by the team are architecture, structural engineering, and mechanical engineering. A second step in the development processes was defining the new studio as a project. On that basis, support for the project was solicited and received from the deans of architecture and engineering, and the provost of the university. It was clear to all that the present programs can be materially improved by focusing attention on the three areas of study which, when reformed, can bring together students from these disciplines, working on teams in a laboratory arrangement. The focus of the project will be around the activities in which the students should engage to help construct the kind of comprehensive knowledge base necessary to build complex structures. A secondary goal is to create a computed-mediated learning environment in which students can obtain information on a need-to-know basis. A tertiary goal is to modify present methods of assessment of student projects, since they will be produced by teams.

The hypothesis of the faculty 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. Traditionally, in the professions, although the design and production of buildings requires collaboration, the work is done serially, with drawings passing among the professions and each adding their skills 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.

The faculty established the following five objectives: 1) to identify the knowledge and skills which students should attain from the design process, 2) to develop an integrated syllabi for a two-semester course sequence to satisfy the knowledge and skills requirement identified, 3) to develop a comprehensive courseware delivery system based upon multimedia technology, 4) to develop teaching modules for the major repetitive elements in the sequence, allowing latitude for the development of additional material in the future, and 5) to develop a laboratory in which to teach the material.

A corollary to the project will be to upgrade the faculty skills in a cross disciplinary manner as a demonstration of the integrated approach. Another corollary of the impact of developing interdisciplinary courses will be the need of the faculty to expand the boundary of their knowledge in order to successfully interact and to develop new skills in order to produce the multimedia courseware.

From the outset, we were encouraged to be innovative. We were also influenced by the ongoing research into delivery methods going on in the School of Engineering and the Computerized Conferencing Center at NJIT. Another influence on our studio development was the place in the curriculum the project will have. For the engineering students it will replace or augment their capstone project. For the architecture students it will build on an intense year of work in the Imaging Labs, which is required in the third year. The Imaging Lab work is based around three-dimensional modeling using 3D Studio and various paint and photo retouching programs. All work in that year takes place in six Pentium-based PC labs. Thus, the intention to create a completely computer mediated environment, where students will work on their designs and problems, communicate with each other and others more distant, and receive courseware and criticism at the workstation builds on the effort of previous research and courseware delivery. The innovative aspect of this project is that it is interdisciplinary, and it is being designed from the beginning to provide the format for the perpetuation, replication and dissemination of the project in a continually upgradeable hypertext format. This is intended to allow for the combination of Internet browsing and asynchronous learning. Asynchronous learning is a situation where the students interact with the instructor and each other via the computer, but not all at the same time.

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 will have the opportunity to see how the separate courses they have taken in Architectural Design, Structural Engineering, and Building Performance are integrated. They will see 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. This, we discovered, was imperative because the way engineering and architecture students learn is different.

IMPLEMENTING THE SOLUTION

The studio is held in an advanced graphics computer lab with video equipment available for both local viewing, editing and broadcasting. This laboratory has been named the Virtual Laboratory because of its potential to easily disseminate the courseware. The primary computer workstations available are Silicon Graphics (SGI) Indy models. Last year the laboratory had its equipment augmented through NSF Grant #DUE-9650748, *Development of Interdisciplinary Courses and Laboratory Facilities*. The laboratory was funded on the basis of its interdisciplinary approach, and its potential impact on science and engineering education. The full complement of equipment is eleven workstations, the fastest of which is an Indigo Impact, with 128 MB of RAM. Adjacent computer labs under the auspices of Engineering Computing are equipped with Sun workstations for supplemental computer use. All of the computers are on the AFS network (Andrew File System) which allows all files to be accessed no matter what workstation the student is operating. The SGI's capability to run some Sun software and PC software in a shell through Windows emulation makes that platform an excellent choice, and broadens the base of student use. The UNIX based workstations are extremely flexible and able to multitask flawlessly. Students can be logged into several computers at once and run several software packages at the same time. The machines are also capable of video input and output. In the future this will allow reception of video-in-window so that taped material can be played by the students at their workstations. It is also planned to link the terminals together through a hardware and software system called Comweb which allows instructor control of all workstations for the purpose of making demonstrations.

While the laboratory and the course methods seem to require an extensive discussion of computing, time in the studio is not dominated by the equipment. The four modes of developing architecture are discussed right at the outset, and the students are made aware of their purposes. First, narrative descriptions of initial and final concepts are required, as are written reports on field trips and research; second, chipboard models of concepts at appropriate scales are required. Students learn to study their work simultaneously via 3D models on the computer and via model and sketches to augment their visual perception and other cognitive skills. My own experience as a designer indicates a multimodal design process is most useful. While there is a pedagogical reason to expand the base of design approaches, the studio time does not allow using all of the design methods available. It would take a two-semester studio to accomplish this and studios of more than one semester are presently against the policy of the School of Architecture. Outside funding for the project, since the project has been defined as multi-semester, may help change the policy.

Pedagogy

The study of building design must be rooted in a general theory of structure and space in which building structure, architectural space, and the effects of the bounding envelope for mitigating the environment must be considered inseparably. Detailed study of highly indeterminate structures is crucial for understanding building frame design. For energy analysis, the scope of the project can either be small or large. Small buildings—depending upon their program—can be skin-dominated buildings; larger buildings have a tendency to be load-dominated. In either case, though they have differing effects, both types are complex problems to resolve. The studio will focus on the development of structural, energy and spatial intuitions and the relationship among them.

To facilitate the teaching and learning, the studio will be organized around teams and groups. Teams are defined as a number of students assembled to complete a design task. Groups are defined as a number of students organized to learn a particular set of the task. Conceptually, the teams and groups will be organized using a matrix with equal numbers of rows and columns. For example, a class of sixteen will be organized around a 4 x 4 matrix. The four rows will be organized as four design teams. The four columns will be organized as four learning groups. Each student is therefore a member of one team and one group. Groups will develop techniques and teams will apply techniques. The sets of teams and groups will act as support clusters for each student. This matrix of organization is hypothetical; the number and mix of the students each semester will determine the organization of the studio.

The Learning Groups

The learning groups will be divided among the three disciplines involved in the project: architectural design, structural design, and mechanical design. Each learning group will be led by an instructor who will develop the educational modules associated with that discipline. The members of each learning group will be responsible for learning the software packages associated with specific segments of the problem. In addition, they will have the opportunity to be aware of the other software available, and broaden their knowledge base as time permits.

The Design Teams

The design teams will develop the building design as a whole. During their sessions with the design instructor they will work together on the development of the project, each member looking at, and engaging, the design from the perspective of their learning group. This project experience drives the whole process. The students will learn to represent their building in as many of the ways that are feasible: 3D models on the computer, drawings, physical models, written descriptions and oral presentations. The notion of multiple representations of concepts is central to the course. Understanding the concept means having access to various forms of representation, selecting ones that are most appropriate for particular uses, and using them accordingly.

Lectures and Organization

TOTAL Studio is designed to have an increased lecture format comprising formal lectures relating to the subject of the studio, e.g., theater design; and lectures relating to general methods, e.g., structural systems, environmental control systems, urban context, etc. The format is designed to foster the continual shift between synthetic and analytical processes. The interdisciplinary and computer-mediated nature of the studio demands a very tight schedule and organization. Lectures are planned to be grouped into two days of the studio with a free day for working a desk or small group criticism.

PRELIMINARY RESULTS AND PROBLEMS

The studio was offered in the spring and fall of 1996. It is currently in session this semester. The following items have been implemented: 1) computer mediated environment, 2) collaborative learning, and 3) interdisciplinary work. My present teaching assignment is to bridge between the third year studio (spring) and the Options Studio (fall). This spring's experiment is to link the studio with the Solar Energy elective.

The computer-mediated environment works as follows: Course material created on the word processor is converted to HTML, stored on the server, and accessed through Netscape. This provides the student access to all of the course material as it is posted. This also provides an easy method for updating the course material. The NJIT library catalog is also available through the workstation so that references to books and articles can be located immediately by the student. The software presently in use in the studio is Alias Studio and Power Animator, Studio Paint, Photoshop, Imageview, and Netscape. Also available are the VRML (Virtual Reality MarkUp Language) browsers. This combination allows us an Internet oriented dissemination and display mechanism, since all of the software components are compatible. In addition, a plethora of software resides on the server. Students have previously learned AutoCad, 3D Studio and other PC based software. They are far enough up the learning curve to have an immediate conceptual grasp of the software. The time necessary to produce results in the studio is a few weeks. Each successive generation of students has become easier to teach in that regard; however, the depth of their interest has diminished.

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 of others 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." (Roberts and Blakeslee)

Collaborative learning is a new concept for students in the Laboratory. A very serious introduction is required to get the students working on teams. While group criticism is a normal activity in the design studio, it has become imperative to find new ways to grade students working on teams. Toward that end, an on-line group grading system is being developed so that students, answering a small set of questions, can evaluate each other and use the evaluation system to improve their communication and, ultimately, their designs. The new system is expected to be implemented on a trial basis this spring.

Problems

A review of the two semesters of experience have yielded the following findings: 1) students continually manage to challenge the speed of a computer no matter how fast it is, 2) students are slow to conceptualize the multitasking potential of their workstations, and are slow to utilize the potential of the UNIX environment, and 3) 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. Students have suggested that a course in using the computer be held before they need to use it. Two reasons temper this idea: 1) a course with no content has no meaning; i.e. a course designed to teach software has to have the students working on projects, therefore they might as well be in studio, and 2) there is no room in the curriculum for a required course in three-dimensional modeling for 100 students.

Using the computer requires more precision right from the outset and therefore the methodology for being fuzzy needs to be created and implemented. Whereas the reasons for going to 3D modeling initially was to aid students in seeing the three dimensional implications of their design decisions early, and to insure the critic that the student has reached an appropriate level of three dimensional awareness, the students have shifted the emphasis the design process to building mass and now lack an understanding of detail. Since the students need to be precise, their lack of facility with geometry is unmasked quite early in the design process. The structural engineering component of the course has not been implemented.

Working on teams is presently unprecedented in the studio culture. About half of the teams operated successfully. The reason for lack of success in teamwork seems to be based on the conflict in personality, differences in work ethic and habits, and the lack of experience in working on teams. Each student in the studio is interviewed at the end to discuss what they feel they accomplished and what might be modified in the studio. Some of the student comments are quite helpful. The students thought that more could be accomplished with a tighter work schedule and more reviews.

THE FUTURE

At this moment there are two alternative paths for the studio: 1) unfunded and 2) funded. If the studio is unfunded there will be little opportunity for any large scale implementation of the interdisciplinary work because there is no "extra time" for faculty development. For the architectural part of things, I can move forward toward implementing my end of things, but will not have the opportunity to work with the engineering faculty. If the studio is unfunded it will continue, more or less as described, seek other funding, and try to improve incrementally as all studios do. There is a natural software upgrade path, and there are many useful ideas to implement based on current paradigms. Specific ideas which can be implemented are: 1) use of VRML for architectural display and criticism. 2) asynchronous learning and team management on the Electronic Information Exchange System (EIES). Asynchronous learning can be used initially for discussion groups. An example of this type of activity is the assembly and discussion of research material.

If the studio is funded, we would hope to have time to clearly understand the difficulty of what we are trying to do, and seek help from all available sources. The faculty require increased technical support to keep all of the equipment running smoothly. This includes everything from wiring to software upgrades. We will also have to work toward "changing the culture" through the interdisciplinary work and through building the course and its syllabus into the curriculum of three departments. I see the latter as the most difficult part of creating change. Outside funding may provide release time to the faculty, student assistants for the laboratory, additional equipment, additional personnel for video and computer maintenance, and the possibility of reaching out to the academic community to acquire information and share results.

NOTES/REFERENCES

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From a practical standpoint, team and group organization will depend heavily on enrollment mix between the departments. In some preliminary discussions it appears that the number of teams will be limited by the type of team member with the smallest number constituting the least number of teams. For example with sixteen architecture students, thirty-two civil engineering students and sixteen mechanical engineering students, there would be sixteen teams consisting of one architecture student, one mechanical engineering student and two civil engineering students.
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