

# Total Studio: Interdisciplinary Collaborative Design for Engineering and Architecture

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## 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."<sup>1</sup> 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 at 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.<sup>2</sup> Recognition of the problem also comes at a time when new teaching methods are emerging.

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 tradeoffs required for an optimal solution. In addition, students do not learn the major differences in approach to problems and solutions each curricula develops. 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."<sup>3</sup> In other words, information systems are being developed which rely on new modes of interaction, intertwining the sociological and technological aspects of the design process. These are the conceptual underpinnings of the development of a new approach.

The literature suggests that there is a growing awareness of the problem of separate education for architects and engineers. In a current article Herbert Wheeler points out that once "architects and engineers were educated side by side; after their schooling they teamed up to work in the fast-growing building industry."<sup>4</sup> He suggests that while the industry saw a need to organize and control their future they did not take it. He laments that "architects and engineers must take charge of their own destiny by redefining how they work together and, as a necessary prerequisite, how they are schooled to understand one another (emphasis added)".<sup>5</sup>

## DESIGNING THE SOLUTION

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 an architectural design studio/engineering laboratory, TOTAL STUDIO, has been organized comprehensively, across departmental boundaries among architecture, mechanical engineering and civil and environmental engineering at NJIT. The hypothesis that a concurrent and collaborative design environment will add to the problem-recognition and problemsolving 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.<sup>6</sup> 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 TOTAL 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 impact of the studio has been 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 see how the separate courses they have taken in architecture, structural engineering, and building performance are integrated. They 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. Thinking this way, we discovered, is imperative because the way engineering and architecture students learn is different.

One 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. One 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 hypertext format which can be continually upgraded. The studio focus is away from the traditional piecemeal design methodology.

## IMPLEMENTING THE SOLUTION

### 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.<sup>7</sup> 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.<sup>8</sup> For energy analysis and building performance, it is preferable to analyze a skin-dominated building so that the relationship between form and energy flow can be considered. One goal of the faculty is to identify projects at the appropriate scale to study these relationships. This year we decided an elementary school seemed to have the requisite components and degree of difficulty.

### Collaboration and the matrix of studio organization

Collaborative design, particularly among students of different disciplines, is a relatively new concept for students. 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."<sup>9</sup> While group criticism and group research is a normal activity in the design studio, designing together is not. Turoff, in his years of development of computer-mediated environments 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."<sup>10</sup> 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."<sup>11</sup> 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 major learning groups are 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 is responsible

for learning the theory and/or software packages associated with specific segments of the problem. They are expected to share their knowledge. As the experiment evolves, different uses of learning groups are being developed. For example, last semester project research assignments were made by the learning groups.

### 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. Understanding the concept means having access to various forms of representation, selecting ones that are most appropriate for particular uses, and using them accordingly. The students are reluctant to work together on the building as a whole. Each discipline defers to the other in the area of expertise.

## THE SIMULATION, ANIMATION AND MODELING LABORATORY (SAML)

The studio is held in an advanced graphics computer laboratory with video equipment available various levels of production. The laboratory is sometimes referred to as a virtual laboratory because of the ability to connect across the campus through our networked file system to computers at remote locations. The laboratory has been developed with support from the University and funding from the National Science Foundation (NSF) for the project titled Development of Interdisciplinary Courses and Laboratory Facilities.<sup>12,13</sup> The workstations are also linked together through a hardware and software system called Comweb which allows faculty to control of all workstations for the purpose of software instructions, group critiques, and other demonstrations. The laboratory is also adjacent to the Multimedia Production Internet Delivery Studio (MPIDS) 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. By combining resources with MPIDS we have established the synergy to provide webcasting.<sup>14</sup>

## 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.<sup>15</sup> 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 from one point of view. This concept contrasts strongly with some computer studios where all work is done on the computer and critiques are done "on screen."

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 as others (especially clients) perceive it. 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<sup>16</sup> models. We have also experimented with webcasting, but have not developed a firm place for the new media.<sup>17</sup>

## 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 was offered in the academic year of 1996-97 as an unfunded pilot effort. With funding during the academic year 1998-99 it is operating, in NSF parlance, as a "proof of concept". The following items have been implemented: 1) collaborative learning and design, 2) computer mediated environment, and 3) interdisciplinary work. The most experience has been developed with the collaborative learning; the computer mediated environment is intended to evolve in an attempt to understand the effect of the changes in methodology in the studio. The use of computers in the studio has evolved over two decades, and is expected to continue to evolve. Working with faculty from another department is the newest element and needs the most fine tuning. Deep within this seemingly complex learning environment are many 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 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.

### Collaborative learning

From the faculty point of view dividing the class into teams has two major effects: 1) it reduces the number of critiques and increases the time available for each critique. 2) it increases management time to continually monitor the interpersonal problems which occur as people adjust to working together; 3) it provides a structured way for students to begin critiquing each other by having to verbalize issues and make objective design decisions. 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 decision-making which, for the better students, keeps the design projects evolving smoothly. A downside to collaborative work is that it tends to strengthen the better students, and quickly unmask the deficiencies of poorer ones. While it might be thought that undergraduate students should spend their time honing individual skills rather than working together, students themselves recognize that they must learn to work together effectively. The individual skills of team sports are always learned in the context of the team; the same should be true of design.

### 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 any distance. The university library catalog and other more remote libraries are available at the workstation so that references to books and articles (and their availability) can be located immediately by the student.

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 share 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."<sup>18</sup>

### The Dichotomy: Fuzzy vs. Deterministic Approaches

Several problems have emerged. Divergent approaches, whether between two architects or the architects and engineers, cause friction on the design teams. Each student has a complete expectation about what their role might be, and fails to approach the problem with the knowledge they have acquired. The engineering students need numbers and equations with which to apply principles. Engineering students ask for solid dimensions right from the start, and do not entertain parallel possibilities. Architecture students, on the other hand, dwell in a world of fuzz and metaphor. They have studied for three or four years in a culture which encourages answers like "just about...", "I want..." and "it could be...". Studio criticism which references structure, mechanical systems or codes, is dismissed as not relevant to design. Some friction is caused because the students are working in parallel. In the professional world the designed has been "nailed down" before the engineers enter the picture. In the end, however, the teams pull together to present their project as holistically as possible. The world of ideas and determinism merge to create a building.

### Other Problems

The development of TOTAL Studio is an evolving effort.<sup>19</sup> 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 recent 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 software and the UNIX environment, 2) there too few teaching hours in a onesemester studio to spend time teaching software. Computing subtracts from the time needed 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 any 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

people 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 collaborative 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, and any hint of modifying the curriculum causes immediate resistance. Efforts to change are curbed by tedious committee discussions. The image if the organization is often at odds with its actual operation, therefore efforts to change become slippery. The efforts to change, though abetted by the layers of accrediting organizations, are held back by the 'viscosity' in the organization. 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."<sup>20</sup>

## NOTES

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- <sup>17</sup> Jackson, B. and Shiffman, S., op. cit.
- <sup>18</sup> Roberts et al, op. cit.
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