Computer Enhanced Learning: New Course Materials to Teach Design of Energy-Efficient Buildings

G.Z. BROWN, SEAN FREMOUW, JEFF KLINE, LANCE LAVINE, TOMOKO SEKIGUCHI, and RUSSELL WEISER
University of Oregon

INTRODUCTION

This paper describes a new automated course and a design studio course to teach architecture students how to design more energy-efficient buildings. The courses are part of the TEACHING ARCHITECTURE+ENERGY project, an effort to develop more and better course materials for incorporating energy considerations into building design and to make these materials accessible to a greater number of architecture students.

A network of teachers was created to help faculty use *Energy Scheming* and the associated course materials. In contrast to the typical approach of centralized distribution of information, we are employing a three-phase network strategy that we hope will be self-perpetuating. Phase I began with four centers—Virginia Polytechnic Institute, the University of Oregon, University of Minnesota, and Washington University—forming a nucleus of the network. In phase II the four schools recruited new network members. In phase III the network is intended to take on its own life based on its usefulness to the participants. We anticipate having a total of thirty-three faculty members from twenty-seven universities by June 1999.

The ultimate goal of this project is to reduce the energy consumption of buildings in the U.S. This is an important issue since the United States accounts for more than a quarter of the world's primary energy use and one third of that energy is consumed by buildings. Therefore, buildings in the U.S. are responsible for a substantial portion of the tons of carbon dioxide released annually into the atmosphere, which is a significant cause of global warming.

In order to create effective courses that would be accessible to a large number of students, the probable barriers to introducing and implementing the course had to be identified and addressed. This paper describes these courses and discusses how they are designed to overcome these barriers.

AUTOMATED COURSE

The automated course uses simulations, an expert system question generator, the Web, and a design problem format to teach architecture students how to design energy-efficient buildings. The course can either be used to augment existing courses or be free-standing. When freestanding it is totally automated and doesn't require an instructor. The main components of the course are a completely graphic interface, a simulation engine (*Energy Scheming* 3.0) and an expert system to give building design advice and to generate questions based on a student's building design. The class is offered over the Worldwide Web and is resident on a server at the University of Oregon.

The Web serves as a wrapper for the simulation engine and the expert system and contains the exercises (called course topics), tests, course descriptions, software manual, guided tour, software downloads, architecture examples, helps, explanations of phenomena, and course administration (figure 1). Each of the eight course topics are divided into three parts–warmups, exercises, and cooldowns–and are supported by explanations, building examples, and help.

The simulation software *Energy Scheming* is used in the course to expedite the evaluation process used to design energy-efficient buildings. The process begins with the student scanning in a drawing, copying one from another application, or drawing a building in the program (figure 2). The building surfaces are then measured graphically or "taken off" with the tape measure cursor and associated with a specification. The takeoffs, specifications and other inputs are entirely graphic. Next the building's energy performance is evaluated and the results shown in a bar graph or displayed as a thermographic image. The thermographic image pinpoints excessive heat gain in red and excessive heat loss in blue on the drawing of the student's building. The bar graph has an optional sound track to cue the student to events that are important to a building's energy performance, such as the arrival of occupants in the morning, turning the lights on at sunset, cooling wind velocity, etc. The software provides advice on how to improve the building's performance. The student elects to redesign, and the evaluation process begins again.

PROBLEM: IDENTIFYING THE BARRIERS

In order to teach more students to design energy-efficient buildings with an automated course, a number of barriers had to be overcome. Some of these barriers are common to the introduction of any type of course to the architecture curriculum, and some are specific to those courses that use computer simulation to teach energy knowledge. In an ACSA report on teaching energy in architecture (Shibley et al., 1984) seven barriers were identified: 1) too much time and effort is required by faculty to introduce a new course, 2) faculty who lack energy knowledge are hesitant to teach about energy, 3) a single course must accommodate wide variations in faculty pedagogical approaches, 4) faculty hesitate to teach analysis courses when they are not linked to the design process, 5) computer courses often have substantial support issues, 6) inaccessible energy information deters faculty from teaching about energy, and 7) energy software can be difficult to learn and use. Three other barriers identified are specific to teaching with an automated course. Since an instructor is not present, 1) the course must be complete and

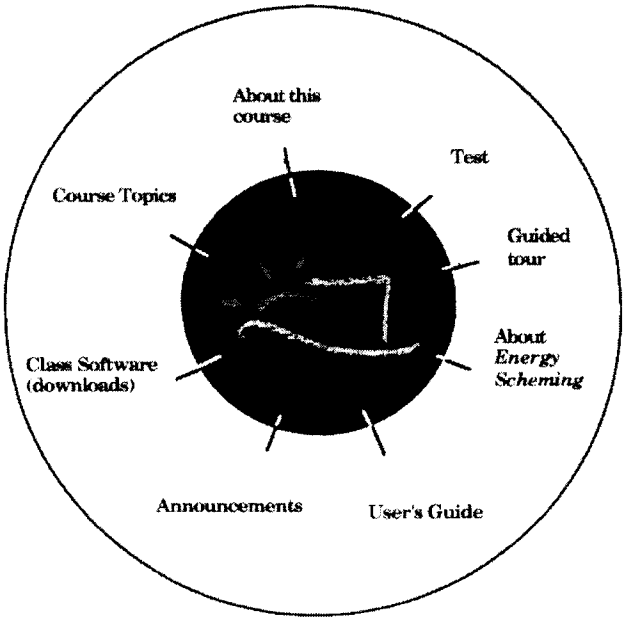

Figure 1: University of Oregon's Web-based seminar. The Web is a wrapper around the simulation engine *Energy Scheming* and contains the course-related information.

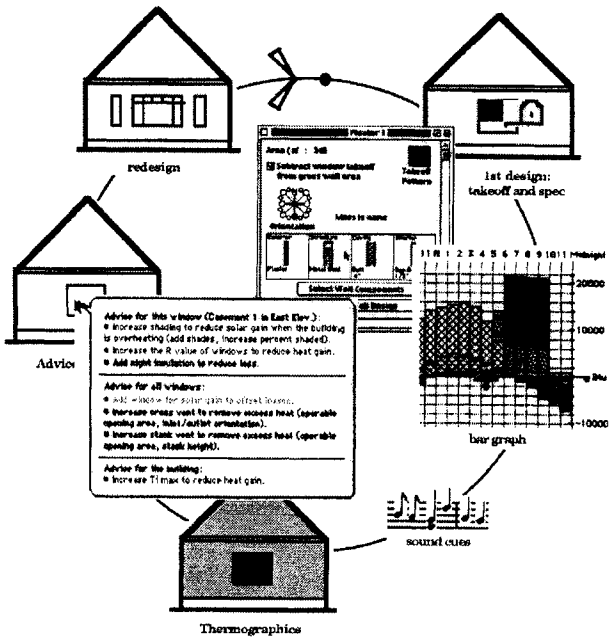

Figure 2: The design process using *Energy Scheming*.

also anticipate questions since "winging it" is not possible, 2) the course must compensate for the lack of personal contact with an instructor and maintain a high level of student learning, and 3) the course must be successful in getting students to complete the exercises even with the freedom allowed in an automated course that is self-paced. For this course to succeed in teaching more students to design energy-efficient buildings, both the barriers to a new course in general and the barriers to an automated course in particular had to be overcome.

SOLUTION: OVERCOMING THE BARRIERS

The ten barriers identified were addressed by the automated course as summarized in figure 3.

Barrier #1: *The time and effort required to handle the logistics of new courses makes faculty hesitate to offer them.*

We estimate that faculty teaching in the quarter system can expect to spend a minimum of 600 hours to develop a new three-credit course, and 60 hours a term to teach it. Used as a freestanding course, with its complete set of exercises and features such as automatic grading, this course requires only three hours of faculty time: two hours to set it up and one hour per term to assign final grades.

Barrier #2: *Faculty who lack energy knowledge are not comfortable teaching about energy.*

For faculty who lack energy knowledge but still want their students to learn about energy in buildings, this course has two features that can help in addition to the complete set of energy lessons in the course topics. The expert advisor contained within *Energy Scheming* (figure 5) gives building design advice, and the question generator (figure 6) in the course generates questions based on a student's own building design.

Barrier #3: *Wide variations in faculty pedagogical approaches must be accommodated by a single course.*

Since faculty can use the course either to augment existing courses or as a freestanding course, they can avoid changing their own pedagogical approach.

Barrier #4: *An analysis course that fails to link energy information with the design process does not appeal to design faculty.*

This course uses a design approach to teach students how to use energy information in the design process. As students become familiar with using *Energy Scheming* in the first exercises they are also learning how their own changes to a building's design affect energy performance. For the midterm exam students redesign a building to reduce its energy consumption. In their final project, students redesign their own building. By speeding up the energy calculations *Energy Scheming* allows students to spend more time trying out their design ideas. This approach also reinforces the link between energy information and the design process. One student commented:

> The World-Wide Web interface and the exercises were helpful in learning how to use *Energy Scheming*; however inputting my own studio design was **much** more helpful. This is because of the knowledge you already have concerning your design, your site, and the materials your building is made from. It is also more interesting because you have a stake in what you are analyzing and improving—it helps your studio design.

Barrier #5: *Computer courses have substantial support issues to contend with, both initially and on-going during the course.*

Since the course is offered over the Web and is resident on a server at the University of Oregon, most of the computer support issues are taken care of by University of Oregon faculty and staff.

Barrier #6: *If energy information is not accessible to faculty, they may think twice about including energy in a course.*

One of the advantages of using the Worldwide Web is the ready access to information (figure 7). This course contains 25 links to energy explanations such as the daylighting equation, the solar savings fraction, and heat flow equations. There are also more than 25 links to example buildings illustrating heating, cooling, and daylighting ideas. One student wrote:

> The World-Wide Web interface was great because it allowed a lot of information to be easily accessed while using the *Energy Scheming* program. The help/information features of the Web interface were also very helpful to the understanding of the program and the exercises.

	Barrier	Response
1	The time and effort required to handle the logistics of new courses makes faculty hesitate to offer them.	It requires less time to set up and run the automated course than with a regular course.
2	Faculty who lack energy knowledge are not comfortable teaching about energy.	The advisor and question generator assist faculty without energy knowledge.
3	Wide variations in faculty pedagogical approaches must be accomodated by a single course.	The automated course allows faculty to maintain their pedagogical approach.
4	An analysis course that fails to link energy information with the design process does not appeal to design faculty.	The redesign of a buildings for the midterm exam and final project link energy and design.
5	Computer courses have substantial support issues to contend with, both initially and on-going during the course.	The course is fully automated and largely supported by the University of Oregon.
6	If energy information is not accessible to faculty, they may think twice about including energy in a course.	Reference materials are contained in the automated seminar.
7	If energy software is difficult to learn and cumbersome to use, faculty will not use it in courses.	*Energy Scheming* is not difficult to learn, and the course teaches the software.
8	"Winging it" is not possible in an automated course.	Course material is complete enough that results show that student learning is equal to that in a course with an instructor.
9	Lack of personal contact with an instructor in an automated course could negatively affect student learning.	Automated "warm and fuzzy" email messages are sent to students.
10	The course must encourage students to complete all the exercises even with the freedom allowed in an automated course that is self-paced.	All the students who took the course completed the exercises and many of them commented that they liked the convenience of a self-paced course.

Figure 3: Barriers addressed by the automated course.

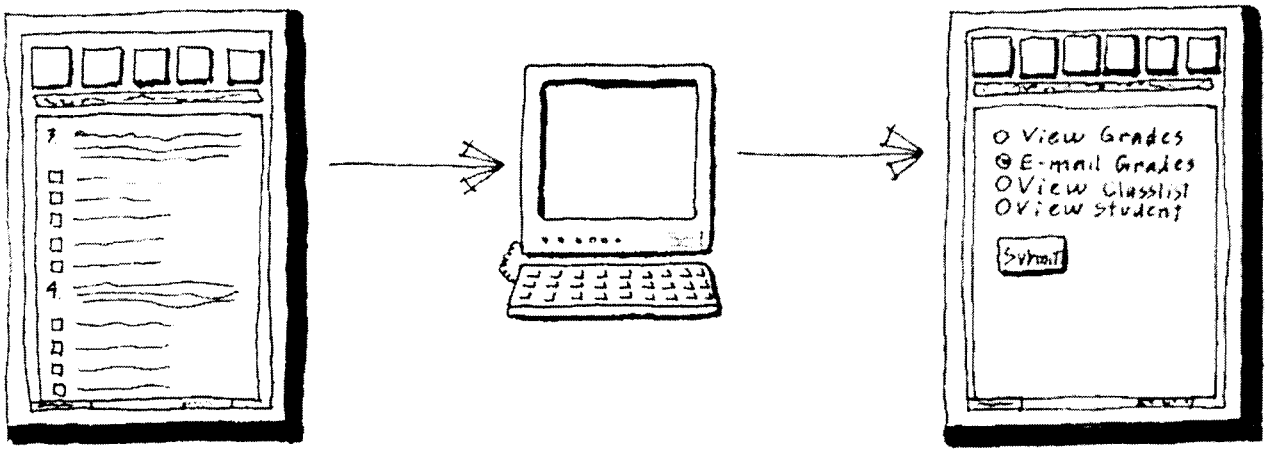

Figure 4: Grading is automatic and immediate

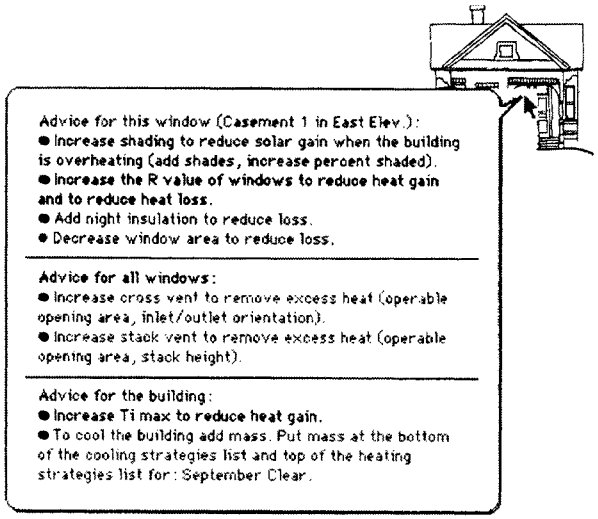

Figure 5: *Energy Scheming*'s expert advisor

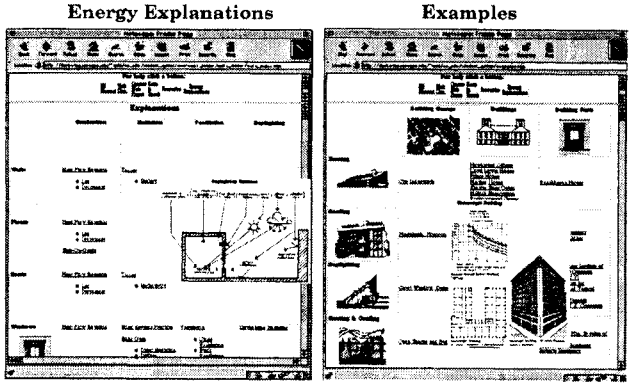

Figure 7: Some of the reference materials contained in the automated seminar.

Barrier #7: *If energy software is difficult to learn and cumbersome to use, faculty will not use it in courses.*

Faculty and students alike hesitate to use software that is difficult or cumbersome. However, the results of a recent survey showed that *Energy Scheming* is not difficult to learn and can save students time even in the first use. In a separate study (unpublished data, Kwok and Peña, 1998), using *Energy Scheming* was compared to doing hand calculations in a class of 116 beginning architecture students at the University of Oregon. After a one-hour lecture, it took students only half the time to complete building heat loss calculations with *Energy Scheming* than with hand calculations even though this was their first use of the program.

Furthermore, in the automated course students learn to use the software at the same time they learn about energy. In the first few exercises *Energy Scheming* is taught step by step in some detail. To accomplish this, students use a split screen to run *Energy Scheming* and the course exercises on the Web at the same time (figure 8).

So we could find out what worked well and didn't work well, students were asked a series of four open-ended questions at the end of the course. The questions were:

1. In the space below, please describe any problems you experienced using the World-Wide Web interface for the exercises and communication, why you felt the problems arose, and what we might do to solve them. Be as specific as possible.
2. In the space below, please describe what you liked about using the Web interface. Again, be as specific as possible.

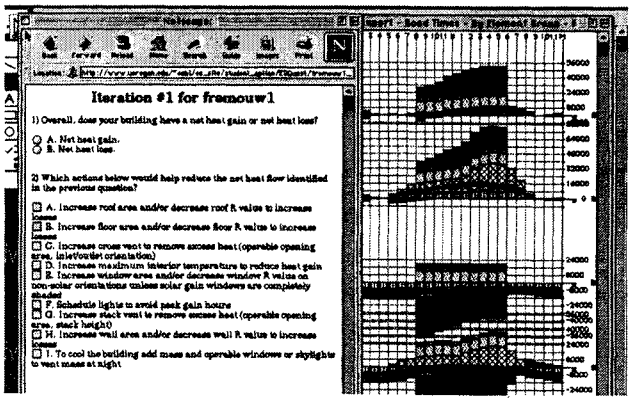

Figure 6, The question generator uses an expert system to ask questions about a students building that are specific to that building.

3. In the space below, please comment about using the Web interface to learn how to use *Energy Scheming*.
4. In the space below, please comment about using the Web interface and *Energy Scheming* to learn about energy and buildings.

The relative importance of a student comment was assessed by the number of students making the comment. When students were asked to comment about using the Web interface to learn how to use *Energy Scheming*, the two most common replies were: 1) that the exercises and interface worked well to learn *Energy Scheming* and 2) that they liked using the Web interface and thought it was appropriate (figure 9). Thus, we conclude that *Energy Scheming* is easy to learn and is taught effectively by the automated course.

Barrier #8: *"Winging it" is not possible in an automated course.*

While an instructor in a traditional seminar can fill in course information extemporaneously or "wing it," giving off-the-cuff explanations and adding course material is not possible in an automated course. Therefore, the content must be complete and self-explanatory. To achieve this, each of the eight exercises was organized into a warmup, exercise, and cooldown format. The warmup replaces the lecture in a traditional course by introducing the students to new material and giving them an opportunity to practice it. The exercise tests the students' knowledge and returns the results immediately. The cooldown explains the answers.

This approach was effective. The majority of the students said they learned energy principles from the course (figure 10). One student commented, "This was one of the best classes I have ever taken. Learning the computer program and the energy concepts at the same time was a great way to learn."

The students' perception that they learned energy principles was confirmed by pre-course/post-course tests (figure 11). The results show that student learning of energy principles in the automated course (Spring 1998) was equal to student learning in a traditional seminar with an instructor (Winter 1994 and 1995). Thus, we conclude that the automated course is complete enough that students learn energy principles even without the need for last-minute adjustments by an instructor.

Barrier #9: *Lack of personal contact with an instructor in an automated course could negatively affect student learning.*

Recognizing that a course without an instructor could feel impersonal to students, we created a more personal interface. In addition to receiving immediate automatic grading on their exercises and being asked questions about their projects (from the question generator), students received email messages several times during the course to update them on their progress and to check for questions. Besides this email to individual students, seven "warm and fuzzy"

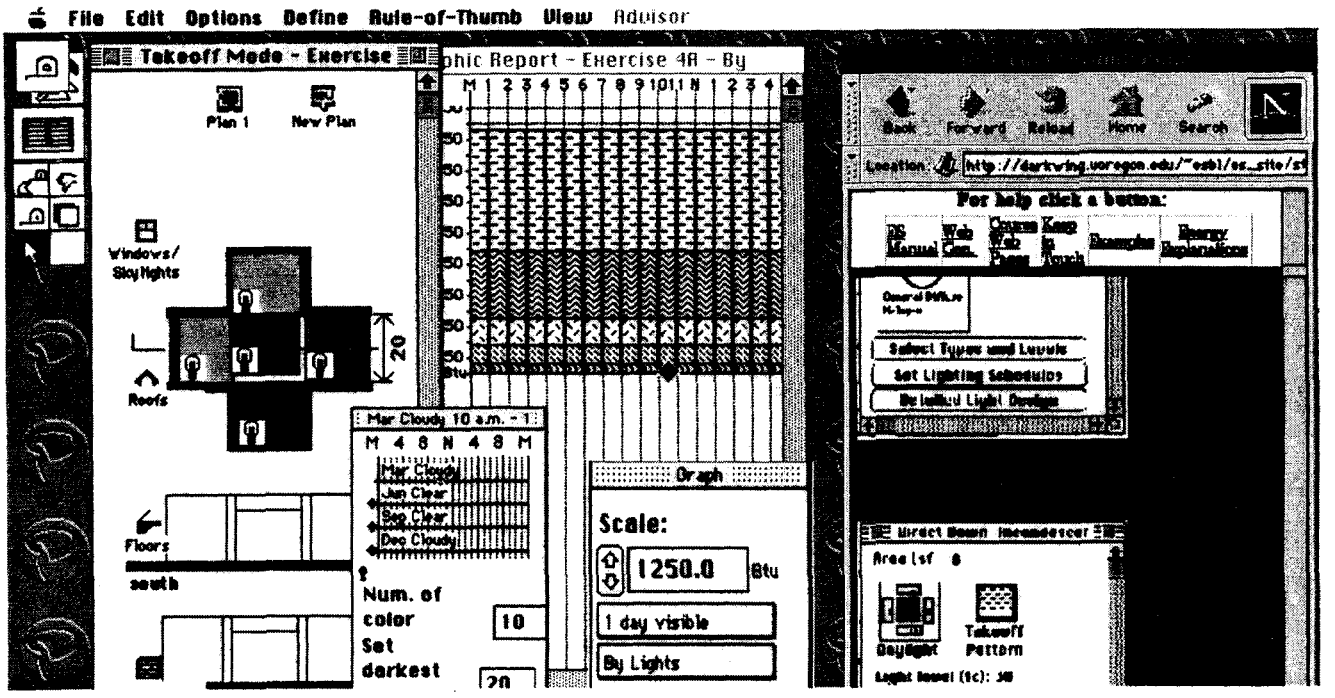

Figure 8: With split screen format students learn *Energy Scheming* at the same time they learn about energy.

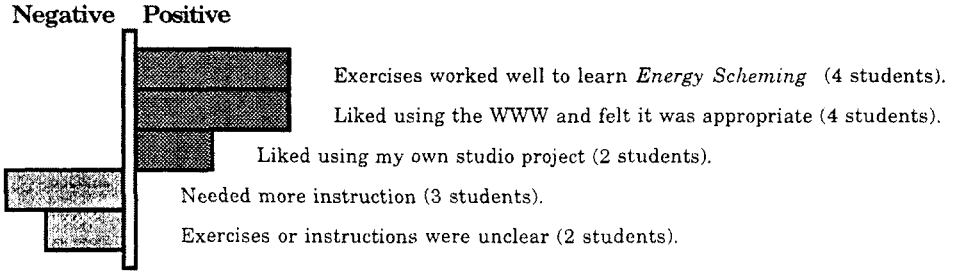

Figure 9: Comments of thirteen students on using the Web interface to learn *Energy Scheming*.

messages were broadcast during the term to all the students. Judging by the student comments, this method was effective, and students did not feel that not having an instructor impeded their learning.

When asked to identify what problems they had with the Web interface, most of the students cited minor technical problems rather than needing more personal contact with an instructor. Only three of the thirteen students responded that they wanted more help or instruction (figure 12). Therefore, we conclude that the lack of an instructor was not a significant problem for students.

Having no instructor was sometimes identified as a benefit. One student commented, "Sometimes I wanted to ask someone a quick simple question, but in the process of figuring it out myself I learned something else, so in the end I think it was more valuable this way [without an instructor]." Another student found the interface ideally suited to the course material. Commenting about using the World-wide Web interface to learn *Energy Scheming* the student wrote, "I believe that the best way to learn a program is to sit down and mess with it. Lecture classes on computer applications don't work well. Computers are real hands on." Therefore, the course was successful in addressing the majority of the students' need for help without using an instructor.

Barrier #10: *The course must encourage students to complete all the exercises even with the freedom allowed in an automated course that is self-paced.*

With the level of freedom allowed in a self-paced course we weren't sure if students would get everything done. However, all thirteen students completed the entire course on time. In addition, when asked what they liked about the Web interface, the majority of the students commented on the convenience of being able to take the course at their own pace (figure 13).

One student wrote, "I liked the freedom to take the class when I had the time. I was busy during the week with other classes, so I did a lot of my *Energy Scheming* stuff Friday nights or on off times on weekends or late some nights." Thus, even though the course was automated and self-paced students not only completed their work on time, but also cited the convenience of being able to work at their own pace as what they liked the most about the WWW interface.

DESIGN STUDIO COURSE

The design studio exercise uses energy as a design generator. In one example, students will spend three weeks on a preliminary design. At week four they will be introduced to *Energy Scheming* and be given an energy target based on current good practice for their climate. *Energy Scheming* will be used throughout the rest of the term to approach a final design that is, a building that is both aesthetically worthy and conserves energy.

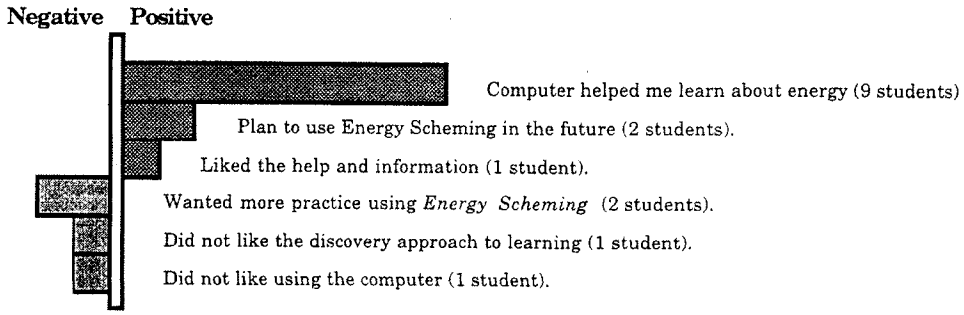

Figure 10: Comments of thirteen students on using the Web interface and *Energy Scheming* to learn about energy in buildings.

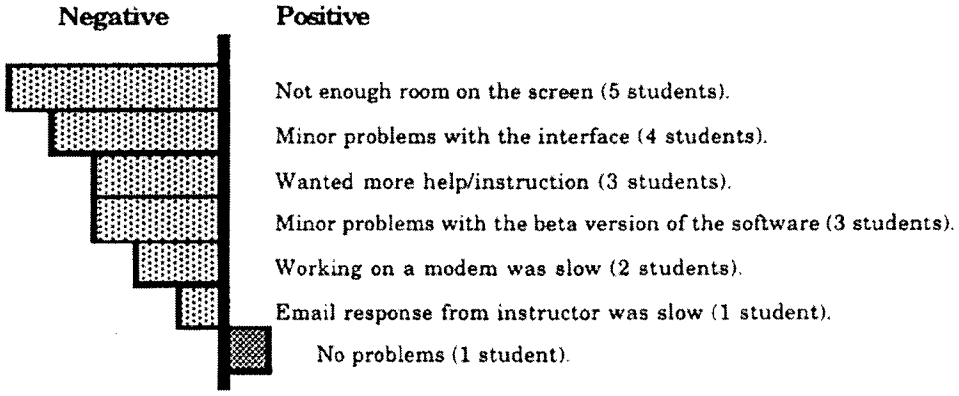

Figure 11: Comparison of pre-course/post-course test results.

Problem: Identifying the barriers.

This approach addresses four barriers. First, finding the time in studio for technical considerations and in-depth analysis has been a barrier to considering energy in studio projects. The second barrier addressed is the view that energy is less important than other considerations, and merely plays a supporting role. Third, there is a barrier of compartmentalization: studio is perceived to be the place for designing, support courses the place for calculating. The fourth barrier addressed by this approach is that the link between good architectural design (quality) and good energy performance (quantity) is not apparent.

Solution: Overcoming the barriers.

To overcome these four barriers the solution was to develop a custom made studio exercise that incorporated energy issues in the project to generate design questions. To accomplish this, one design faculty member and one technology faculty member from the same university will be teamed together to teach a studio. The studio course thereby addresses all four barriers by finding time for technical considerations, giving energy issues importance, eliminating compartmentalization, and linking good architectural design and good energy performance.

Summary

In the automated course the most frequent comments by students indicated that: 1) using the computer helped them learn about/ develop their intuition about energy; 2) they liked the convenience (anywhere, any time, at own pace) of the class; 3) they liked being on the cutting edge of technology; 4) they learned how to use *Energy Scheming* well in the course; 5), they liked using the Web; 6) they needed more space on the monitor; and 7) they had minor problems using the interface. Given the overwhelmingly positive response by students to the interface and simulation software, we conclude that the course was largely effective for the students. The studio course will be taught for the first time during the 1999/2000 school year.

CONCLUSIONS

The automated seminar developed in this project was successful in overcoming the ten barriers identified with teaching greater numbers of students how to design energy-efficient buildings. The barriers were overcome as follows: 1) the automated course reduces the time it takes a faculty member to set up and administer a course to only three hours, 2) faculty without energy knowledge can use the automated seminar as a freestanding course, 3) since it can be freestanding, the course accommodates faculty with different pedagogical approaches, 4) the course links energy information with the design process and reinforces this link by applying the process to the student's own building, 5) the support issues typical for a computer course are almost eliminated since the course was designed to be self-sufficient and offered over the Web, 6) energy information is made accessible through electronic links within the course, 7) the simulation software *Energy Scheming* is easy to learn and use, and students in the automated course learn the software at the same time they learn energy principles, 8) students learned just as much in the automated course as they did in a comparable course with an instructor, 9) based on student comments, the lack of personal contact with an instructor was not a limitation to most students, and 10) all the students of the course finished all the exercises even

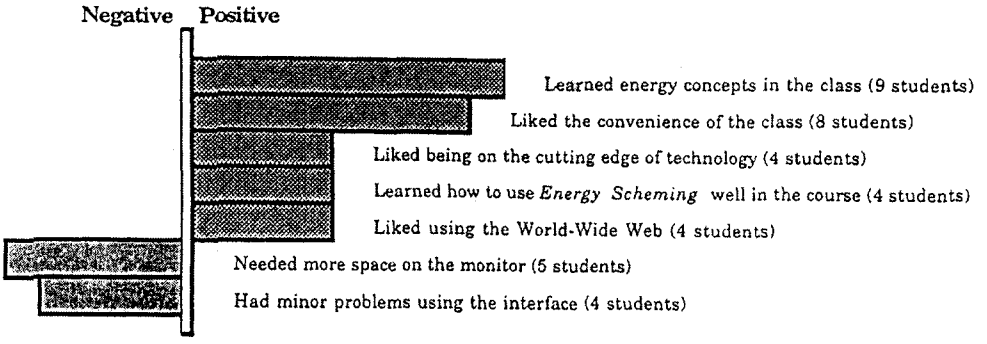

Figure 12: Comments of thirteen students on problems experienced using the Web interface for the exercises and communication.

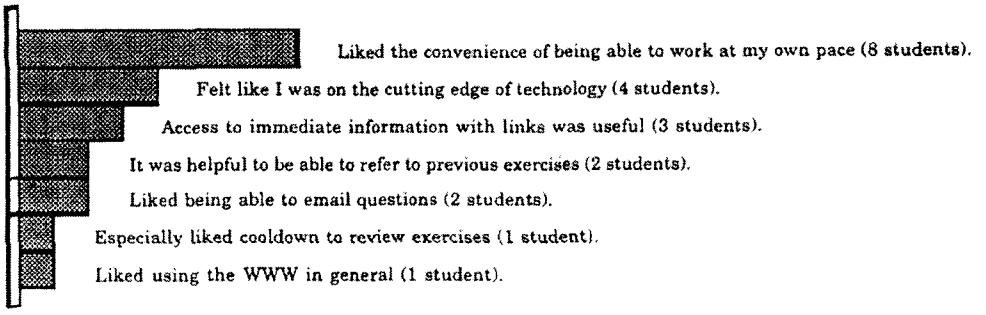

Figure 13: Comments of thirteen students on what they liked about the Web interface.

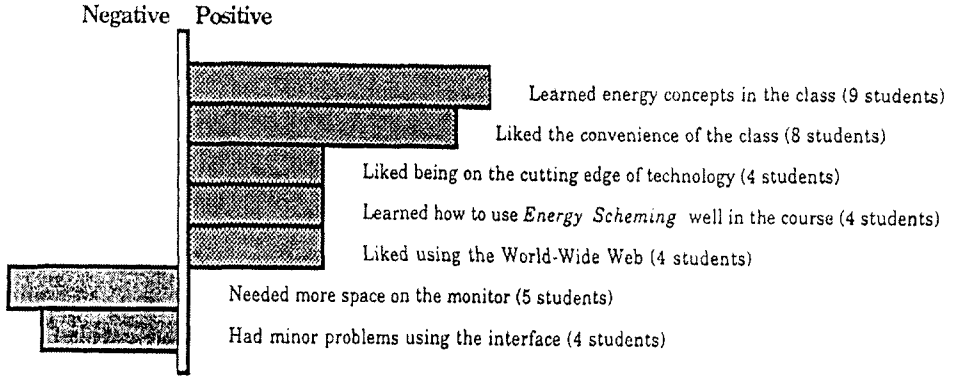

Figure 14: Final comments made by four or more of the thirteen students.

though the course was self-paced. By overcoming the barriers to teaching more students to design energy-efficient buildings, this course is an important contribution to the newly developed TEACHING ARCHITECTURE+ENERGY project. By the end of the 1988/1999 school year this course will have been taught to a growing number of students at six universities.

REFERENCES

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