ARCHITECTURAL FORM AS AN ENVIRONMENTAL CONTROL SYSTEM

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Introduction

This chapter describes the environmental control sequence of courses (see inset) at the University of Utah Graduate School of Architecture, its fundamental premises, its professional education perspective, and its curriculum approach and implementation strategies. Based on the fundamental principles of sustainability and stewardship of the built environment, the courses are designed to enable the students to draw from earlier successful environmental design strategies and to encourage their continued implementation and integration of those strategies into the built environment. This design scenario includes not only the reuse of the existing built environment but also the carefully considered expansion into new built environments. This philosophical approach encapsulates a shift in environmental control curriculum for the architecture student. Specifically, the shift is a renewed focus on using architectural elements of a building as the primary source of environmental control. Design integration that recognizes the architecture as the primary environmental control system presents a significant opportunity to reduce downstream problems in building construction and operation. The analysis and synthesis skills, defined by modern "pioneers" such as Aalto, Olgyay, Fitch, Yellott, and Knowles, who have worked to ensure that "modern" design practices incorporate the physical principles which pre-1940s designers understood well, must be well integrated into course materials and continually reinforced so that they will become a fundamental and valued part of the students', and eventually the practitioners', design approach. This will thus enable the architectural designer to more readily communicate with allied disciplines to ensure a more successful design.

There is a familiar quotation which states that "those who can not remember the past are condemned to repeat it."[1] With regards to environmental control in modern practice, the opposite seems more common in that those who do not understand the traditional concepts of architectural design as an environmental control system are prone to *ignore* them and the design opportunities they provide. This latter statement often provides the key to understanding how modern design strategies have evolved into an ever increasing reliance on man-made "artificial" thermal and illumination technologies and have thus resulted in many overly complicated and oversized thermal and illumination systems being constructed. Instead of the architect fully understanding the implications of form as an environmental control system with the man-made technological components providing auxiliary assistance when the building system is deficient, current practice has become a sequence where the designer develops a form and then hands it to the engineers who are told to "make it work." Along with this widespread design "amnesia" which constitutes this currently diminished understanding of architectural form as an environmental control system, the architect ultimately loses control of the building when the engineers need to integrate their respective systems. The result is an abundance of buildings without any sense of the architectural form being environmentally sensitive and the control systems within them being oversized due to lack of communication and coordination between disciplines.

The recent trend toward environmentally sensitive architecture has brought cries for "new" design strategies. Instead of viewing the future as looking for more technologically based "artificial" strategies as part of the environmental controls integration process, educators and practitioners have an opportunity to "rediscover" the strategies of the

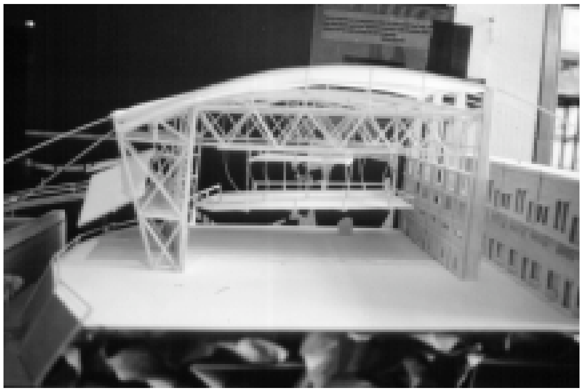


Figure 1: Integrated Daylighting Model

not so distant past and redevelop them into an updated design vocabulary. In this manner, greater emphasis on the synergisms of architectural form can make the most significant contributions to reducing demands on environmental resources by enabling architects to design buildings which integrate solutions and mitigate resource depletion at the outset rather than trying to continually overcome problems by throwing more man-made technology into the process.

Architectural Form as Environmental Control: A Fundamental Perspective

Seemingly unknown to many present practitioners or perhaps simply ignored are many pre-1940 design strategies which had formerly been common practice for environmental control because of the lack of "modern" technology. The fluorescent lighting systems[2] and the major HVAC systems[3] that are now taken for granted were either in their infancy of use or had not been fully commercially developed in that era. Accordingly, architectural designs incorporated "passive" environmental control strategies such as daylighting, regional design, and solar access which together promote the architectural form as the primary environmental control system. With the advent of the "modern" technology of the post-World War II era, these strategies have eventually been lost on a large scale.

Advances made since the mid-20th century have resulted in an increasing reliance on man-made technologies in environmental control at the expense of the ability to use the architectural form of a building as part of the control system itself. As man-made "active" technologies became more sophisticated and more readily available, the human scale and condition within the workplace fostered by the earlier passive systems became diluted, outdated, or in the view of many designers and clients of the time, not cost-effective. Concurrently, advances in these technologies lead to a greater level of sophistication being needed to understand their design requirements and therefore subspecialty disciplines oriented toward engineering emerged with the control of these environmental control design aspects being delegated ever more frequently to the engineer and away from the architect. In this post-war period, energy was considered an insignificant factor in the design of new buildings and accordingly buildings became increasingly larger and more climatically disjointed. This disjointedness and the "freedom" from having to understand environmental control influences caused building designers to even further ignore and even reject the benefits provided by daylighting and other passive strategies. However this freedom eventually forced designers to begin relying significantly on the products of man-made technologies to overcome the "problems" created by the design which ultimately broke the connection of the building from its site and regional location. With the modern technologies becoming further dominant. buildings became a commodity of sorts and the recognition of the sophistication and subtleties of the unique features based on regional climate which made them effective as environmental control systems were lost.

Despite the industry-wide "awakening" received during the energy crises of the 1970s and the immediate scramble for ways to, at first, conserve energy and subsequently to protect the environment, the real estate development boom of the 1980s far outpaced the implementation of research design guidelines. Not only were new designs complicated by the use of technologically advanced systems but there was a growing awareness of the importance of reusing the built environment as well. Today the profession is faced with an extremely complex and integrated environmental control paradigm. One factor interrelates in so many ways with many others that one seemingly simple "solution" generates numerous previously unforeseen "problems." Many of the early energy conservation strategies of the 1970s resulted in subsequent visual comfort, thermal comfort, and indoor air quality problems. Much of this stems from the fact that attempts to solve the conservation problem were, borrowing a term from environmental activist vocabulary, "end of the pipe solutions." While the country is embracing environmental protection, the recognition of the problems associated with the initial clumsy reactions to energy conservation has emerged and the newer generation of designers in this area are finally attempting to view the comprehensive picture. While these earlier concepts are included in what is currently denoted by such terms as "green architecture" and "sustainable design," the successful readoption of these design strategies and concepts is based in part on the recognition of the impact of incorporating them more readily into the fundamental approach to design. Therefore, if future building designers are to succeed, environmental conservation and control integration need to be integrated into the initial design concept rather than tacked on at the end or, even worse, ignored.

Collaborative Professional Practice as an Educational Goal

Recently there have been attempts to redefine the way architecture is practiced. As described in *Building Community: A New Future for Architecture Education and Practice*[4], one major hurdle to be removed is that of interdisciplinary coordination communication. Full service architectural-engineering firms can offer the opportunity for in-house interdisciplinary coordination more readily than other single discipline service firms but, overall, there remains diminished communication between the disciplines as the design first emerges. Identifying all personnel who have a vested interest in the outcome of the project to communicate effectively can range from problematic to impossible. There are a growing number of instances which have demonstrated the process needed to construct a successful collaborative design. A recent example is the Audubon Society Headquarters[5] which were designed by Croxton Collaborative, Architects (CCA). Seeking to implement an environmentally sensitive design, the Audubon Society commissioned CCA to design its new headquarters. The result was "Audubon House," a renovation of a late 19th century office building in New York, which has been highly praised for energy efficiency, daylighting, indoor environmental quality, and sensitivity towards depletion of natural resources by the selection of the materials and equipment used in the renovation. The outcome was a sophisticated model of not only what can be achieved in reusing an existing facility but also a model of how to make a comprehensive collaborative effort succeed as well.

The expertise needed to achieve Audubon House resulted from the combination of interdisciplinary efforts of architects, engineers, environmentalists, research scientists, interior designers, and contractors. However, much of the information needed centered on the architectural aspects which included the awareness of the potential materials and environmental control and structural systems available for the design and the analysis methodologies available to evaluate them. Since so many of the decisions were so architecturally related, this project clearly shows the importance of the role that the architect must be able to play in determining which design practices are eventually to be implemented.

University of Utah Graduate School of Architecture: Challenging Traditional Instructional Paradigms

The design and communication expertise needed to achieve success in a project such as Audubon House is not commonly integrated into a single academic design studio or its corequisite courses. The acquisition of this expertise is the result of the integration of the fundamentals of these skills concurrently in both studio and corequisite courses. While the basics of these skills are oftentimes introduced in corequisite courses, the expression of these skills is first refined in the design studio. The successes achieved by Audubon House provide a challenge to the academic instructors to facilitate the skills necessary to define (1) a programmatic solution which meets an actual client's goals and then (2) in collaboration with the requisite experts (3) use that program to design a building solution based on evaluating the choice between designing a completely new facility or renovating an existing one. Typically, traditional academic studio projects consist of (1) a theoretical design program which is taken by (2) an individual student and developed into (3) a building design solution for a completely new building. To avoid "overcomplicating" a traditional academic design problem only one of these three parameters may typically be varied but the overall result is still an *individual* using *theoretical* information for a *new* building.

Much of the contemporary architectural instruction does not foster collaboration skills and lacks the direct and immediate integration of materials and assignments of corequisite courses presented in conjunction with the studio. Seemingly constrained by a variety of obstacles, common practice in these corequisite courses is to provide lecture and reading materials, homework problems, examinations and even design projects that are separate from the design studio project but yet leave the actual integration of the respective corequisite course material into the studio design project to the initiative of the individual students. Use of this approach has resulted in the lack of full integration of corequisite materials into the design studio and therefore further increases the likelihood of producing students who neither fully appreciate the potential impact of these materials on their designs nor have the skills to appropriately integrate the materials into their designs.

For schools to produce graduates who can better grasp the skills needed to effectively work in the collaborative mode, curricula modelling these traditional paradigms need to be revised. The emerging paradigm is one in which the faculty of the corequisite courses work more directly with the design studio faculty to assure the successful integration of interdisciplinary materials either by directly assigning projects which relate to the design studio project or by indirectly assigning homework problems which build upon skills needed in the concurrent design studio. At this point the appropriate paradigm appears to be the presentation of materials in corequisite courses which ultimately result in the collaborative integration of the corequisite course material directly into the studio.

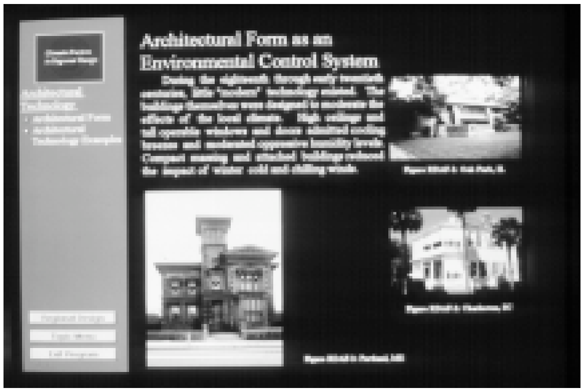
For the environmental controls sequence at the University of Utah Graduate School of Architecture, this has been successfully accomplished. This three term course sequence respectively focuses on thermal, luminous, and sustainable environments. The course sequence begins in the senior year of the undergraduate program and concludes in the first year of the graduate program. During this progression, the material is presented in an ever-increasing degree of complexity in concepts and design collaboration. Initial assignments are less formal, completed individually, and ultimately proceed to more integrated projects combining several corequisite courses and design studio with projects completed as a team of three or more students. Assignments are supplemented by lectures, site visits, guest speakers, laboratory exercises, computer simulation tools, and interactive computer-based instruction modules.

Thermal Systems in the Built Environment

The first course, ARCH-537, explores the thermal environment and the factors that influence it. The course objectives are to develop the fundamental understanding of technical concepts and to enable the student to understand the factors which influence thermal comfort and performance in the built environment. The course is initiated with personal observations of the students on technical concepts of thermal comfort and proceeds through performance based design analysis of passive thermal systems and concludes with the students exploring the role of the mechanical engineer. To accomplish this progression, there are four assignments that are collected for grading. First is an analysis of thermal comfort in the built environment. Second is a research paper focusing on vernacular architecture of a student selected region anywhere in the world. Third is a solar aperture design problem. Last is a heating and cooling load analysis. Also presented are a series of worksheets which are not collected for grading purposes but allow students to work through sample problems based on the materials presented in lecture and recitations.

In the introductory homework exercise the individual students explore a built environment of their own choosing to evaluate the respective comfort factors of that environment and how the designer has used (or not) architectural forms and site elements as the controlling factor for thermal comfort. The students use their own experiences and qualitative responses to employ the existing built environment as a personal learning laboratory[6] and compile that experience into a report that describes their selected environment, their comfort-based reactions to it, and their observations and analysis as to whether the design had been a success or a failure and which factors contributed to that condition. As this is the first assignment in the course sequence, these evaluations are performed by the individual students. Students report that this is actually quite an enlightening exercise in that it allows them to look at their environment in a way they had not done before and once completed they tend to carry this analytical process with them after the exercise is finished.

The next assignment is an individual analysis of how vernacular traditions have evolved in a specific region of the students' choosing. The students explore how the climatic driven responses of particular vernacular building traditions moderate or enhance the local microclimate conditions. This research-oriented exercise not only develops the students' research skills but also provides a means of analyzing and understanding a building form climatically. The elements discovered and described in this process can be translated into a design/construction vocabulary that can be integrated into more "modern" designs. This provides the first step in developing the integration of architectural form as an environmental control into their design vocabularies. This exploration is supplemented by an interactive computer-based module *Climatic Factors in Regional Design* that was developed by the course instructor[7] which delineates the form-driven aspects of vernacular design and construction.



Architectural Form as an Environmental Control System

Figure 2: Sample of Screen from *Climatic Fcctors in Regional Design* Interactive Instruction Module

The third assignment is the design of a solar aperture that meets a specified set of performance criteria for solar penetration and exposure during the heating season and solar shading during the cooling season. This exercise may be done following the predetermined criteria or may be modified to meet the students' concurrent studio project assignment. The design criteria include the need to integrate the solar aperture/shading device configuration into the design so that it does not simply appear to be an afterthought as often seems the case in actual practice. Students are encourage to use horizontal and vertical elements, multiple louvers, and vegetation as means to make the design meet the seasonal design criteria. Students design their solar aperture/shading device configuration using solar geometry to develop a scale model. The scale model is then tested on either the solar table in the design studio or is taken outside to test in the actual sunlight. The students then evaluate their success and make recommendations for alterations to improve any deficiencies in performance. Construction drawings are then developed. These include construction details and a rendering of the configuration as it would appear on the facade of the building. These drawings and the calculations which the students used to develop them are submitted for grading. This assignment has resulted in these configurations being designed to simulate porticos, porte-cocheres, balconies, and walkways in sensitive well considered designs that do little to reveal that their original purpose was in fact a solar performance-based design. Students report that meeting the performance criteria while integrating these designs provided a stimulating challenge.

The final assignment involves the computation of a heating and cooling load for a sample building and then sizing a ductwork distribution system to simulate the role of the HVAC engineer in the design process. Since this assignment provides little design license for the students, they have not surprisingly noted displeasure with it. However, this assignment also provides them with an insight into the procedures that the HVAC engineers must go through to accomplish their ductwork designs.

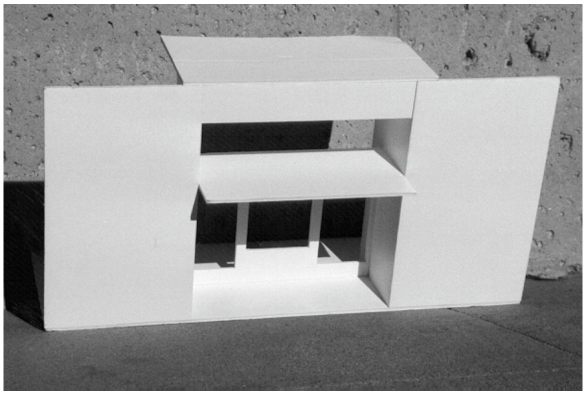


Figure 3: Solar Aperture as an Entryway

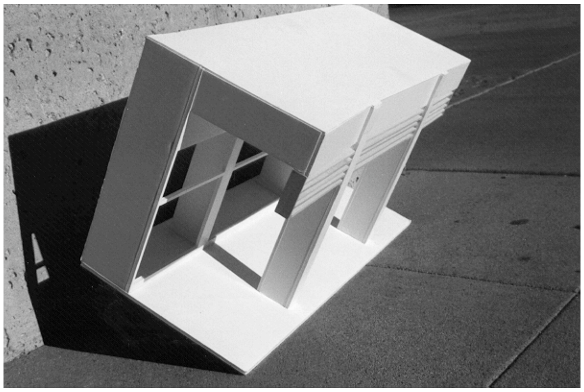


Figure 4: Solar Aperture as an Arcade

In conjunction with these assignments, guest speakers, lectures, and readings, there are site visits to local construction sites to view the fabrication and construction of HVAC and mechanical service systems. Although the class size of sixty students does not allow for a single common site visit, the opportunity to visit a site and focus on the services aspect provides a first-hand exposure to the complexity of integrating distribution networks within the ceiling cavities and duct chases as well as mechanical room functional needs.

Lighting Systems in the Built Environment

The second course of the sequence, ARCH-635, explores the luminous environment and the factors that influence it. The course objectives are to develop the fundamental understanding of technical concepts and to enable the student to understand the factors which influence visual comfort and performance in the built environment. The course explores visual comfort as a design requirement, then explores daylighting systems and concludes with an exploration of electric lighting systems. A main component of the class is the analysis of how daylighting and electric lighting interact with one another physically and economically. The course is initiated with personal observations of the students on technical concepts, proceeds through performance based design analysis, and concludes with the students exploring the role of the lighting designer. To accomplish this progression, there are three assignments that are collected for grading. First is an analysis of visual comfort in the built environment. Second is a studio project that combines project requirements from this course, the design studio, and the structural design corequisite course. Last is the design and fabrication of a lighting fixture. Students also complete a series of worksheets which reinforce lecture and recitation materials but are not collected for a grade.

In the introductory homework exercise the individual students explore a built environment of their own choosing to evaluate the respective comfort factors of that environment and how the designer has used (or not) architectural forms and site elements as the controlling factor for visual comfort. The students use their own experiences and qualitative responses to employ the existing built environment as a personal learning laboratory and compile that experience into a report that describes their selected environment, their comfort-based reactions to it, and their observations and analysis as to whether the design had been a success or a failure and which factors contributed to that condition. As with the first course, since this is the first assignment in the course sequence, these evaluations are performed by the individual students. Students report that this is actually quite an enlightening exercise in that it allows them to look at their environment in a way they had not done before and once completed they tend to carry this analytical process with them after the exercise is finished.

Figure 5: Daylighting Study Model A

Figure 6: Daylighting Study Model A Interior

The next assignment is an interdisciplinary collaborative effort within the design studio. This collaboration combines the environmental controls course, the corequisite structures course and the design studio project into a single venue. In establishing the basis for this integration two significant curriculum shifts within these three courses were put into place. First, a "client" agrees to work with the students in developing a design program and a design project is selected which enables the students to deal with the design of a clear span steel structure and incorporate daylighting as a major aspect of design. Second, the faculty coordinates their lecture materials and project deadlines into a sequence which allows time for students to accomplish the necessary design and analysis components of each course. The "client" is typically a non-profit organization with intentions of developing a project that is suitable for the level of collaboration desired in the assignment. At the start of the process, the only program objectives are that daylighting and visual comfort be maximized and that the facility allow for structural elements to be a visible part of the design. These two requirements directly drive the need to integrate the environmental control and structural design aspects of the coursework into the studio. Beyond these initial simple requirements, the client agrees to allow the students observe the client's activities and to interview the client's staff to enable the students to define a program based on actual needs. The goal is to facilitate the collaborative efforts between the students, the faculty, and the client as frequently as possible. To achieve this goal, the studio problem challenges several aspects of the traditional studio described earlier. These goals focus on the students becoming aware of the benefits of cooperative learning methods and enhancing their abilities to achieve design solutions based on (1) a program from an actual client rather than a theoretical design program; (2) a collaborative effort in student teams rather than an individual effort; (3) the choice between either constructing a new facility or renovating an existing one rather than just a new building alone; and (4) integration of materials and assignments of corequisite courses presented in direct integration with the studio rather than separate and perhaps unrelated projects for corequisite classes. After programming development is complete, the teams implement their design solutions based on their program. This design serves as the daylighting and structural analysis model for the project. For the daylighting aspects of the project, each team analyzes the success of their integration of daylighting strategies. A 1/4"=1'0" scale model is analyzed for both overcast and clear sky conditions. Depending on the configuration of the proposed solution a minimum of 216 light level

Figure 5: Daylighting Study Model B

Figure 6: Daylighting Study Model B Interior

measurements are taken. Concurrently, photographs of the interiors corresponding to a variety of times and sky cover conditions are taken to provide visual simulation of the performance of these spaces. Students also note any unusual findings that they encounter. Each team then prepares a report of their findings. The findings are presented to the class and the class members vote for the best design concept and presentation. To ensure all members participate equally, team members also submit an evaluation of their project, each team member's contribution and their own contributions. At this point, the students proceed with the development of the design for the remaining weeks of the term and make a presentation of the final design to a jury consisting of the faculty, the client, and local practitioners. Overall, the success of the process is clearly evident by the high level of energy and pride that has been displayed in the final presentation in every iteration of the course. Evaluations from the students frequently include comments about how challenging it had been but how worthwhile it had turned out.

While the design studio proceeds from this point incorporating the lessons learned from the daylighting analysis into the final design, the environmental controls course has one last assignment. This assignment is the design of a working electric lighting fixture that meets a specified set of performance criteria for a lighting scenario. This exercise may be done following the predetermined criteria or may be modified to meet the students' concurrent studio project assignment. Students are encourage to work in groups and derive their design aesthetic from their just previously completed daylighting project. Students design their light fixture as a prototypical full scale functional model and perform a photometric distribution analysis on it. The specific design descriptions and test results are then incorporated into a catalog specification sheet similar to those found in a manufacturer's catalog. This specifications sheet and working model are submitted for grading. There is a budget set for materials which has resulted in a variety of creative design solutions that draw numerous comments from faculty and students from other classes. As with the daylighting project, the students vote for the light fixture which they like the best. This project more than any other draws the greatest amount of interest from students outside the course. Students report that this project is one of their most enjoyable experiences in the University of Utah Graduate School of Architecture program.

In conjunction with these assignments, guest speakers, lectures, and readings, there are site visits to local buildings to view the fabrication and construction of daylighting systems. In this instance the smaller class size (30 students) allows the opportunity to visit a site and talk first-hand with the building architect about the complexity of integrating daylighting systems within a building.

Figure 7: Lighting Fixture

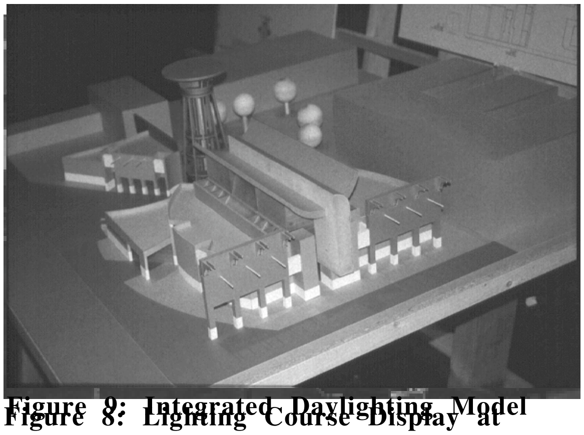


Figure 9: Integrated Daylighting Model

Figure 8: Lighting Course Display at Accreditation Exhibit

Sustainable Systems in the Built Environment

The final course of the sequence, ARCH-636, explores the sustainability of the built environment^8 and the factors that influence it. The energy related course objectives are to tie together the technical concepts presented in the two previous courses and provide an overview of how they are managed in the built environment. This portion of the course essentially provides a discussion orientation to further explore how these concepts affect energy conservation as part of the larger concept of sustainability in the built environment. This includes electrical energy conservation and demand side management opportunities as well as the negative impact of resource depletion due to common energy intensive construction practices. The assignment for this portion of the course is a research paper on sustainability as it relates to a topic of the students' choosing. This affords the student the chance to expand previously covered course material or extend course coverage into topics not covered earlier.

Reaction and Feedback

There were numerous and varied reactions and comments about this course sequence, its goals, its planning, its process, and its outcome. The sequence has been publicly praised during the most recent NAAB accreditation visits as being one of the strong points of the program. Students who have completed it have noted a great deal of satisfaction with the latitude and challenge that it provides and have given ovations to the instructor at the end of the course sequence. Local practitioners have commented extremely positively about the process and the extension of the curriculum into the built environment and the opportunities for learning that it has provided.

Efforts in this direction have continued to be integrated into the curriculum at the University of Utah. While this course sequence is succeeding in its academic goals, there will be an understandable delay of several more years before the students who have completed this course sequence rise to the decision-making positions that will enable them to act on the skills they have acquired here and ultimately prove its success as a valid curriculum method. Until then, there are two aspects of academic architectural education that need to be highlighted to ensure that this course sequence can be repeated here or emulated successfully elsewhere. First, in current architectural practice the significant trend is toward collaborative processes. In that light, group work and conflict resolution skills need to be introduced early in the architectural education process to ensure that all group members can view the larger picture and their part within it. Second, there needs to be a method to evaluate individual performance within the team. As described above, this was done by each team member and was an incentive to encourage full participation by all team members. This still needs further refinement to reduce potential grade inflation and account for personality conflicts.

Concluding Remarks

From an environmental perspective, design integration paradigms which recognize the architecture as the primary environmental control system present a significant opportunity in reducing the downstream problems in building construction and operation. The analysis and synthesis skills, defined by the modern "pioneers" such as the Aalto, Olgyay, Fitch, Yellott, and Knowles who worked to ensure that "modern" design practices incorporated many of the physical principles which pre-1940s designers understood well, must be well integrated into the design studio and continually reinforced so that it will become an intrinsic part of the students', and eventually the practitioners', design approach. Most of all, the arrogance or the ignorance that has led to the notion that technology will solve all of the problems generated by climate insensitive designs and has thus resulted in the current collective design amnesia must be eliminated.

As demonstrated by the curriculum described in this chapter, it is possible to bring together several diverse and often conflicting parameters into the academic classroom and even invite the "real world" to participate in the cooperative learning process and ultimately be successful in recognizing architecture as an environmental control system. However it takes an open-minded approach to defining the design problem, and a flexible and coordinated method of integrating analytical methods from corequisite courses. The design solutions throughout the range of assignments varied widely but the common aspect was the integration of architectural form as an environmental control system and the development of collaboratively sensitive designers with a broadened perspective on the entire environmental control system spectrum. The expertise obtained by the students could neither have been achieved nor reinforced as well through the traditional separate presentations of the course materials as is common elsewhere. Overall, within this course sequence, students rediscover some of the common design strategies of the not so distant past and learn how to use them in the modern built environment. This in and of itself can go a long way in reducing the continued depletion of energy resources and in the long term *re*-create a more climatically derived and subsequently less energy intensive built environment in the future.

Endnotes

[1] Bergen Evans. *Dictionary of Quotations* (New York: Delacorte Press, 1968) 511.

[2] Fluorescent lighting was commercially introduced in 1937 with many numerous revisions and upgrades occurring through to present times.

[3] Modern distributed heating and ventilating systems have been in use throughout the 19th and 20th centuries. Air conditioning systems were introduced commercially in 1904. Collectively, these systems have undergone numerous design revisions with the most recent focus being made on computerized electronic control technologies and system interfaces with building automation systems.

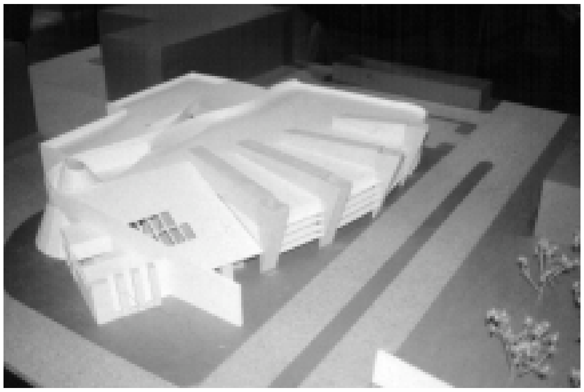


Figure 10: Integrated Daylighting Model

[4] Ernest L. Boyer and Lee D. Mitgang. *Building Community: A New Future for Architecture Education and Practice* (Princeton: The Carnegie Foundation for the Advancement of Teaching, 1996).

[5] National Audubon Society, Croxton Collaborative, Architects. *Audubon House: Building the Environmentally Responsible, Energy Efficient Office* (New York: John Wiley & Sons, Inc., 1994) 1-203.

[6] This is a recurrent and necessary theme that runs through the entire environmental controls curriculum. The premise is that by evaluating their own built environment and challenging the perceived design concepts that created it, the students learn to critically evaluate how design in the built environment is controllable. Likewise, the premise that the built environment is their own personal laboratory extends the classroom into their everyday experience. As a result, this exercise *reactivates* their senses and enlightens them in a way that they can explore and explain to a potential client or collaborative designer how their fundamental design concepts will affect them at the primary level of physical comfort.

[7] This module was developed on the software application program Authorware by Macromedia Corporation as part of a grant funded by the Utah Higher Education Technology Initiative. The module is only available on the GSA computer network and contains 260 separate screens containing more that 300 images which illustrate these concepts as defined by seventeen climate regions in the United States.

[8] This course also covers acoustics but this will not be discussed here.

ARCHITECTURE AS AN ENVIRONMENTAL CONTROL SYSTEM
COURSE DESCRIPTIONS

ARCH-537 introduces thermal comfort in buildings; passive thermal systems; heating/cooling load calculation; heating, ventilating, and air-conditioning system design and selection; energy code requirements; sustainable architecture; and life-cycle costs.

ARCH-635 introduces the student to the luminous environment in buildings; visual comfort; and the fundamentals of daylighting systems analysis and design; lighting load calculation; electrical lighting energy cost avoidance strategies; electrical and lighting system design and selection; energy code requirements; sustainable architecture.

ARCH-636 introduces the student to energy use and management in the built environment; energy cost avoidance strategies; and energy economics.

COURSE OBJECTIVES

The objectives are to teach the student to understand:

- the thermal environment and the comfort criteria required for human occupancy;
- the impact of design elements (roofs, walls, windows, etc.) on thermal system sizing, selection,and energy usage;
- the concept of using the building as a thermal system;
- the basic concepts of thermal performance in sustainable architecture;
- the basic passive thermal strategies employed in buildings;
- the thermal energy systems used in buildings;
- the impact of energy codes on building design;
- the fundamentals of life-cycle cost analysis for selection of energy systems;
- the methods for selecting appropriate thermal systems for buildings;
- the parameters of visual comfort;
- the application of architectural daylighting practice fundamentals to design;
- the components of daylighting systems as expressed in architectural forms;
- the application of architectural electrical lighting practice fundamentals to design;
- the components of electrical lighting systems;
- the applications of different lighting types in the luminous environment;
- the primary components of electrical lighting energy cost avoidance strategies;
- the fundamentals of life-cycle cost analysis relative to the methods for evaluating and selecting appropriate lighting systems and the components of automated lighting control systems;
- the basic electrical systems employed in buildings;
- the basic concepts used in electrical energy cost avoidance strategies;
- the concepts of electrical energy consumption and demand billing;
- the overall perspective of sustainability in the built environment.

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