Environment and Buildings I: A Case Study in the Evolving Technical Education of Architects

Mark DeKay, University of Tennessee, Knoxville
ABSTRACT

This paper describes the educational goals, teaching strategies, and results of a graduate architecture course, “Environment and Buildings I,” taught at Washington University in St. Louis, MO. It is presented as the first step in a series of evolutions of the school’s technical curriculum, evolutions that seek to significantly integrate energy, environmental, social, and aesthetic issues in the education of architects. The course introduces the theory of an ecological approach to architecture and covers the schematic design of buildings for heating, cooling, lighting, and water. The intention is for students to learn to design responsible and beautiful places that sail elegantly into the twenty-second century on available renewable energy. Lectures and projects are organized to parallel the design process, with emphasis on the architectural implications of technological systems. Where possible, students’ design studio projects are used as the vehicle for class assignments.

1. INTRODUCTION

Climate and region are approached as a context for design. Principles of thermal comfort, regional design strategies, bioclimatic design theory, and ecological design process are covered. Systems for heating, cooling, lighting, and water are addressed holistically and simultaneously, rather than topically and discretely. Architectural strategies are explored at a range of scales: element, building, and site. Lectures and assignments include bioclimatic site analysis, schematic design strategies, and schematic level design and analysis with computers.

Site forces and energy sources are studied in detail, allowing students to become competent at using the sun for heating, the wind for cooling, the rain for domestic water, and the sky for lighting. Two user-friendly computer programs are used to facilitate rapid feedback about the energy consequences of design decisions. Mechanical intervention is considered only after the architecture has significantly reduced the need for equipment.
the seven semester program generally enroll in their second year, while two year students are encouraged to take the course in their first year. Currently, it is the only required course in the traditional curricular area of “environmental systems.” The course is intended to both present design issues in relation to technological systems and, where possible, to integrate these issues with the students’ studio work.

4. EDUCATIONAL GOALS

4.1 Learning to Reduce Environmental Impacts

The design of buildings and cities is a contributing cause of every major environmental problem today. Buildings use one-third of the energy in the U.S.; consume vast quantities of finite non-renewable resources; produce one-half of the world’s carbon dioxide emissions, encouraging global climate change; and consume half of the world’s CFC’s, contributing to atmospheric ozone depletion. Architectural design decisions are responsible for: 1) environmental externalities, such as the off-site effects of energy and materials production and consumption; 2) on-site effects, such as destruction of local ecosystems, habitat, and the pollution of air, water, and soil; 3) indoor pollution, caused by toxic buildings materials, poor construction practices, and poorly designed ventilation. Students must learn the consequences of their design decisions and reduce their impact.

4.2 Process-Integrated Technology

Students learn about technological questions within their design context. In this view, technical systems are presented as integrated with design process, with appropriately detailed methods applied at each stage. For instance, rule-of-thumb methods and graphic analysis are used for preliminary design and more detailed analytical calculation procedures are introduced as more detail about the design emerges. In this way, analysis can integrate with the generative and iterative process of architectural design. The interrelationships between different technical systems and between technical systems and other design concerns is stressed, particularly the aesthetic, formal, and experiential opportunities in environmental control systems.

4.3 Holistic Systems Thinking

In the most general terms, a “system” is any entity with emer-
gent qualities at the scale of the whole, which are not present in the individual parts. Whole systems theory perceives the world as integrated relationships, interconnections, processes and patterns. Systems Theory treats wholes (systems) as made up not only of parts, but also of relationships, therefore the study of the interconnections (in space, time, and process) between parts is critical. The theory of whole systems emerged simultaneously in the disciplines of biology, psychology, ecology and physics. Ecologists of the 1920's observed the diverse complexities of plant and animal cohabitation terming their inclusive interdependence of life as ‘ecosystems.’

Architecture is a holistic discipline, including technical, social, and aesthetic concerns. The act of designing buildings is an act of reverence, as stewards of the Earth and as a privileged professional class in service to society. The greatest task of an architect is to make a place that is whole and has the quality of being alive. Within an increasingly developing culture of specialization, architects have the responsibility to physically manifest in buildings the consciousness of interconnectedness and life processes. Architectural education must graduate professionals capable of designing buildings and communities that accommodate human needs, represent the values of their users, and are characterized by wholeness, aliveness, reverence, integrity, and responsibility.

4.4 Form Implications of Technology

Technology is most often thought of as a subject of practicality, considered after the more glamorous activity of ‘design.’ Rather than having students learn about technology as means to more romantic expressive ends, it is, more important for them to understand the formal implications of technological systems, and the possibility for the convergences, overlaps, and tensions between technical agendas and other architectural intentions.
The class intends for designers to be able to create a building as a light fixture, a building as a heat exchanger, a building as an energy storage system, as catchment system, and ideally as ecosystem (1).

Within the life-span of buildings built today, many of the energy sources for buildings will be substantially depleted. Thus, today’s new buildings will be required to primarily run on finite renewable energy. It follows that passively designed architecture will have to do most of the work, while still offering opportunities for delight and affection.

5. TEACHING STRATEGIES

5.1 The Ecological Paradigm

Rapid cultural, environmental, and technical changes are presently occurring. While most indicators of environmental quality are falling, public values are shifting strongly toward increasing responsibility for ecological health. Architectural theory and practice are rapidly evolving to address these changes. Yet, architectural education has not achieved a successful integration of ecological principles with design principles. It has been suggested that the move away from modernism reflects a philosophical shift from a dualistic, mechanistic, reductionistic, industrial-centered world view to a more comprehensive, integrated, systems-oriented paradigm. In architecture, this move away from modernism has created a fragmented multiplicity of architectural and urban theories. Ecology can serve as a theoretical framework to integrate the pluralism of contemporary architectural theory.

5.2 Thematic and Temporal Organization

Contrary to lecture course tradition, the concepts in this course are not approached topically, but rather several topics are addressed simultaneously. For instance, building organization patterns are introduced for heating, cooling, and lighting at the same time. Scale and phase of design process are used to organize the material. Precision and sophistication of design tools for energy and environmental concerns are matched to the phases of a design process (i.e., quick rough tools for schematic design).

5.3 Focus on Design Strategies and Tools

The overriding theme of lectures is the relationship between environmental forces, energy, and form. A generative language of typological strategies at a range of scales is presented. Precedents and examples are used generously, from both vernacular and contemporary, U.S. and foreign sources. Tools and easily replicable methods are taught, focusing on rule-of-thumb schematic level tools that allow rapid exploration. Tools are used generatively, to help form concepts; analytically, to understand the problem and its context; and evaluatively, to assess performance.

5.4 Learning about Energy While Learning to Design

For designers to retain a deep understanding of energy and environmental issues, they must learn about them in the process of learning to design. Lectures and projects are organized to parallel the design process, with emphasis on the architectural implications of technological systems. The course presents design strategies and design methods that are accessible to students in the design process. Lecture material is design-oriented. Students use their studio projects as the vehicle for all course assignments, thus taking the course, “out of the lecture hall.”

5.5 Hierarchy of Decisions

Site and building design must be considered integrally with environmental control decisions. Further, there is an important hierarchy of environmental control decisions by design phase, degree of impact on building form, and degree of impact on energy use and environmental quality. An awareness of the real limits of natural resources and the temporal magnitude of building and urban design decisions, or what I call “natural realism,” dictates that environmental control system design decisions are not made in a value hierarchy of: 1) conservation, 2) passive, 3) hybrid, 4) active site-based, and 4) conventional mechanical.

6. STUDENT WORK

Students are assigned six projects (see Fig. 2) in a fifteen week semester:

1) Climate as Context: Bioclimatic Analysis and Design Strategies: The objectives are to understand the site resources of sun, wind, and light; to understand the climate, in terms of cycles of
temperature and humidity, and to select appropriate generic design strategies in response to climate and site. The software, "Climate Consultant," is used (2). Its main advantage for architects is the ability to visualize climate data in hundreds of ways, thus facilitating pattern recognition.

2) In a Particular Place: Site Design: Using a site model, a sun peg chart, and graphic wind flow exploration, students determine the best place on the site to build, in relation to patterns of sun, shade, and wind (3). See Fig. 3.

3) Thermal Beginnings: Pre-form Diagrams: This is a short programming and schematic design exercise looking at thermal zoning, migration, hierarchical groupings, and orientation. Students develop a graphic presentation that communicates and summarizes their reading of the schematic design opportunity and possibilities for each major space, considering thermal, luminous, and hydrological issues.

4) Form and Substance: Schematic Design: In this exercise, a schematic design is developed, using qualitative and conceptual approaches, working simultaneously with passive solar heating, natural ventilation, daylighting, and water. Emphasis is on visualizing by graphic means the flows of water, wind, heat, air, and light as dynamic forces in the building.

5) Energy Scheming: Iterative Design With a Computer: In this assignment, the schematic design is evaluated for its energy and lighting performance using the software Energy Scheming (4). As graphically summarized in Fig. 5, students set their own goals for lighting and energy performance and then use the software, in iterative cycles of design and analysis, to meet their goals, while also meeting their architectural and aesthetic agenda.

7. RESULTS
I have taught this course for four years; I now have some degree of comparative results using different methods, albeit from my own subjective perspective.

Students clearly learned fundamentals of energy design and were able to reduce the projected energy use of their design. Each student had a scheme for heating, a scheme for cooling, and a scheme for lighting. The simultaneous treatment of heating, cooling, and lighting seemed to give student a better grasp of the relationships between different thermal issues (i.e., daylighting, cooling load, and electrical use) than when I have treated them sequentially.

Use of Energy Scheming, more than with hand methods, helped students understand the relative impact of different elements of energy use. Additionally, it helped students to understand daily cyclical patterns and seasonal difference in building performance. Many students used computers for the first time. Students are "pushed" by the requirements of the software toward "complete" solutions at each stage of design. They were anxi-
<table>
<thead>
<tr>
<th>Monday</th>
<th>Wednesday</th>
<th>Projects/Lab</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>22 Aug</td>
<td>24 Aug</td>
</tr>
<tr>
<td>2</td>
<td>29 Aug</td>
<td>31 Aug</td>
</tr>
<tr>
<td>3</td>
<td>Labor Day</td>
<td>7 Sep</td>
</tr>
<tr>
<td>4</td>
<td>Comfort and Psychrometrics</td>
<td>12 Sep</td>
</tr>
<tr>
<td>5</td>
<td>Schematic Design Strategies: Site &amp; Building Groups</td>
<td>21 Sep</td>
</tr>
<tr>
<td>6</td>
<td>Programming Issues</td>
<td>28 Sep</td>
</tr>
<tr>
<td>7</td>
<td>Bioclimatic Design Theory</td>
<td>5 Oct</td>
</tr>
<tr>
<td>8</td>
<td>Thermal Principles</td>
<td>10 Oct</td>
</tr>
<tr>
<td>9</td>
<td>Schematic Design Strategies: Building Scale</td>
<td>17 Oct</td>
</tr>
<tr>
<td>10</td>
<td>Schematic Design Strategies: Building Scale</td>
<td>24 Oct</td>
</tr>
<tr>
<td>11</td>
<td>Schematic Design Strategies: Building Scale</td>
<td>31 Oct</td>
</tr>
<tr>
<td>12</td>
<td>Schematic Performance: Tools for Heat Gain</td>
<td>7 Nov</td>
</tr>
<tr>
<td>13</td>
<td>Schematic Performance: Tools for Heat Gain</td>
<td>14 Nov</td>
</tr>
<tr>
<td>14</td>
<td>Schematic Performance: Tools for Water Design</td>
<td>21 Nov</td>
</tr>
<tr>
<td>15</td>
<td>Mechanical Systems Options</td>
<td>28 Nov</td>
</tr>
<tr>
<td>16</td>
<td>Tools for Mechanical systems</td>
<td>5 Dec</td>
</tr>
</tbody>
</table>

**Projects/Lab**

- **1) Bioclimatic Analysis and Design Strategies**
  - Film: After the Warming I
  - CLIMATE CONSULTANT: computer analysis tool
  - Activity: Bioclimatic Charts
- **2) In A Particular Place: Site Design**
  - Tools for Site Design: inventory, sun peg, wind flows
  - Activity: sun charts
- **3) Thermal Beginnings: Pre-Form Diagrams**
  - Tools for Programming: diagrams, graphic thinking
  - Activity: Thermal Diagrams
- **4) Energy Scheming Tutorial**
  - Design Process Tools: Regional Guidelines; Patterns
  - Activity: Design Process Map
- **5) Design Patterns & Diagramming Flows**
  - Schematic Performance: Tools for Daylighting
  - Activity: DF R/T
- **6) Energy Scheming**
  - Schematic Performance: Tools for Solar Heat Design
  - Activity: Solar R/T
  - Film: Mindwalk I
  - Ftijof Capra
  - Schematic Design Strategies: Mechanical Systems
  - optional HELP session

- **6-A) Energy Scheming: Input file DUE: NOV 14**
- **6-B) Energy Scheming: Iterative Evaluation I DUE: NOV 21**
- **6-C) Energy Scheming: Iterative Evaluation II DUE: DEC 5**

---

*Fig. 4 Course Syllabus*
Passive energy issues were engaged by students in their studio work (to varying degrees). This is something that has rarely happened before in our school. Enhanced dialogue with studio faculty about energy issues resulted. Energy was raised as an issue in the school. One team of students won top honors in the American Plywood Association competition for a sustainable house.

The course itself won a 1995 American Institute of Architects (AIA) Education Honor Award and a citation from the National Architectural Accreditation Board (NAAB) during a recent accreditation visit to Washington University.

Despite these successes, a variety of issues remain outstanding. Many students still exhibited a perceived split between design and technology. The inherited culture of the design school worked against students initially. By the end of the term, about half of them were able to begin to see technology as integral with design. Next year’s course will include a more explicit structural integration of the course content with studio activities.

Students at the end of the course still did not reach the level of “integrative thinking” capacity intended, raising doubts as to whether wholistic architectural systems thinking can be taught didactically. Concepts were so unfamiliar that students became overwhelmed easily. Future courses will be designed to deliver less information – in favor of time for more active learning and iteration. If possible, the course project load will be shifted to the studio arena.

Additionally, several remaining issues are outside the domain of the course. Students had significant difficulty with process graphics and with representing the non-visual, active, dynamic flows and forces, such as lighting distribution patterns, air movement paths, and the thermal qualities of spaces. Students’ familiarity with “pre-design” thinking and programming was also minimal. They retained basic stereotypes of program as a list of spaces and sizes. These issues must mostly be addressed in other areas of the curriculum, although increased studio integration may also address these issues.

7. CONCLUSION

The design of buildings and cities has a direct link to and is a contributing cause of every major environmental problem today. Architects, educators, and students are beginning to recognize this, but architectural education has repeatedly failed to graduate students who can design buildings that reduce environmental impacts. While no one course can correct the faults of the whole educational system, each course can address the current technical incompetence and ecological illiteracy of graduates. It can also address the deep cultural divisions in schools between so-called “design” and “technical” perspectives.

The continued use of a mechanistic paradigm by design schools, with its associated disconnection of technology from design and reliance on analytic methods for teaching technology, will contribute to the continued degradation of the environment by buildings. Conversely, the results of this course suggest that it is possible to adopt an ecological paradigm that incorporates multiple perspectives while substantially reducing energy used and other environmental impacts. However, it is equally clear that the embedded cultural knowledge and attitudes of the design school are powerful influences on students. If we are to create design school capable of educating students to become ecologically competent designers of regenerative human ecosystems, then the schools must become a model, a microcosmic example of both ecological design and of the living systems that sustain us.

8. REFERENCES

(2) Milne Murray, Climate Consultant, computer software, Los Angeles: UCLA School of Architecture
(3) adapted from Brown, G.Z., Sun, Wind, and Light, architectural design strategies. New York: Wiley, 1985
(4) Brown, G. Z. and Tomoko Sekiguchi, Energy Scheming 2.0, software, Eugene, OR: Univ. of Oregon
### TRADITIONAL ENERGY CURRICULUM

<table>
<thead>
<tr>
<th>Content Evolutions</th>
<th>Curricular Evolutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>• E/E issues taught as engineering/building science</td>
<td>• E/E issues taught as architectural design</td>
</tr>
<tr>
<td>• Emphasis on principles, analysis, technique</td>
<td>• Emphasis on generation of form, meaning, performance, aesthetics, human experience</td>
</tr>
<tr>
<td>• Abstract, formal beginning studies;</td>
<td>• E/E issues from beginning studio;</td>
</tr>
<tr>
<td>form separate from natural process</td>
<td>form linked to natural process</td>
</tr>
<tr>
<td>• Tecnology as applied knowledge, later stages of design</td>
<td>• Creative knowledge, engaged in early schematic design</td>
</tr>
<tr>
<td>• Technology as a discreet subject</td>
<td>• Technology considered holistically with social and aesthetic concerns</td>
</tr>
</tbody>
</table>

### Structural Evolutions

| • E/E issues as advanced material learned after basic design                        | • E/E issues as fundamental to learning to design                                      |
| • Taught by experts and specialists who have little interaction with generalist studio faculty | • Taught by teams of specialists and generalists; energy "experts" support several studio faculty. |
| • E/E content in one course, in one year of sequence; students are "loaded up" once  | • E/E content spread across several courses at various levels of curriculum; students engage material in cycles |

### Methodological Evolutions

| • Design studio and lecture separate and competitive                                | • Design studio and lecture linked and integrated                                      |
| • Formulas, reductionistic model, simple “textbook cases”                          | • Logical reasoning and critical thinking; "real-world" complexity problems            |
| • Non-visual phenomena described numerically                                        | • Graphic “visualization” of non-visual phenomena                                      |
| • Portable generalizable knowledge                                                 | • Generalizable knowledge and knowledge engaged in particular situations               |
| • Once-through process, right/wrong ansers                                          | • Reiterative revision, cycles of proposing and testing; ambiguous solutions            |
| • Literal symbols                                                                   | • Literal and presentational, or suggestive symbols                                     |
| • Passive listening: knowledge "supplied" to students                               | • Active, hands-on learning: knowledge "engaged" by student                            |
| • Detached, quantitative character                                                  | • Sensory, qualitative character with quantitative validation                         |

Fig. 1 Summary of Technical Curriculum Evolutions