POSSIBLE EVOLUTION OF TECHNOLOGY EDUCATION IN ARCHITECTURE: THE CASE OF ENERGY AND ENVIRONMENTAL ISSUES

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SETTING

The design of buildings and cities has a direct link to and is a contributing cause of every major environmental problem today. Buildings use over a third of the energy in the U.S.; consume vast quantities of finite, non-renewable resources; produce one-half of the world's CO_2 emissions (encouraging global warming), and represent one-half of the world's CFC consumption (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 building materials, poor construction practices, and poorly designed ventilation.

Architects, educators, and students recognize these issues, but *architectural education has repeatedly failed* to graduate students who can design buildings that reduce these environmental impacts. Design education has so far been incapable of addressing three problems associated with the environmental crisis: 1) technical incompetence of graduates; 2) ecological illiteracy of graduates; 3) deep cultural divisions in schools between design and technical perspectives.

CAUSES OF THE PROBLEM(S)

This paper proposes that the causes of this failure are a combination of content, structural, and methodological problems with current curricula. These include: 1) predominant use of a mechanistic paradigm; 2) disconnection of technology from design; 3) narrow reliance on scientific and analytic methods.

CONTENT: ATOMISTIC, MECHANISTIC PARADIGM

Architecture is a holistic discipline, including technical, social, and aesthetic concerns, yet the teaching of energy and environmental issues rarely engages architecture's social and aesthetic components. This is symptomatic of the dualism and reductionism of a mechanistic paradigm. The fundamental metaphor of most conventional design schools places *the individual as the basis* (manifested as the mythic creative artist) *while paradoxically employing the machine as its most important model.* For example, in many schools, visual and formal principles (harmony, balance, contrast, proportion, color theory, etc.) are taught as the fundamental introduction to design. This formality and visuality ignores ecology by limiting perception to small system boundaries: what is important is what can be seen, drawn, and frozen in time. The machine metaphor leads to a reductionistic, objectivistic, sometimes technocentric perspective that assumes unlimited resources and is founded on a blind faith in technology to solve problems. It is characterized by short time horizons.

While living systems are at every level complete interconnected webs with unique qualities of the whole, the mechanistically derived root structure of most schools and curricula can be described as one of *dualistic fragmentation.* Architecture, in this view is divided between "Design" and non-design "Other." Form, the statics of design, is able to be considered without thought of Process (flows), the dynamic forces interacting in and around form. It has become self-evident that the biosphere and its processes can not be understood fully in terms of the fragmented atomism of contemporary knowledge disciplines.

STRUCTURE: ISOLATION IN SUPPORT COURSES

Educationally, technology is disconnected from design. Technical issues are not taught as a part of learning to design but are isolated in "support" courses. Traditionally, technology has been taught in peripheral courses outside the culturally-central design studio. These courses have focused on the calculation and prediction of performance, such as heat loss or light levels. These numeric methods first require a proposed design before evaluation can be conducted, but no satisfactory *generative* methods that help designers *create* a preliminary scheme have commonly been implemented.

The design studio is, at present, without question the most important course in every architectural school. The segregation of a set of issues into a supporting, non-design, lecture course embodies a cultural message that these issues are peripheral or optional. When technical, energy, and environmental issues are not deliberately brought into the studio course by faculty, the student's model of a dualistic world of architecture is further reinforced.

METHOD: TAUGHT AS PHYSICAL SCIENCE

Educationally, technology is usually approached scientifically and analytically, rather than aesthetically or integratively. Present curricula often treat energy and environmental issues as a rationally based physical science, while design students think more associatively and relationally, like artists, poets, entrepreneurs, or social activists. Architects do not usually begin a design by thinking analytically about particular issues, such as saving energy. Instead, the early design stage is a process of conjecture or synthesis in which graphic, diagrammatic images are used to

generate and represent several ideas simultaneously. Ideas with which most architects are concerned, and thus those that drive major design decisions, are aesthetic, formal, social, experiential, and contextual, rather than purely technical.

Despite this widely accepted view of the intentions and methods of designers, methods of teaching technological issues in architectural curricula have been based on a reductionist scientific way of thinking. This analytic engineering orientation is foreign to visually and sensually oriented design students. Separating facts and values, it also does not directly address the important social concerns at the heart of the practice of architecture. Technology is commonly viewed as merely instrumental and "applied" after "design." This approach to teaching has been ineffective in fostering a deep understanding of energy and environmental concerns as a foundation for approaching architectural design.

CURRICULUM/DEVELOPMENT PRECEDENTS: INSIDE/OUT

Past curriculum development work in the area of environmental systems has focused on making quantitative methods accessible to designers and on matching the complexity of numeric tools to phases in the design process (simple tools at the beginning). The *Inside/Out* curriculum (Brown, Reynolds, Ubbelohde, 1984) was an important step in connecting quantification methods to architectural form and the process of design. However, this approach tended to interpret all of architecture through the lens of energy. It was often applied in lecture courses, rather than in studio courses. Because it was a design–oriented set of exercises, it had the effect of adding a time and attention consuming second design course (with studio-type projects) to the students' plate, and was unpopular with students and faculty when applied in this way. *Inside/Out* was released in a second edition (Brown, Haglund, et. al., 1992) as a modular set of design procedures, with much less emphasis on its use as an explicit design curriculum.

DIAGRAMMATIC LANGUAGES

Some limited work has been done on developing diagrammatic languages of passive solar heating and daylighting, but it is generally oversimplified and limiting (Franta, et. al., 1981; AIA Research Corp., 1976). Often, when used by students, these diagrams are mistakenly taken to represent the full range of possibilities. Other work has focused on very small scale decisions, such as materials selection (AIA, 1992-4), or on professional application (vs. learning to design) (Brown, 1985). Mazria (1979) published a limited set of patterns which was widely influential, but its coverage was limited to solar heating of small buildings. Few significant efforts to date have focused on making fundamental changes to the teaching of the design curriculum as a whole.

BARRIERS TO STUDIO INTEGRATION: HISTORICAL BARRIERS

Shibley (1984) in summarizing the "Architecture, Energy, and Education" project from the early 1980's identified several barriers to successful integration of energy issues into the studio. For the most part these barriers still exist:

Methodological Barriers: Traditionally, processes of "design" differ from methods for dealing with energy and environmental issues.

Structural Barriers: Academic division between studio and technical courses discourage integration.

Attitudinal Barriers: Most students and faculty believe that energy concerns are unimportant, too complex or difficult to address, or too limiting to the designer.

Informational Barriers: Faculty, educated under older models, lack the knowledge or appropriate access to knowledge about what constitutes environmentally responsible buildings.

DIVERGENT PERSPECTIVES

Lavine (1986) developed a critique of existing curricular materials that was developed for the first of a series of curriculum development workshops held by the Society of Building Science Educators. Because the design studio is the mainstay of most educational programs, the focus of the critique was the relation between the teaching of technology and the creation of architectural form. It is well understood that if support course work in technology is unable to generate sufficient linkages with design, then students regard it as unimportant, it fails to influence their education, and later, in practice, technical issues, including their design opportunity, tend to be treated as the domain of engineering consultants. Lavine proposed that the failure of architectural education to generate linkages with and influence upon design was due to: *"Design attitudes concerning technology and those concerning the generation and meaning of architectural form stem from fundamentally different perspectives."* (Lavine, 1986, p. 3) The critique identifies four fundamental dilemmas:

a) Competing views of space: buildings seen "from without," objectively, as contrasted with "space from within," utilizing the "full range of human perceptual, emotional, and intellectual powers" (Lavine, 1986, p. 4).

b) Differences in the goals of knowledge., contrasting the traditional focus of energy education on portable, generalizeable knowledge with the design studio's interest in elegant solutions to particular problems.

c) Differences in the kinds of symbols used to achieve these goals, identifying the difference between "literal symbols," meant to precisely identify a single referent, and "presentational symbols," whose meaning are dependent upon the specifics of its context.

d) Differences in the processes of learning associated with each perspective, "the application of principles," or "knowledge–in" process, as compared to a "discovery of opportunity," or "knowledge–out" process.

The conclusion of this critique is that curriculum revision is not simply a matter of switching from one model to another, but in promoting a more mature view that holds *both of these perspectives simultaneously,* examining the tensions and convergence between them.

SUCCESSION OF TWENTIETH-CENTURY CURRICULAR MODELS

Although the evolution of technical education in architecture is extremely complex, it may be helpful to think of it (even if oversimplified) as evolving, apparently irreversibly), in roughly three conceptual jumps of succession.

The earliest and simplest *elemental* approach to technical education of architects dealt with problems primarily by

examining their constituent parts analytically. Often these courses were (and sometimes still are) taught by engineers or consultant specialists, sometimes as adjunct faculty or as "service" courses in engineering departments. This historical approach, dominating for much of the century, addressed architectural technology as "building science." Courses might be titled "HVAC" or "Mechanical, Electrical, and Plumbing Systems." Technology was most often addressed as "instrumental," a (often hardware-driven) means to achieve particular practical ends. This view of technology tended to see energy and architectural issues as separate domains, to be addressed by separate professionals.

During the last decade and a half, many schools adopted a *systematic* approach that emphasized the relationship between form and energy, addressing design problems as a set of interacting sub-systems. Relationships between constituent parts and between buildings and the site forces of sun and wind occupied these educators' interests. Courses were often titled "Environmental Control Systems" or something similar. Typically, courses with this approach are taught by architects with a special interest in technology. While this approach still embraces the shared knowledge base of building science, it also began to connect technology to design by proposing that technological concerns could help *create* form, rather than merely support it.

The recent *holistic* paradigm of technical education treats buildings as whole systems. It emphasizes the interrelations between systems, and between elements and their context. Ecology is increasingly adopted as an integrative model, so that design problems are seen as complex, multi-layered fields without clear, correct answers. Technology is seen less as a separate topic and more intimately tied to social meaning, human experience, values, aesthetics, and design intentions. In this view, the duality between design and technology, between parts, wholes, and meanings, dissolves. Facts are used both to help generate and to test ideas, while being freed from determinism. Courses and design theories have expanded beyond a focus on resource conservation to include off-site impacts of design, indoor building ecology (human health issues), local site environmental impacts, and the larger urban and landscape contexts of buildings. These courses have begun to take labels such as, "Environment and Buildings," "Sustainable Building Systems," and "People, Environment, and Technology."

As our technology becomes more sophisticated and as our knowledge of both technology and ecology develops, the progression from an elemental to a systematic to a holistic approach for teaching the architectural technology of environmental systems seems to follow a directional line that few schools, if any, retrace.

THE EVOLUTIONARY MODEL

The outlines of a fourth way are beginning to emerge in the minds of a few educators across a broad range of disciplines; it can be thought of as the *evolutionary* model. If we are to create design schools capable of educating students to become technically and 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. To create such communicative and transformative educational environments, we can look to models from the natural sciences for organizing and understanding the multi-scalar, multi-spatial, dynamic nature

of complex interactive whole environments. In looking for models and analogs that help us to create symbiosis of nature and culture, the idea of evolution offers such a possibility.

The rationale of design education based on evolutionary thinking goes like this: 1) Planetary ecological health is declining, in large part due to the negative contribution of an ecologically destructive built environment; 2) Higher education in general and design education in particular are part of the problem and schools should change themselves to educate ecologically literate designers; 3) Natural systems are the definition and measure of long term sustainability and operate by the rules of the planet. If we look at how natural systems are designed and how they operate, then we will find both analogs for human systems and the principles that all life, including humans, must follow; 4) Since natural systems seem to evolve and adapt themselves to better survive, fit their environment, and keep their options open, evolutionary theory might be a good basis for understanding how our human systems might achieve the same outcomes.

Life on Earth has evolved over 4 billion years. In doing so, it represents the stored accumulated intelligence of billions of lifetimes. Evolved life is what works here. Design which ignores the intelligence of evolution is doomed to pre-mature extinction. Evolution, in traditional biological terms, "refers to change in organisms over [geologic] time" (Odum, 1989). Darwin's theory of the origin of species and their evolution is based fundamentally on the idea of *natural selection,* whereby the development of species is controlled by the survival of individuals in relationship to the stresses of their environment. Contemporary Neo-Darwinists hold that random genetic mutation and recombination's of genes in sexual reproduction are the sources of variation, while external environmental pressure is the driving force of evolution.

Organic evolution is accepted by scientists as fact, but fossil anomalies, or "missing links," have led to the development of "punctuated evolution" theories to explain "macroevolutionary leaps." Morphological change seems to occur in minor ways within a species and in more significant ways during speciation. After a new species develops, evolution shifts to fine-tuning. "Coevolution" theory was developed to explain the related evolutions of two species linked in ecological relationships, but with no genetic exchanges. To account for widespread diversity and cooperation of species for mutual benefit, the idea of "group selection" was proposed. By this theory, traits favorable to populations and communities as a whole (the public good) are maintained, and complex, mutualistic relationships develop. Postdarwinism suggests mechanisms or behaviors, beyond random mutation and selection, that act on long term evolution and are behind much of the creation of novelty, complexity, and innovation. They offer several controversial alternatives, including symbiosis, directed mutation, saltationism, and self-organization (Kelley, 1995).

Traditional notions of evolution as constant linear development are being modified, with the perspective of chaos theory, general systems theory, and the new sciences of complexity. Erich Jantsch (1975), in his book *Design for Evolution,* defined evolution as the "order of process," meaning the way in which systemic processes change over time. He extended the Nobel laureate Prigogine's (1984) concepts of "order through fluctuation" from physical and biological systems to include social, cultural, and knowledge systems, human consciousness,

and design processes. In this theory, human evolution is meaningful and important to planetary evolution as a change agent. Evolution is seen as a building up process of increasing complexity and self-organization, or negative entropy, working opposite the second law of thermodynamics.

Key elements of this emerging view (Jantsch, 1989; Jørgensen, 1992; Waldrop, 1992; Kelly, 1995; Laszlo, 1994) of evolution include the ideas that:

· Evolution is a dynamic, progressive, and far-from-equilibrium world view, rather than a mechanistic, static or equilibrium view. Systems are highly complex and thus not deterministically predictable.
· Systems evolve in self-realizing, self-balancing processes of increasing complexity, unfolding "in continuous feedback linkages to their origins," meaning that systems are evolutionarily self-regulating.
· Evolution of systems, whether social or ecological, are seen as following a natural developmental rhythm, but in uneven and nonlinear patterns.
· Technological change drives most human evolution and is, so far, irreversible.
· Technological change triggers change in the social structure in which it occurs.
· Human systems exhibit intersystem convergence (parts coordinating for higher activities) in "progressively more complex and diversified social, economic, and political systems."
· Systemic evolution progresses in "cascades of bifurcations" to increasingly higher levels of organization, structural complexity, flexibility, creativity, energy efficiency, and effective use of information.

MULTIPLE LEVELS OF PERCEPTION

According to Jantsch (1984), human systems evolution can be understood in a three level complementary structure of perception:
1. Rational (separation between subject and object)
2. Mythological (feedback between subject and object)
3. Evolutionary (union of subject and object)
Each approach can be taken to inform different aspects of the world. Each is a partial aspect of a multi-faceted unity. *All three must be taken together* for a holistic perception of reality to form.

1) At the rational level, humans see the world as objectively separate from and outside themselves. It is the abstract domain of often useful but nevertheless reductive science and has lead to the dualisms of nature/culture and mind/body. 2) The mythological approach perceives the world as a realm of systems and relationships that places humans in a subjective relationship with and as a part of the world/nature. In the mythological approach, humans understand the multiple feedback relationships and mutual adaptation of organism, society and environment. This mode of perception is the origin of existentialism, art, psychic perception, ecology, and religion. In the mythological perception, the mechanics of the rational level are given meaning and purpose, change is given direction, and artistic creativity becomes truly inventive. 3) The evolutionary approach "is marked by the dissolution of the boundaries between self and the surrounding world." (Jantsch, 1975, p. 88). In evolutionary understanding, humans are concerned with

essential actions and universal purpose. It is characterized by a perception that "our own being [is] a form of expression of an all-embracing evolution..." (Jantsch, 1975, p. 89). This is the only level which allows for anticipatory planning that is not merely an extension of observed trends.

The (future) regenerative (restoration beyond sustainability) design school would recognize the differences and limitations of each of these three classic modes of perception—and the synergy of taking them together as a trans-experiential perception. We would reconsider and redevelop our systems of knowledge, representation and communication (as traced in the preliminary outline below) to expand the limitations of the contemporary perspective, which generally attempts to use rational inquiry to describe more mythological subjective experience.

POSSIBLE EVOLUTIONS

The reader should now direct his or her attention to the tables, which summarize some of the major evolutions in technical education possible when a multi-leveled perception is employed. This format allows the introduction, within limited space, of a matrix of interrelated concepts—and the consideration of the connections between them. The tables should be considered as the central text of the paper. Major systemic properties of technical curricula are considered in three categories, successions in structure, content, and methods. Each property of technical design education is considered from the three levels of perception. *The perceptual levels are not mutually exclusive; mythological perception includes the rational level, and evolutionary perception includes all levels.*

A curriculum of wholeness requires concurrent design of structure, content, and methods. "Content" can be thought of as *what* we teach and learn. "Methods" refers to *how* we teach and learn. "Structure" is the way in which we *organize* what and how we teach and learn.

In ecological terms, content, as knowledge and experience, is the "substance" (analogous to energy or nutrients) that "flows" in the system. Similarly, methods describes the nature of the flows, their paths, and the transformation of energy, materials, and information, both within the student and the larger living systems of the school. In simple terms, methods are how design is taught, learned, and practiced as a discipline. Structure, used in this sense, includes the number, type, distribution, pattern, and relations of the system's elements (courses, curricular modules, lectures, terms, classrooms, etc.).

SUMMARY AND CONCLUSIONS

Perceiving the technical education of architects from a multi-level perspective, such as the one outlined by Jantsch and applied in this paper, offers many potential improvements for curricular design over current models. It is likely to educate more technically competent designers, graduate designers who are more ecologically literate and foster more whole academic and professional communities. When technology can be seen by faculty and communicated to students as simultaneously a matter of practical means, a source of and partner to architectural ideas, and an integrative change agent allied with living systems, then those who practice this perspective have the potential to create more elegant, profound, meaningful and