Architecture's Dysfunctional Couple: Design and Technology at the Crossroads

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Abstract: Architectural design studio pedagogy stands on the twin pillars of abstraction and defamiliarization. Students, immersed in this culture, develop a subjective artistic consciousness aligned with various evolving artistic tendencies within the profession. Technical considerations – those dealing primarily with structure, enclosure, energy/environment, life safety, and, in particular, the continuity of building control layers – are usually introduced within separate courses, and integrated with design at some point in the curriculum through comprehensive design exercises. While architecture remains both an "art" and a "science," the teaching of architecture has not caught up with radical changes in building technology that call into question the strategy of applying "technology" to designs that have been conceived and developed largely on the basis of subjective expressive goals. Architectural pedagogy prior to the twentieth century could "separate" building technology from design largely because building technology was firmly embedded within the various design vocabularies that formed the basis of an architect's education. This is no longer the case. Increasingly abstract building design objectives and increasingly subtle technical requirements have created a perfect storm of building failure in practice – a failure rooted in current architecture design pedagogy.

Introduction

In some ways, professional practice remains independent of architectural pedagogy: the requirements for contract drawings and specifications bring with them a necessary attention to detail and to aspects of reality (loads and resistance, fire safety and accessibility, zoning constraints, and so on) that are not always critiqued or even addressed within studio instruction. In fact, a case can be made that the separation of technical considerations from more abstract design concerns that typify architectural education has a rational basis that corresponds to the way technical matters are separated from design concerns in practice.[1] Nevertheless, and in spite of an ideology that supports an abstract conception of "design" as the underlying basis for architecture – whether in studio instruction or in practice – it has become increasingly clear that this strategy for designing buildings is seriously flawed, and that it leads directly to various types of building failure. This hypothesis, though not immediately self-evident, can nevertheless be tested by examining the following propositions:

1. That there have been fundamental changes in the nature of abstraction, beginning with the advent of modernism.
2. That there have been fundamental changes in the nature of architectural technology (from a reliance on "heroic" materials to a reliance on relatively delicate control layers).
3. That there are important implications for building failure when abstract design is disengaged from technological considerations, the most important of which have to do with the misapplication of – and, in particular, discontinuities in – control layers.
4. That design pedagogy generally prioritizes abstract formal experimentation over forms of expression based on an understanding of technical opportunities and constraints.
5. That there is a false symmetry between the application of "design" and "technology" in pedagogy and practice – i.e., it may appear that one can either begin with an abstract and conceptual design and then

add in "technology"; or that one can begin with a technologically-sound idea to which "design" is added – and that treating these two potential strategies for creating buildings as equally viable is intellectually flawed.

6. That there are problems reconciling a pedagogy based on design as an abstract and conceptual formal process with the practice of architecture.

Changes in the nature of abstraction

Architecture cannot be understood without reference to the notion of abstraction. We discuss buildings in terms of form, space, geometry, context, color, meaning, or anything else only to the extent that we *abstract from* the infinite qualities that are actually present in its material. Tabulating or adding up the infinite objective qualities of building elements does not get you any closer to an understanding of architecture, so abstraction is a fundamental necessity in both critiquing and producing architecture.

Understanding architecture as having a conceptual basis is the same as understanding architecture as an abstraction: a concept describes what the architecture is by abstracting from what it is not. As an example: if the concept of the Pantheon in Rome is of a sphere within a cube, such a description simultaneously abstracts from all that is not relevant to this concept – the particular qualities of each brick, stone, and concrete element from which it is constructed, the ornamentation of the exterior and interior surfaces, and so on. If a designer is unable to abstract from these useful and specific material qualities, a design concept will never emerge.[2]

That architecture has a conceptual basis does not mean that prosaic material properties and material relationships are not important. It only means that, to the extent that architecture is understood conceptually, such information is placed in a different file folder. If it is accepted that abstraction is a requirement for the appreciation, understanding, and creation of architecture, the question remains as to how all the elements abstracted from – those things placed in our metaphorical file folder – become part of the building, as they must: for one cannot build an abstraction.

Pre-modern abstraction

Up until the end of the nineteenth and the start of the twentieth century, the type of abstraction underlying architectural design was generally built upon – paradoxically – an acceptance of conventional building elements, building materials, and building construction techniques. Windows remained windows, doors remained doors, walls remained walls, and roofs remained roofs. In general, structural forces were resolved in conventional ways, construction proceeded along conventional lines, and environmental constraints on site planning, building orientation, and so forth were respected.

The conceptual basis of such architecture neither challenged, nor threatened, these prosaic elements and conventions, but was rather developed with these elements in mind. Window openings may have been elaborated or framed with Ionic columns and decorated with various ornamental forms, and the geometric organization of the facade may have abstracted from the material or constructional logic of brick, stone, or plaster surfaces from which its expression emerged, but the window was still understood as a window, and the wall was still understood as wall. That architecture took as its point of departure walls, columns, windows, and roofs was rarely questioned; Alberti and other fifteenth- to nineteenth-century architects and writers maintained a conventional and uncontroversial attitude towards such building elements even as they explored issues of architectural design and abstraction.

The origins of a more radically abstract way of understanding architecture were already present, but were not recognized as serious alternative strategies for designing buildings. Rather, examples of conceptually pure forms devoid of references to conventional building elements appear almost exclusively in works of monumental scale, expressing the most unfathomable and sublime concept of all: death. The Great Pyramid of Giza, completed in 2560 BCE, and the Cenotaph for Newton designed – but never built – by Étienne-Louis Boullée in the late eighteenth century, can be cited as precursors to the radically abstract forms characteristic of later works of architecture. However, such precedents were not considered, at the time, to be legitimate role models for non-funerary building types. Whether or not this notion of the sublime ultimately became the defining factor in modern art or architecture, as claimed by Jean-François Lyotard, is not relevant to this argument: all that matters is that the nature of abstraction changed.[3]

Modern abstraction

Architectural abstraction as a mere elaboration, or ordering, of conventional building elements began to be challenged in the late nineteenth century, and especially in the early twentieth century. While the canonical houses of twentieth-century modernism were hardly representative of domestic building, then or now, they were extraordinarily influential in creating a kind of beachhead from which radical attitudes towards abstraction could take root and ultimately become major factors in both the pedagogy and practice of architecture.

This new form of abstraction differed markedly from traditional forms of abstraction. Le Corbusier's five points of architecture describe the potential of new technologies – in particular, the replacement of loadbearing walls by a structural framework – to overcome what were considered insufferable constraints of traditional construction.[4] In many of his buildings, windows are abstracted as rectangular openings, or voids. Other conventional building elements are defamiliarized or eliminated entirely: stucco replaces clapboards as it betrays no material origin, and can be more easily understood as abstract surface; roof shingles, along with sloped roofs of any sort, are simply eliminated, as they contain such strong references to the traditional tectonic geometry of attics and gables; brick chimneys are replaced with painted metal cylindrical pipes; and all traditional ornamental or decorative embellishments are banished. The point here is not to criticize any particular aesthetic outcome, or to propose a return to any particular stylistic tendency. The key change, from the standpoint of building failure and building function, is that – for the first time – architectural abstraction was made independent of building construction and building conventions.

Changes in the nature of building technology

Many advances in building technology can be cited to explain the motivation, as well as the potential, for changes in architectural form and construction associated with modernism. Perhaps the most obvious were major improvements in the production of ferrous metals used to create structural frameworks, leading to the widespread use of standard I-beams and, later, wide-flange sections made from rolled steel. At about the same time, near the turn of the nineteenth (into the twentieth) century, reinforced concrete also became, for the first time, a viable structural material. It is hardly accidental that the formal inventions of modern architecture drew upon the structural potential of these new materials.

Other materials used in modern buildings were not particularly new, but – at least in some cases – were becoming available as mass-produced commodities. However, unlike structural frameworks that used steel or reinforced concrete to create formal typologies associated with modernism, it is not as easy to make explicit connections between these other building materials and this type of formal abstraction. Even glass, which served as a necessary bridge between the spatial ideals of modernism and the realities of enclosure, was not exactly a new material at the beginning of the twentieth century, although incremental improvements in its manufacture did permit greater experimentation with formal compositions that relied on large "voids."[5]

If structure were abstract grid (or abstract plane, in the case of load-bearing walls), and if glass were abstract void,[6] other constructional elements or materials required to complete the desired abstract compositions of modern design were harder to find. The neutral *solid* surface had to consist of something, but nothing new was available, except perhaps the mottled grey surface of reinforced concrete. More often, such surfaces were created as they had been for thousands of years – by applying a layer of stucco to an underlying substrate of brick or concrete block.

The important point is this: in spite of an abstract conception of buildings which eschewed conventional building elements and conventional material expression, modern buildings still needed to be actually and physically constructed. Moreover, modern architects had hardly given up, or gone beyond, a traditional understanding of building construction as consisting fundamentally of physical things whose value was measured as it had always been measured: by their strength, by their resistance to movement, and by their durability. Expressing such characteristics of building materials – as heroic elements that were both visible and tangible – may not always have been a formal preoccupation of modern architects, but the heroic quality of constructional elements remained for modern architects an unchallenged model for putting together, for *building*, their abstract concepts.[7]

The belief that traditional (heroic) materials constituted the basis of building construction, if not always the conceptual basis of the architecture, became increasingly untenable in the twentieth century because the underlying basis of architectural technology underwent a radical transformation. The reasons for, and results of, this transformation can be summarized as follows:

1. Steel and reinforced concrete frameworks, together with newly invented elevators, made it possible to develop tall commercial and residential buildings.
2. The obsolescence of load-bearing masonry walls in this context created both the possibility, and the incentive, for reducing the thickness and weight of cladding systems.
3. Air-conditioning as part of mechanical ventilation systems – and therefore the ability to eliminate natural ventilation – made it possible to think of the building enclosure as "skin" or "envelope" rather than as wall and window,[8] while the elimination of the requirement for natural ventilation also permitted deep floor plates and formal geometries that were no longer constrained by the need to create "rooms" with "windows."
4. The relatively high costs of mechanical air conditioning provided an incentive to develop and deploy thermal control layers (insulation) at the building perimeter.
5. Problems with failed sealant joints, condensation, polluted outside air, increasing energy costs, and water intrusion led to the conceptualization and deployment of rigorous control layers for vapor, rainwater, and air, in addition to the thermal control layer.[9]

It is important to emphasize the fact that what had previously controlled rainwater, vapor, air, and heat loss – the thick and more-or-less monolithic walls of traditional construction – were the same elements that largely defined the "architectural expression" of traditional buildings. That is, architecture grew out of, and supported, this underlying technology, just as the technology supported the architectural expression. However, while the technology of control layers migrated from the "heroic" materials of traditional architecture to the separate, optimized, and non-heroic membranes and insulative materials characteristic of contemporary construction, formal architectural design in the twentieth and early twenty-first centuries remained stuck in the paradigm of traditional and heroic material expression, not only ignoring this profound technological shift, but actually moving in directions that exacerbated problems of vapor, air, and rainwater intrusion, as well as energy efficiency.

Problems when abstraction is disengaged from technological considerations

In the new paradigm for architectural technology, four control layers need to occur consistently at the boundary between inside and outside space in order to control these four environmental factors: rainwater, vapor, air, and heat. Wherever a control layer's integrity is violated along that boundary, the potential for problems increases, in the following ways:

1. Thermal bridges (i.e., discontinuities in the thermal control layer) not only may lead to unintended heat loss or heat gain, but may also alter the temperature gradient between the outside and inside surfaces of the enclosure system, leading potentially to condensation, whether on interior surfaces, exterior surfaces, or interstitially. Such condensation may lead to structural damage, nonstructural damage, and to the growth of mold.
2. Holes or gaps in the rainwater control layer obviously increase the potential for water to enter the building in unintended ways. Water is probably the single most damaging element in buildings when not properly controlled: in its presence, wood may rot or decay, ferrous metals may rust, dissimilar metals in contact with each other may undergo galvanic corrosion, gypsum board may be damaged, mold (mildew) may grow, and so on.
3. Holes or gaps in the air control layer can increase the probability that air will move through the enclosure wall, or within the enclosure wall, in unintended ways. All sorts of negative consequences may result: in particular, energy may be lost in much greater quantities than from discontinuities in the thermal control layer, since pressure differentials between outside and inside areas can drive large amount of unconditioned air into the building (while driving large amounts of conditioned air out of the building). Such unintended patterns of air intrusion can also wreak havoc on HVAC systems, and create unexpected condensation within enclosure walls as conditioned or unconditioned humid air finds its way onto cold surfaces outside or inside the thermal control layer.

4. Where a vapor control layer is not properly configured, or where an unintended vapor control layer is created by the inappropriate use of low-permeance materials (e.g., vinyl wall coverings in air-conditioned spaces[10]), water vapor can migrate through enclosure wall assemblies, whether originating on the outside or inside of buildings, and condense on cool surfaces.

Assuming that the various control layers are properly configured with respect to each other – so that, for example, an air barrier isn't positioned within the enclosure wall assembly in such a way that it prevents water or vapor from draining or drying out – the primary task is to make these control layers *continuous*. This is not particularly easy to do: because control layers are most efficiently deployed outside the building's structural frame (so that they are not constantly interrupted by interior partitions and floor-ceiling assemblies and so that the building's structure is protected from thermal changes and other environmental damage), they must be supported by, or connected to, the building's structure in some way. Unless they are adhered to the building's structure (or to some sort of back-up surface or substrate supported by the building's structure), then their means of support (clip angles, bolts, screws, nails, etc.) invariably penetrate not only the control layer being supported, but also any control layers positioned between the control layer being supported and the structural substrate. And even if all the control layers are light enough so that they may be adhered without the use of penetrating fasteners, the outer "rain screen" cladding material – needed not only to establish some sort of architectural presence for the building, but also to protect relatively delicate control layers from various forms of damage and, in some cases, to create an air cavity or pressure-equalization chamber – still requires some sort of fastening system that invariably must penetrate the control layers it covers and protects.[11]

Roof systems require the same control layers, but have different problems to reconcile – in particular, problems with penetrations for mechanical equipment or skylights, and transitions between vertical, sloping, or horizontal surfaces.

This illustrates a fundamental contradiction in the theory of control layers, but it is a contradiction that can be largely overcome both by minimizing these inevitable penetrations, and by detailing them explicitly where they occur (e.g., at windows or other openings, penetrations, and at the fasteners themselves) to maintain the continuity of the various control layers that would otherwise be interrupted. This strategy, however, is compromised when the architectural design itself – not just the inevitable encounters with windows, penetrations, and fasteners for cladding support – has a conceptual basis rooted in the expression of discontinuity.

Such discontinuity takes many forms, and it is not the purpose of this paper to document them all, or to suggest that all contemporary architectural expression is aligned with this tendency. The important point is this: where conceptual or schematic design is understood as a process of abstraction in which formal ideas can be developed without any consideration of control layer continuity, where contemporary modes of representation can capture virtually any formal geometry, where structural and energy analysis software can provide numerical validation for the most complex and indeterminate geometric models imaginable, and where architectural culture in general, and generative design methods in particular, encourage a disjunction between formal conceits and constructional logic (Figure 1), the probability of encountering problems with control layer discontinuities dramatically increases.[12]

(a) (b)

Figure 1: Problems with control layer continuity became evident at (a) Peter Eisenman's Wexner Center for the Arts at Ohio State University (1989);[13] and at (b) Frank Gehry's Stata Center at the Massachusetts Institute of Technology (2004).[14]

Paradoxically, not only the expression of discontinuity, but also the expression of a kind of hyper-continuity can lead to control layer problems – this may occur when walls and roofs become indistinguishable from each other as morphed and flowing building enclosure surfaces turn the conventional understanding of "façade" or "roof" into quaint anachronisms. Potential problems with such hyper-continuity come about because necessary connections at vertical walls are different from those at steep-slope or low-slope roofs. Control layer penetrations that are required for fastening cladding panels may be tolerable in the vertical surface of a metal rain screen wall, for example, but may well become increasingly risky as the enclosure surface bends or curves from a vertical to a more horizontal position. The orientation of enclosure surfaces with respect to the force of gravity matters, and it is dangerous to confuse the abstract formal desire for "continuity" with the practical requirement for control layer continuity derived from building science principles.

There are, of course, other causes of building failure that are not necessarily related to control layer issues – these include problems with interior acoustics, slab cracking, veneer delamination, and indoor air quality, to name just a few. However, in analyzing the relationship between building failure and *design* pedagogy, control layers have been singled out as deserving special attention for the following reason: whereas the multiplicity of other building failures can be attributed to carelessness in detailing or construction, or to a lack of understanding of basic building science principles, or to incompetence or even greed, such problems do not generally come about because of stylistic or formal manipulations that have been nurtured and encouraged within design studio pedagogy. It is only, or primarily, at the building perimeter that such attitudes and practices lead to a higher risk of building failure, for the reasons outlined above.

Design pedagogy and the prioritizing of abstract formal experimentation

The intention here is not to conduct a systematic survey of design studio methods, intentions, and results, nor to suggest that there is a monolithic strategy evident within all studios. There is, however, a great deal of anecdotal evidence that formal abstraction, independent of serious consideration of technical/functional issues, typifies design studio pedagogy. In an analysis of the "fictions of studio design," Deamer uncovers a consistent hidden agenda at work in the beginning design studio, independent of the apparent or stated objectives: "[T]he role of form and aesthetics cannot be overlooked. No matter how smart a student's concept is, if it isn't visually appealing, no one will pay attention."[15]

A cursory look through the literature of design studio pedagogy confirms this general proposition, while reinforcing the idea that even technological considerations are subsumed within the formal ideals of modernist/postmodernist abstraction. Where an awareness of materiality, structure, tectonics, light, energy, and sustainability appear as pedagogic objectives, it is almost always within a framework predicated on obsolete building science, more often than not fatally compromised by the formal fetishizing of solid and void within a stylistically "appropriate" composition.

For example, the overwhelming majority of papers presented at the *National Conference on the Beginning Design Student* (NCBDS) in 2011 show little concern for technical or functional issues, but rather seek to introduce design students to the abstract "culture" of architecture, often also inculcating some skills related to drawing, model making, representation, and so on.[16] The formal agenda within these studios, mostly hidden, generally abstracts from all control layer considerations that might otherwise inform the design process. Only one paper of the 80 presented (labeled No. 52 in Table 1) is explicit about the importance of control layers within the design process: "The students are expected to demonstrate understanding that materials and assemblies are not merely subject to whatever form the design supposes, but that the complex layers of building assemblies – structural, thermal, protective, and expressive – are inherent in the final experience and performance of the architectural work."[17] More commonly, even where technical issues are included within the studio program, underlying formal biases compromise the outcomes.

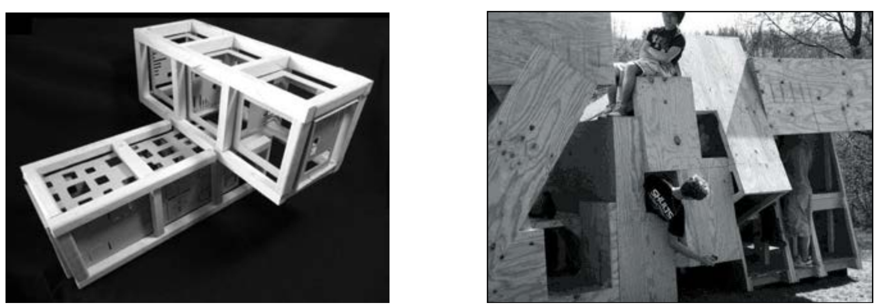
Evidence for this lack of attention to building enclosure or control layer requirements can be found by examining the 79 (out of 80) papers within which such issues are not seriously addressed. Two broad categories can be identified: first, those papers where building enclosure and control layer requirements are nowhere evident; and, second, those papers where some concern for "technical" or "environmental" integration is articulated, but where this concern does not seriously consider the importance of control layer interactions and requirements, and therefore still encourages an attitude towards design in which the probability of building failure increases.

In the first broad category, in addition to those specialized studies that make no attempt to foster any particular formal design strategy (for example, "Online / On Target: Reflective Practice through Blogging" [18]), are familiar odes to expression, feeling, invention, poetics, and abstract formal experimentation. It is not necessary to document all of the variations on this theme; the following five examples give some indication of the range of pedagogic intentions:

1. "So, we set about finding a way to teach how to see surface, how to describe surface, how to shape surface, how to record surface, and ideation in surface."[19]
2. Students are asked to "make a 2-D object (area) that exhibits a total figure-ground alternation."[20]
3. Students "were charged with a simple task—look at your body and pick an idle position as the basic value to initiate an intensive and precise mass production of drawings."[21]
4. "This paper argues that the use of analogy and metaphor offers an optimal pedagogy for introducing beginning design students to integrated thinking."[22]
5. "For pure inspiration (concept, theme), students explored the linear notions associated with a piece of instrumental music to translate into architectural space."[23]

The second broad category is of more importance, since the ideas of technology, environmental systems, sustainability, or technical integration are made explicit within the studio project. Yet even so, the design of building enclosures based on a rigorous examination of control layer issues is absent. Three aspects of this phenomenon can be identified as follows:

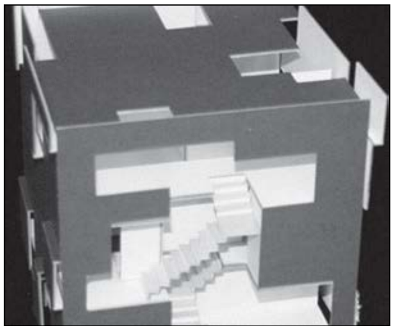
The first and most common aspect deals with a kind of materiality, detailing, or even full-scale building that, nonetheless, abstracts from actual building enclosure and control layer issues (see the16 papers labeled in Table 1 as Nos. 5, 7, 11, 12, 13, 20, 23, 32, 46, 51, 57, 59, 64, 65, 70, and 79). Whether such studios utilize detailing exercises or full-scale building (Figure 2), issues involving control layers are almost always abstracted from, in favor of explorations of formal and material expression.



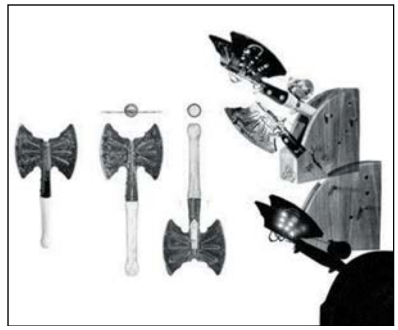
(a) (b)

Figure 2: (a) As model: The prioritization of design based on "material and dimensional realities," along with analogies to music, abstracts from issues of control layer interactions and continuity. (b) As constructed full-scale project: The expression of form and materiality takes precedence over consideration of building enclosure issues (i.e., thermal, air, rain water, and vapor control layers). *Sources: See Table 1, Paper No. 12*[24] *and Table 1, Paper No. 20*[25]

The second aspect is based on what might be characterized as a LEED-checklist-calculation approach (whether of energy use, carbon footprint, illumination levels, or other parameters). Such an approach also abstracts from building enclosure and control layer issues (see the five papers labeled in Table 1 as Nos. 16, 18, 31, 53, 69). In one project, for example (Figure 3*a*), numerical calculations demonstrating a "net-zero building" are conjoined with a formal approach to design that maintains the modernist abstractions of surface and void characteristic of control layer failure.



(a)



(b)

Figure 3. (a) An investigation leading to a design for a net-zero building still maintains the modernist abstractions characteristic of building failure. (b) Studio projects in this studio address various "sustainability" issues from an expressive standpoint, but generally abstract from technical considerations and control layer issues. *Sources: See Table 1, Paper No. 18*[26] *and Table 1, Paper No. 38.*[27]

The third aspect focuses on a view of technology that is virtually indistinguishable from that of pure expression (see the five papers labeled in Table 1 as Nos. 38, 44, 55, 62, 71). As an example (Figure 3*b*), one studio investigated found objects, searching for the poetics embedded in their form and materiality (inspired by Gaston Bachelard's concept of the imagination). This type of approach to design and technology has links to contemporary notions of sustainability and to the reuse of material resources (recommended within LEED guidelines as well as in writings by McDonough and Braungart referenced in Table 1, paper No. 38), but the studio work appears to place greatest value on the expressive qualities of the objects in relation to the students' abstract formal or psychological preferences.

Thus, it seems clear that issues of building science or environmental science are not seriously considered in the typical beginning design studio. Most often, such issues are simply ignored (53 of the 80 design studios represented in the 2011 NCBDS); otherwise, they are typically considered in a manner that abstracts from critical issues of building enclosure and control layer interaction and continuity (26 of the 80 studios). Only one of the 80 design studios represented in the 2011 NCBDS considered building enclosure and control layer issues in an explicit and serious manner.

The false symmetry of building science and formal expression

The notion that architecture is both an "art" and a "science" is widely acknowledged, even if the terms of this disjunction are debated.[28] It seems clear, even to those who value the types of abstract thinking encouraged within design studio pedagogy, that somehow – at some point – such abstractions must be reconciled with real conditions encountered when projects are actually constructed and occupied. What is less clear in such formulations are the specific aspects of "reality" which ought to be addressed, if at all, within the academic studio, and the proper means to accomplish this synthesis.

In fact, the types of "building technology" issues that might impinge upon a purely formal or expressive design pedagogy are quite numerous, and include things like structure (strength, stiffness, and efficiency); control of air, rain water, vapor, and heat at the building perimeter; fire (and other life) safety issues; energy use; production of global warming gases (carbon footprint); daylighting and electric lighting; site orientation issues (sun, wind, drainage); acoustic isolation and interior acoustic environments; toxicity of building materials; use of renewable materials and renewable (or on-site) energy; reduction or recycling of potable water and waste water; and so on.

All of these issues need not be addressed in every design studio, and some are almost never critical in terms of influencing or altering the conceptual basis for the design: that is, some "technical" issues can safely be left out of schematic design without compromising the viability of the scheme as it is further developed. For example, the ubiquitous use of electricity within buildings (at least when generated off-site) is never considered within schematic design, in spite of being perhaps the most fundamental of all the "technologies" necessary for the functioning of modern buildings. This is because buildings, no matter how they are formally configured, can accommodate panel boxes, conduit, switches, and outlets in routine ways that have almost no impact on the design concept or on a project's overall cost.

Electrical contractors, in fact, routinely run conduit from panel boxes to switches to lighting fixtures and so on based on nothing more than abstract drawings with curved arrows pointing in general directions, leaving the specific pathways for the field installer to work out; and architects routinely let electrical engineers determine the pattern of outlets, or sometimes even of lighting, well after schematic design decisions have been made. In this case, the "technology" can be "added" to the "design."

Such a model (technology added to design) is often extrapolated to encompass a much greater range of technological decisions. For example, Mohsen Mostafavi, former Dean of the College of Architecture, Art, and Planning at Cornell University, describes a comprehensive design studio project at Cornell as follows: "We asked a group of students whether, as an experiment, they would be prepared to continue working on their old project, the one they had supposedly finished, and to *take it to another level of development*" (emphasis added).[29] By "another level of development," Mostafavi means factoring in issues of building technology not ordinarily considered within the design studio. However, while it may be rational to "add" certain technologies to projects that were conceived without prior consideration of building technology issues, framing this as a general model for pedagogy or practice is both dangerous and counterproductive.

Such a strategy – "adding" technology to design – presumes a kind of symmetry between the process of abstract design and the requirements of building technology. That is, it is presumed that one can begin at either pole of the art-science duality and still end up with a viable building. But this is a false symmetry based on numerous logical errors including "a misplaced confidence in the power of science to compensate for any *a priori* design decisions."[30] In other words, some aspects of building technology are so fundamental, and also so sensitive to unusual or peculiar geometric manipulation, that their underlying logic must inform, if not precede, a schematic design process that prioritizes abstract form and expression.

Problems reconciling abstract design with technology

Of all the many technological systems that fall loosely under the umbrellas of building technology and environmental science, the most important, at least in terms of their relationship to abstract and formal design decisions, are the control layers and cladding systems that together comprise building enclosure systems, constraining in various ways the movement of air, vapor, rainwater, and heat between the outside and inside of buildings.[31] There are many specific requirements and attributes that characterize each control layer but the most fundamental – common to all four layers – is continuity. If continuity of all four control layers is maintained, and if control layers are properly configured so that, for example, materials that absorb water are able to dry out, vapor does not condense, rainwater is directed out of cavities, air leakage is limited, and heat loss is minimized, then the overwhelming majority of building failures will be prevented.

Conversely, if control layer continuity is made difficult or impossible because of formal or expressive design decisions that abstract from the underlying logic of such enclosure systems, then the probability of experiencing various types of building failure will increase. Unfortunately, many of the formal design conceits that prevail within schools of architecture (and in practice) – even and especially those that fetishize "materiality," or are based on abstract compositions of figure-ground or solid-void, or are derived from complex geometric or generative manipulations, or are otherwise governed by peculiar manipulations of site, surface, or mass – work against such continuity. Complexity and peculiarity, qualities that characterize many of these compositions, correlate strongly with various types of building failure.[32]

Objections to the argument

While the idea that architectural design pedagogy is complicit in the epidemic of building failure within the U.S. may be inescapable, it is hardly self-evident. An examination of several potential objections follows:

Objection 1: There really is no epidemic of building failure in the U.S. It is, in fact, difficult to find systematic documentation of building failure within U.S. practice. Owners, developers, manufacturers, contractors, and architects are not required to submit information about roof leaks, curtain wall failures, slab cracking, and so on, to any central database. On the contrary, there are enormous disincentives to provide this information to interested researchers. Manufacturers are not inclined to publicize defective materials or systems; architects are not inclined to publicize defective buildings; and contractors are not inclined to publicize unsatisfactory work. We are left with anecdotal observations, small-scale studies, or evidence revealed through class-action lawsuits (e.g., of EIFS failures in North Carolina[33]). Nevertheless, the prevailing wisdom is that such nonstructural building failures are extremely common,[34] and that the overwhelming majority of such problems – at least those that result in litigation – are related to control layer failure.

Objection 2: Being adventurous with design and detailing actually "pushes the envelope" and ends up improving the technology of building enclosure. There is some truth to this objection. The history of architecture is filled with stories of building failure that led to improvements in the prevailing technology. For example, lacking numerical modeling programs, medieval builders often "pushed the envelope" of Gothic construction to the point where some large structures actually collapsed, most famously the Cathédrale Saint-Pierre de Beauvais in 1284. Lessons learned from these failures led to improvements in the construction of *subsequent* buildings. A more recent example concerns the curtain wall designed for the Hancock Tower in Boston (1976) by I.M. Pei and Partners; the use of a traditional lead solder with an unexpectedly strong adhesion to reflective coatings on the unusually large glazing panels led to fatigue cracking and, ultimately, to the replacement of more than 10,000 glass lites. William LeMessurier, one of several engineers who examined the building (thinking, at the time, that the glass failure might have been triggered by structural deflection) claimed that this failure "spawned a whole new profession of skin consultants" while also leading to the growth of the "science of wind tunnel investigation and surface forces...[and to] an enormous amount of academic interest in more refined structural analysis..."[35]

Where resources and expertise are available, this type of investigation and research can *precede* the construction of a building, and can result in new products, systems, or formal geometries.[36] However, such research expertise and monetary resources are hardly typical for ordinary, or even for extraordinary, building projects. To embark on uncertain terrain – to push the envelope – without having the expertise or resources to thoroughly model and test any such unprecedented construction materials, methods, products, systems, or geometries, is simply asking for trouble (i.e., increasing the probability of failure).

Objection 3: There is nothing inherently dangerous about formal manipulation even when it transcends the bounds of conventional, or ordinary, building design. Drawing a line, whether with a pencil or with the most sophisticated modeling software, is a seductive act: like the sculptor Pygmalion, students and practitioners seek to breathe life into their abstract representations. Yet transforming even the simplest lines into real material constructions may pose enormous difficulties. For example, a large number of building products are formed, molded, or extruded into flat or linear elements. Some, like symmetrical steel sections or drywall panels, can be bent into curved forms, at least within certain limits. Yet other products must remain as they were initially formed, and resist efforts to bend them into shapes that are so easily represented on paper (or in digital models). Curving a piece of rigid polystyrene or even a corner bead intended for the edge of a curved gypsum board partition is difficult. Yes, it is possible to find a way, but this often involves a great deal of research and experimentation (while the resulting construction processes may involve greater costs) that are not always factored into the design process. And that is the point: unless a student (or practitioner) has the time and expertise to conduct such research or experimentation, the abstract line will eventually confront an obstinate and unsympathetic reality; and in such confrontations, reality will always prevail.

Complex or peculiar geometries compound such problems and create additional ones, simply by proliferating the number of unique and idiosyncratic intersections with the potential to wreak havoc on control layer continuity (Figure 4). As before, a thorough and exhaustive detailing exercise can overcome some, but not all, of these problems: just the act of multiplying the number of material intersections and joints increases the probability of building failure.

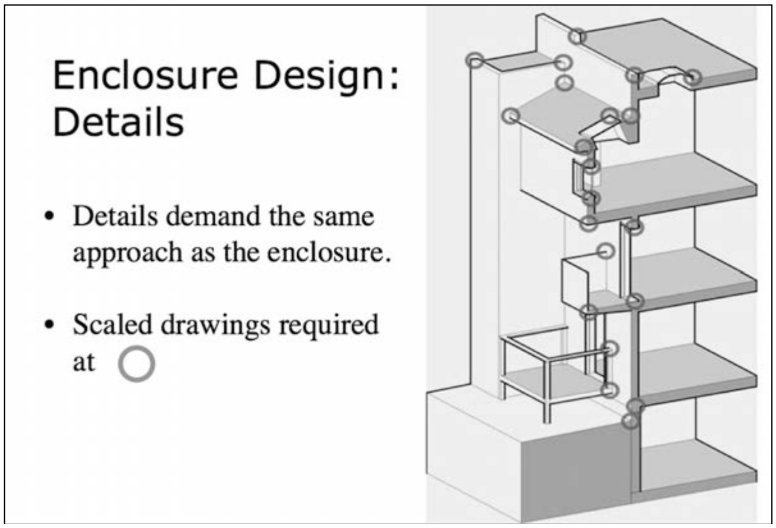


Figure 4: Continuity of control layers is relatively easy to keep track of and document with simple geometries; the same level of attention needs to be given to peculiar or complex buildings. *Source: Presentation slide 37 from: Joseph Lstiburek, "Adventures in Building Science," www.buildingscience.com, at http://eetd.lbl.gov/dls/pdf/dls-lstiburek-10-01-10.pdf (accessed Nov. 7, 2013)*

Objection 4: Problems with building enclosure are not the fault of the enclosure design, but rather the fault of sloppy construction practices. It may be true that some instances of building failure are the result of construction practices rather than inherent in the design of the building. Even so, it is clear that faulty design is often the cause of failure: "According to the insurer CNA/Schinnerer, each year between 1994 and 2005 there were between 15 and 21 professional liability claims filed for every 100 [architectural] firms."[37] Even if only a fraction of those claims had merit, it points to a serious problem, especially since many additional nonstructural building failures are resolved without recourse to litigation.

It is also true that the culture of competition and the contractual basis for compensation may lead some contractors in the U.S. (at least those operating under standard owner-contractor agreements based on a stipulated sum) to cut corners in order to increase their profits. On the other hand – especially in other countries, operating with different traditions, different project-delivery systems, and different cultural expectations – it may be possible to rely more on contractor expertise and conscientiousness to overcome defects, or complexities, in the design documentation. Yet this just means that the attention paid to detailing and designing, especially as it relates to control layer issues, is split between the architect and other players in the construction process: the need for serious consideration of such issues hasn't mysteriously disappeared. In the U.S., or in any culture where the architect is ultimately responsible for proper consideration of control layer issues, abstracting from such issues within the educational program remains counterproductive and dangerous.

There is a variant on this theme: because some complex designs avoid control layer problems while some ordinary designs experience such problems, then why bother making any special effort to control such apparently random results? Moreover, given this "evidence," isn't it really unfair to blame nonstructural failure on the complexity or peculiarity of the design itself? A similar argument is commonly used to justify all types of risky behavior, and reflects an inability or unwillingness to examine well-defined random events from a probabilistic standpoint. In other words, while any individual building may defy the odds and avoid nonstructural failure in spite of its complexity or peculiarity, the overall incidence, and costs, of building enclosure failure will increase. Encouraging a design process that abstracts from, or increases the difficulty of, control layer continuity contributes to the epidemic of nonstructural building failure.

Objection 5: It's no big deal if a few buildings leak – better to live in a world with formal design freedom (even if accompanied by various forms of building failure) then in a dull, repetitive world where everything functions properly. This attitude, at its most extreme, can be found in the "client's response" to Peter Eisenman's House VI, a building constructed in Cornwall, Connecticut in the mid 1970s. By 1980, the homeowner writes, "...physical problems with the house caused a hiatus. As I mentioned, from the beginning we had problems with leakage, and by 1980 they had become serious. We had often asked Eisenman to help us in this regard, but he backed away from our pleas... I think he also mistakenly considered such problems to be beneath his interests. [My husband] called in a local builder to put a sloping roof over the back door at the south and the living room at the west, where leakage was worst... Eisenman spread the word to the architectural community about how his clients had spoiled the lines of his design. Probably as a result of this, Martin Filler, who was then architectural editor of *House and Garden*, in his article on Eisenman's polemical houses... questioned whether this was an act of cultural vandalism."[38]

There is some truth, and a number of fallacies, in the argument that accepting and applying principles of building science within the design process prevents a designer from heroically pursuing an avant-garde agenda – what for Eisenman in the context of his House VI involved "inverting the accepted canon" of spatial strategies.[39] The truth is that such considerations do constrain design freedom. A "paper" architecture conceived without gravity, for example, will surely be frustrated when confronted with the reality of, and requirements for, vertical equilibrium.

Yet it is equally true that the constraints brought about by what might be termed "reality" – not only gravity, but also the necessary control of air, vapor, rainwater, and heat at the building's perimeter – can be reconciled with a desire to create new architectural forms of expression. Yes, freedom is constrained, but it is not entirely destroyed. The problem is that in a world of architectural production driven by competition,[40] any logical constraint on a designer's freedom of expression leads the designer – perversely but inevitably – to explore precisely those forbidden places outlawed by prevailing conventions. In defying such logic, the designer seeks to "defamiliarize" what has become so commonplace that it is no longer capable of eliciting an aesthetic response and, therefore, serving as a useful mode of competition.[41] This is the heroic conceit of the contemporary avant-garde: to confront "danger" in whichever of its manifestations appears as an appropriate target at any given point in time.

Joseph Campbell abstracts from the culture of competition that motivates artists to embark on such counterproductive heroic journeys, seeing only the mythical and idealized shell of heroism in such attempts: "Artists are magical helpers. Evoking symbols and motifs that connect us to our deeper selves, they can help us along the heroic journey of our own lives... Over and over again, you are called to the realm of adventure, you are called to new horizons. Each time, there is the same problem: do I dare? And then if you do dare, the dangers are there, and the help also, and the fulfillment or the fiasco. There's always the possibility of a fiasco. But there's also the possibility of bliss."[42]

Ironically, an inattention to building science is – precisely – what this version of heroism entails. The architect (*qua* artist) is not so much "help[ing] us along the heroic journey of our own lives" but rather creating, out of thin air, a heroic journey for herself: leaving the world of safe, predictable constructions; proposing buildings that have both the appearance and the reality of danger (where danger comes from challenging conventional notions of aesthetic, and sometimes literal, comfort; challenging class-based conventions regarding economy of means; and especially, challenging forces of nature such as gravity, or rain, or snow); and returning in glory after having confronted the agents of conformity (whether owners, users, public officials, etc.). For such a hero, having proposed, or built, such a brave thing with all the attendant risks of failure is a badge of honor.[43]

Conclusion

The argument propounded here – that changes in the nature of both abstraction and building technology have contributed to a virtual epidemic of nonstructural building failure in which design studio pedagogy is complicit – is not entirely convincing, in part because it relies on probabilistic reasoning rather than on some definitively causal smoking gun.

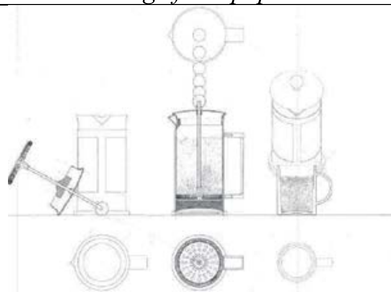
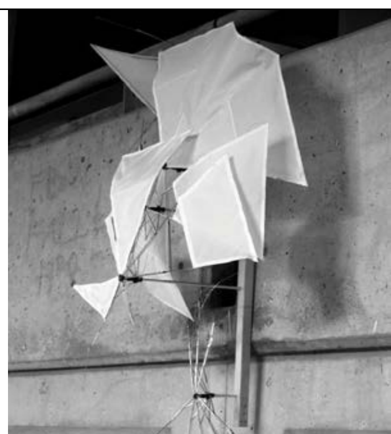
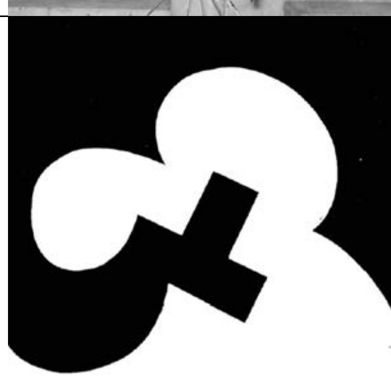
Moreover, the alleged problem and its causes remain largely invisible. Even well publicized instances of nonstructural building failure can be easily dismissed as exceptional cases, pointing not to a general crisis but only to the hubris of a few architectural superstars. The bulk of evidence that might otherwise point to a bigger problem is largely unavailable, and so cannot be systematically compiled and analyzed.

In addition, architectural critics, educated primarily in the history and connoisseurship of culture and form, can be counted on neither to understand architecture from the standpoint of building science, nor to challenge it on that basis. They tend, therefore, to lend support to a mode of education and practice that reinforces their own educated prejudices.

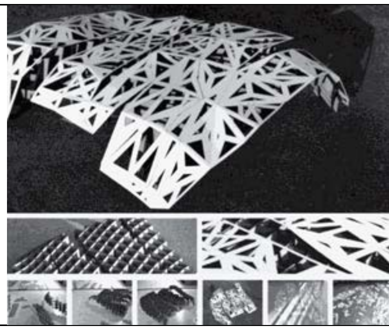
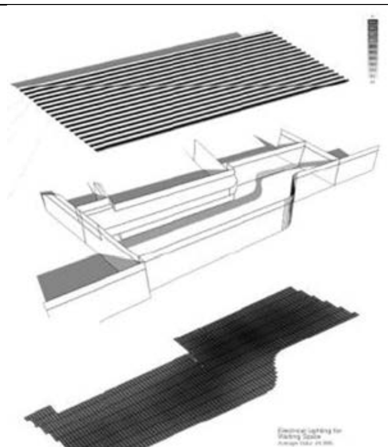
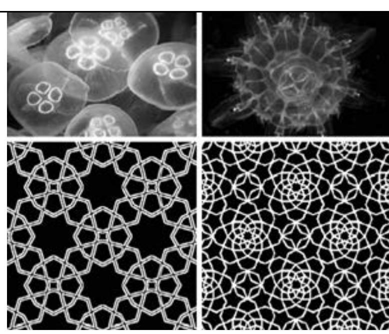
Control layers are fundamental to the functionality of buildings. Because the probability of control layer failure is directly correlated with the proliferation of discontinuities in both geometry and material that are characteristic of complex and peculiar designs; and because the education of architects (reflecting and enabling the intense competition among practicing architects for recognition based upon increasingly complex and peculiar formal manipulation) often abstracts from the underlying logic of control layer design, one can conclude that *architectural design pedagogy is complicit in the epidemic of building failure within the U.S.*[44]

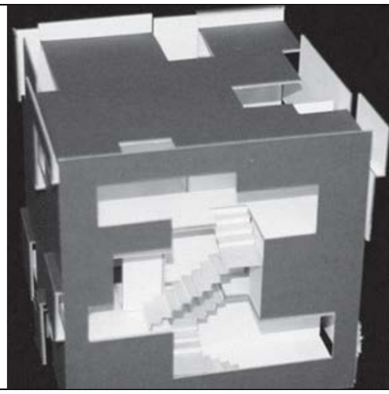
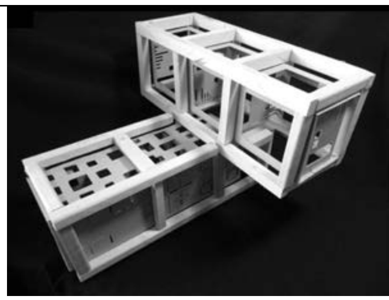
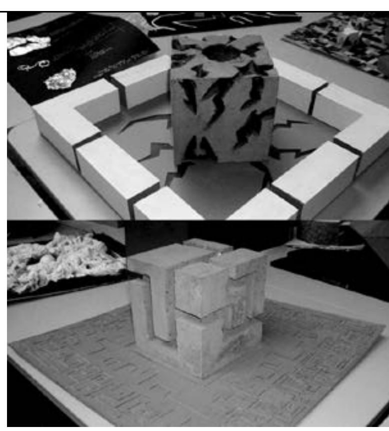
Hannes Meyer famously attempted to devalue the role of the artist while emphasizing functional and technological issues within the curriculum of the Bauhaus. Such an extreme formulation of the art-science duality is only marginally relevant to the argument advanced in this paper, since there is no reason to "abolish" or even to denigrate the role of artistic expression within the design process. Even if "the idea of the 'composition of a dock' is enough to make a cat laugh,"[45] such a finding (*and I'm purposely taking this quotation literally*) should not be extrapolated into the realm of human cognition. We construct – and in doing so, *compose* – our world irrespective of any desire, however rational, to prioritize function and technology. The question isn't whether art should be eliminated from architecture – art is unavoidable; the only question considered herein is whether and how the art of architecture can adjust its trajectory so that it aligns itself with the most fundamental requirements of building science.

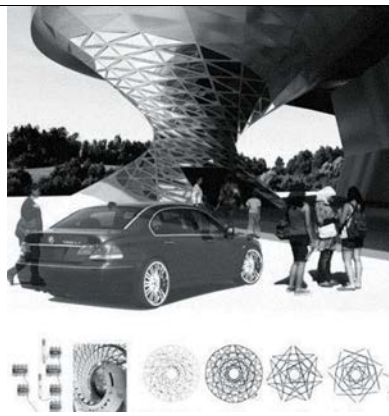
Table 1: Papers from NCBDS 27 (2011)[46]

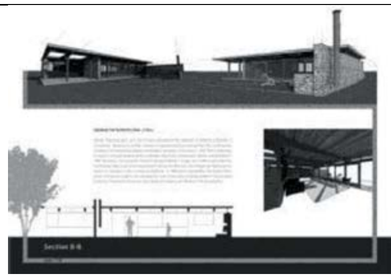
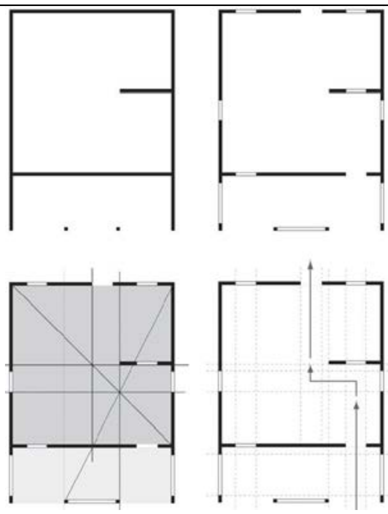
No.	*Selected image from paper*	*Quote from paper*	*Comments*
1		This project "empowers each student with a method of unveiling an object's intentionality through the precision of orthographic drawing... close observation, analytical thinking, and orthographic drawing – make it inherently valuable as an introductory assignment."	Encourages an attitude toward "analysis" that abstracts from technical considerations.
2		"So, we set about finding a way to teach how to see surface, how to describe surface, how to shape surface, how to record surface, and ideation in surface."	Encourages an attitude about surface and form that abstracts from technical considerations relevant to building surfaces.
3	Unavailable in PDF form		
4	No image; abstract only	"This paper proposes that the beginning design community does not yet know itself properly as a discipline."	Unable to comment, as the paper itself is unavailable in the proceedings.
5		Describes "an experiment that put materials, tools, and ideas directly into the hands of first-year students before a traditional pedagogy would dictate that they are 'ready' for the experience."	Exploration of materials and joints tends to focus on expression and structure, but abstracts from technical considerations relevant to building enclosure.
6		Students are asked to "make a 2-D object (area) that exhibits a total figure-ground alternation. When your instructor and classmates look at your finished surface they should see "ground" as figure as well as "figure" as figure."	Not directly relevant to the question of teaching building technology.

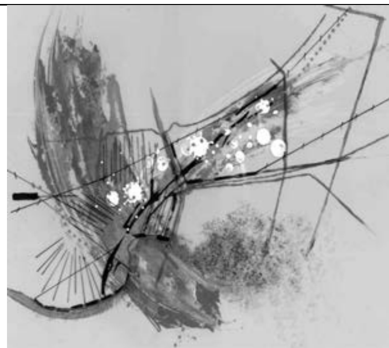
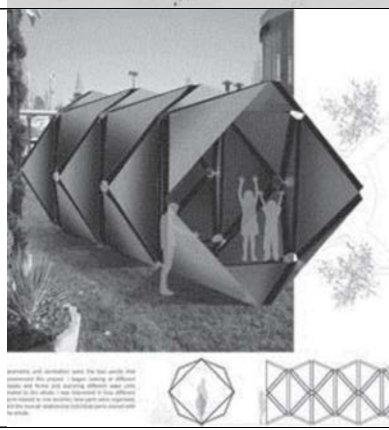
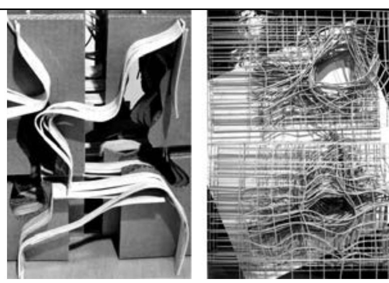
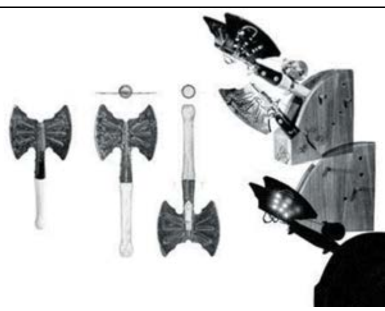
7		"Critical to the success of the studio was the development of a culture where architectural design and building technology were understood as complementary, rather than dichotomous... the separation of the posts expresses the sense of enclosure of the thick walls as well as the 'freedom' of the thin walls."	Technology is examined for its heroic and expressive potential; there does not seem to be a serious examination of important control layer issues.
8	No student work illustrated.	"This paper explores the concept of Integrated Design by considering it broadly as a form of practice while noting fundamental explorations that foster an awareness of the extents of relationships established by design."	Not directly relevant to the question of teaching building technology.
9	No student work illustrated.	"Integration of technical topics into studio is a goal of our college... Architectural practices, in their quest to design higher performing buildings, are integrating technical requirements earlier and earlier in the design process."	An interest in integrating technology and design is articulated, but the specific content is not discussed.
10	No student work illustrated.	"While tedious, all of these contractual relationships [e.g., architect-owner, etc.] have tremendous impact on design."	Not directly relevant to the question of teaching building technology.
11		"The contradictions between self-creation and client community should be seen as the productive working space between private and public ideals." The "trailhead" project shown "was a fairly straight-forward, orthodox project, built as a sign-board for the community at the edge of a parking lot and the start of a sidewalk"	Community-design work doesn't seem to engage questions of control layer continuity.
12		"...early design studies are developed into full-scale projects that effectively integrate structural and environmentally driven concerns with architectural design."	Built projects abstract from building enclosure (control layer) considerations.
13		"...the act of drawing, making, building is inherently about a material based set of decisions. Unfortunately, the design process as taught is often considered a composition of formal complexity and cultural conditioning, prior to, or devoid of, material specificity."	An interest in integrating technology and design is articulated, but actual design projects are either free-standing (interior) objects, or else they abstract from considerations

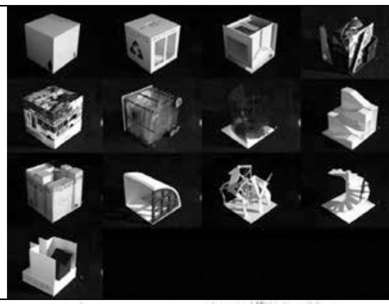
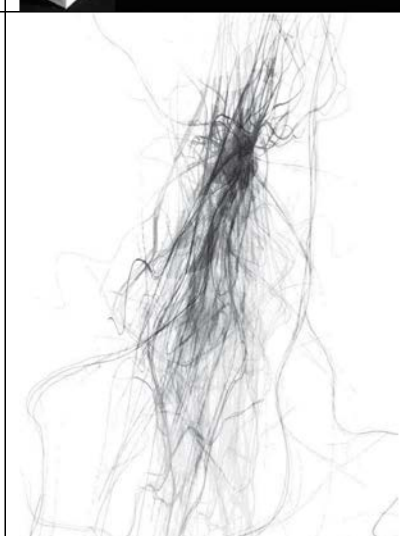
			of control layer issues, focusing instead of structure.
14		First, "... students were charged with a simple task -- look at your body and pick an idle position as the basic value to initiate an intensive and precise mass production of drawings." Next, they were asked to " produce clear and instructive flow charts in order to detail a process of motion using configurations that could yield alternate outcomes."	Encourages an attitude about formal manipulation that abstracts from considerations of control layer issues.
15	No student work illustrated.	"By its very nature, an integrated design pedagogy will emphasize the interactions among the technical systems, connecting otherwise discrete bits of information to form a coherent whole."	Talks about the ideals of technological integration, but offers no specific insights into how current models of "technology" lead to non-structural failure.
16		"The paper will focus on the integration of course content during this consolidated second year of curriculum... With this simple designation of project focus (façade, plan, section and structure) we believe we have established a mechanism for securing faculty involvement across courses and competent student work that begins to integrate thinking across courses."	Design studies are integrated with lighting and energy evaluations, but there seems to no systematic analysis of control layer issues.
17		"...analogy and metaphor play two different roles in the design process. Whereas analogy is commonly used as a tool for concept generation and problem solving, metaphor is used, in the early design phases, for framing and defining design problems... This paper argues that the use of analogy and metaphor offers an optimal pedagogy for introducing beginning design students to integrated thinking."	Encourages use of metaphor and analogy, based on natural systems, but draws no useful conclusions about control layers.

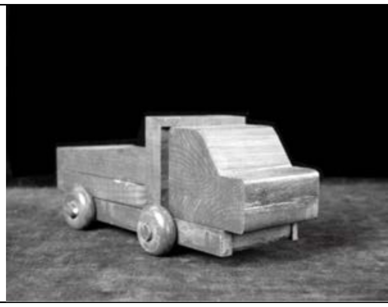
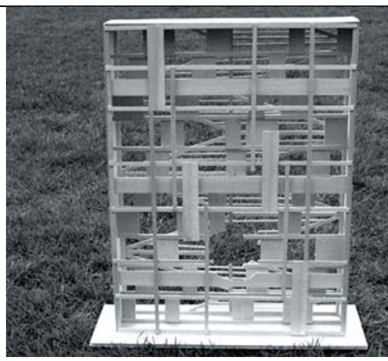
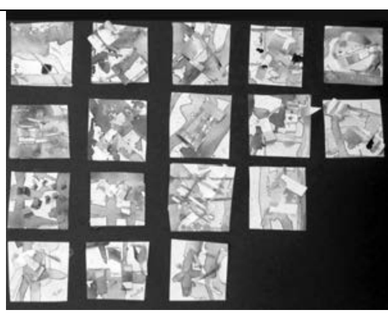
18		"By teaching how energy use is related to architectural form, space and order, students were able to design a simple building that eliminated the need to use fossil fuel for heating and cooling in a Midwestern United States climate."	The image shows that the investigation leading to a design for a net-zero building still maintains the modernist abstractions characteristic of building failure.
19	No student work illustrated.	"I designed a humanities module at AUW to engage students in learning and to generate interest in visuals, arts, and culture."	Not directly relevant to the question of teaching building technology.
20		"Restricting form language to include all elements meeting at 90, 180, and 270 degrees, students learned to prioritize and shape their design ideas given material and dimensional realities. For pure inspiration (concept, theme), students explored the linear notions associated with a piece of instrumental music to translate into architectural space."	Encourages an attitude towards structure, modularity, and analogy (i.e., to music) that abstracts from issues of control layer continuity.
21	No student work illustrated.	"A recently redesigned First Year Program...places color in the context of culture, environment, and dimension."	Not directly relevant to the question of teaching building technology.
22	No student work illustrated.	"Blogging in electronic portfolios can contribute to architectural education by strengthening reflection, communication, contextualization and collaboration."	Not directly relevant to the question of teaching building technology.
23		"Through architectural design, we re-enact Primeval cosmogony. We make order, we shape space, and we regulate and differentiate movement out of space – out of amorphous chaos. The Primeval act of creation has never left us as a problem of design. The issues that confronted Ancient man are still the issues that confront us... The task involved casting a concrete block about 8 inches cube, using whatever their imagination and written narrative allowed to intervene with the supplied timber formwork."	Deals with materials in a literal way, but otherwise does not seem directly relevant to building technology and the central importance of control layers.
24	No student work illustrated.	"I sit down with my students and ask them to rhyme blue. They answer with words like grew, shoe, true. I respond “no.”	Not directly relevant to the question of teaching building technology.
25	No student work illustrated.	"What if designers simply began with	Not directly relevant

		writing as a brainstorming method of distilling observations, necessities, and project goals?"	to the question of teaching building technology.
26	No student work illustrated.	"I want to thank you for the course…I never had any understanding there were ideas behind buildings- Psychology major's comment"	Not directly relevant to the question of teaching building technology.
27	No student work illustrated.	"I developed a course in which students used writing as an integral component of the design process."	Not directly relevant to the question of teaching building technology.
28		"This paper sought to disseminate the pedagogical goals of the 'communications' stream..." Various classes are described: raster vs. vector; relevant software applications; BIM, Grasshopper, etc.	The paper suggests that courses in building technology should be more "digitally" fluent. However, as the author is teaching in the Communications stream, the projects he describes do not address specific building technology, or control layer, issues.
29		"To inquire possibilities of space-making and formmaking through the notion of folding as an avenue for a designer in architectural design processes seems to be on the rise in the last decade... Instilling the idea of discovery in design or exploring unknown qualities of fold as a strategy of form-making in the beginning studios remains the focus of this paper."	Encourages an attitude toward "form-making" that abstracts from technical considerations.
30		"Although collage and found objects were used well before the beginning of the 20th century, they came into significant exposure through the Cubist movement and more specifically through the work of Pablo Picasso... This project begins with a photography exercise where students are challenged to capture shadows in the built environment with the camera, purposely excluding the object making the shadow."	The image shows a project made from playing cards (found objects). This encourages an attitude toward "form-making" that abstracts from technical considerations.

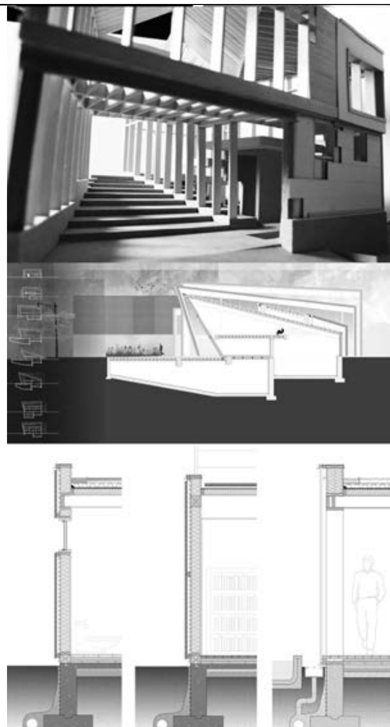
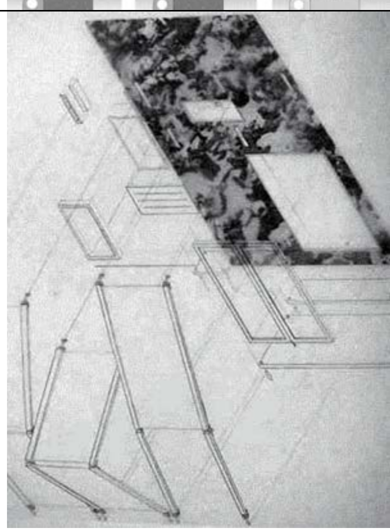
31	No student work illustrated.	"A shift to a thermodynamic architecture, or an architectural project that does not place in the foreground tectonic issues requires a rethinking of design and design pedagogy... With a quick download from Autodesk, a student can use Vasari to quickly make mass model and perform a conceptual energy analysis..."	Describes an effort to coordinate design studio with other "support" courses. Software for energy analysis or lighting does not necessarily lead to a serious consideration of control layer strategies.
32		"Through a collaborative effort... students gain access to and can examine primary source materials (original hand-drawn plans, sketches, and project correspondence, etc.), and they use these artifacts as a basis for their digital models and drawings... The act of drawing or modeling the house becomes the vehicle for learning software as well as some essential lessons in architectural composition, building components, structural organization, material expression and appropriateness, and building-to-site relationships."	The image shows a student's re drawing or re-modeling of an archival work. It is unlikely that a serious understanding of control layer issues will emerge from such studies.
33		"What we wish to get at are some of the underlying visual principles and intellectual attitudes that underwrite architectural diagrams."	The image may or may not be an example of student work; it illustrates diagram types: "plan drawing, reduced drawing, abstraction, and drawing with overlay." While diagrams may be quite useful in representing issues of control layer continuity and so on, it does not appear that these issues were addressed in the paper.

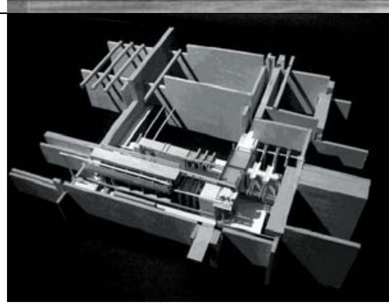
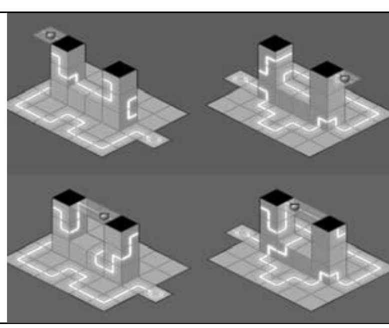
34		Discusses "synthesis as a viable means to merge disparate ideas, taking raw thoughts and creating a new type of amalgam...This amalgamation is at the very root of design, and consistently becomes the most valid basis for the emergence of form in architectural design."	Encourages an attitude toward "form-making" that abstracts from technical considerations.
35		"Beginning design studios are the ideal place, a breeding ground of sorts, for introducing such complex ideologies and developing programs needed for a new generation of designers that will be able to seek solutions from information processing or reasoning, rather than intuition... The approach injects the basic fundamentals of parametric thinking in order to find generative tectonic results."	Encourages an attitude toward "form-making" that abstracts from important technical considerations, at least in this case.
36	No student work illustrated.	"...this paper proposes a framework of principles to guide the activity of drawing in the context of collaborative groups — a key element in meeting the challenges of sustainability."	Not directly relevant to the question of teaching building technology.
37		"The beginning design course, outlined below, attempts to place the student squarely in the experience of gaining knowledge while simultaneously opening up unknown territory. Proceeding from the premise that the natural world (landscape) is fundamental to our perceptions of our spatial world, our first studios are conducted in a forest."	Encourages an attitude toward "form-making" that abstracts from technical considerations.
38		"It is in the joining of the formal and material where a sustainable imagination is developed, where complexity enriches rather than bewilders."	The studio projects described in this paper address various "sustainability" issues from an expressive standpoint, but generally abstracts from technical considerations and control layer issues.

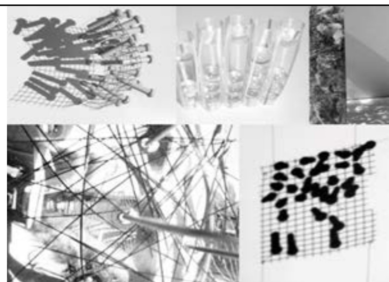
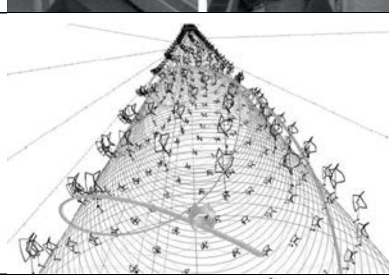
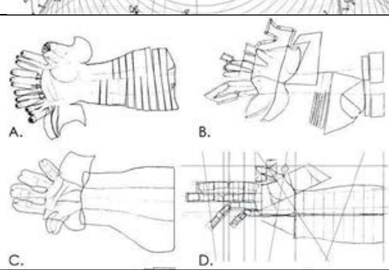
39		"One of the basic skills that students must develop is their sense of making connections... One strategy for introduction into the beginning design pedagogy is through the use of mythology and collage..."	Encourages an attitude toward "form-making" that abstracts from technical considerations.
40		"The use of the student's true body reinforces the potent idea that we are all unique individuals. We must take personal responsibility for our designs; we are our Designs. An artistic composition must have a thoughtful response to its Site; it is this relationship to context that elevates a design beyond mere logo."	Encourages an attitude toward "form-making" that abstracts from technical considerations.
41		"...students' analysis of the works consisted of careful readings of both written texts and the built environment of their campus context; Las Vegas. The poetics of space making and architectural thinking were explored through three weekly exercises."	Encourages an attitude toward "form-making" that abstracts from technical considerations.
42		"As informational networks bind us ever more tightly together, they also introduce unseen gaps and fissures within fields of knowledge... it is also possible to engage and embrace the unknown, unknowable, episodic, and incomplete as fundamental aspects of contemporary experience... Building on the highly speculative and conceptual work of the first two years of study in our program, Architectural Design 5 addresses the inherent complexities of the direct physical site, and its bearing on the act of making architecture."	Encourages an attitude toward "form-making" that abstracts from technical considerations.
43		"In the beginning design studio, there remains a strong predilection toward short, abstract design projects. These quick projects have a powerful history and are heavily steeped in 20th century Western design education tradition. Unfortunately, these sorts of projects often leave little opportunity to integrate humanitarian concerns into the	While such projects introduce students to a "social" context, they also encourage an attitude toward "form-making" that abstracts from technical considerations and control layer issues.

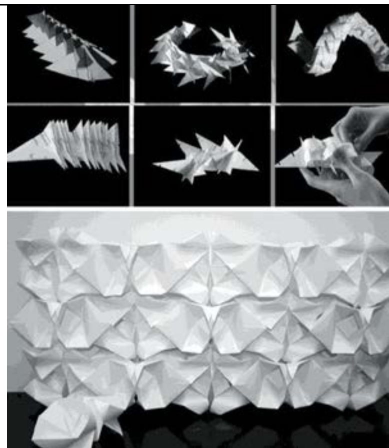
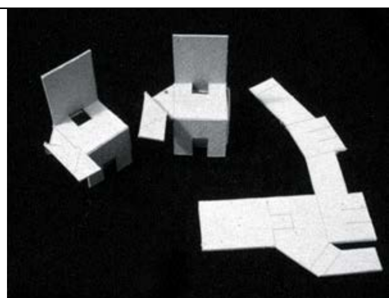
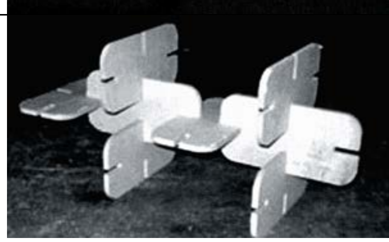
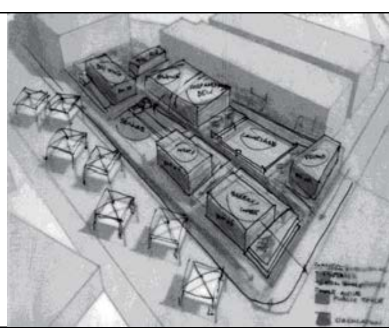
		learning outcome... Students were asked to design a Women's Shelter to be located in inner city Chicago."	
44		"How can this holistic view including the social, economic and environmental aspects of sustainability be incorporated in the early stages for the design student?... First year Design Platform Students...were assigned the task of designing a wooden toy"	Encourages an attitude toward "form-making" that abstracts from technical considerations.
45	No student work illustrated.	"Design students, educators and professionals tell stories. While the continued relevance of any single example can be debated, I will insist upon the importance of story-telling itself."	Not directly relevant to the question of teaching building technology.
46		"...a wall is no longer merely a solid shell of masonry, or a series of studs hidden behind layers of sheetrock, but a complex layering of individual skins, each with its own characteristics...As an attempt to develop familiarity with spatial and material nuance in architecture, particularly concerning the nature of the thickened boundary or in-between space, the Weaving Walls project serves as an excellent primer for both material and theoretical issues in architecture."	While referring to "material nuance," the studio encourages an attitude toward "form-making" that abstracts from important technical considerations, such as control layer continuity.
47		"The initial solution attempted to remove the students from the tracks of thinking that were leading to the dead ends and involved exploring realms of artistic endeavor and media not typically associated within the discipline...This bias toward the rational has downplayed the role of the emotional, intuitive thought process and has developed a prevailing attitude that these types of mental operations are somehow less valid."	Not directly relevant to the question of teaching building technology.
48	No student work illustrated.	"Architects must delineate a means for people to flourish within local communities, international societies and global environments. Technology based educational training does not prepare students for problem solving which promotes this sort of democratic living."	Not directly relevant to the question of teaching building technology.

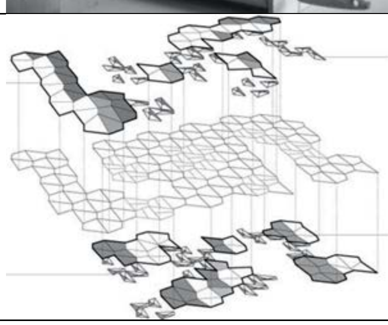
49	 	"Prior to material manipulation shouldn't there be lessons in historical precedents?... Many similar questions have been raised through dialogue with incoming students that have come up through the ranks of college preparatory curricula... The new beginning design student with years or even decades of experience working in the profession often comes to the academy with efficiencies and deficiencies similar to those of the high school student."	The image may or may not be a student analysis of the Wollaton House compared to the Bellagio Casino. In any case, the focus of the studio is not directly relevant to the questions of building technology and control layers.
50	No student work illustrated.	"The data from this survey in addition to the progress seen in the coursework and discussions show that teaching of design methodology and theories coupled with basic architecture knowledge, can help students to become more aware of their own design process and approach to architecture."	Not directly relevant to the question of teaching building technology.
51		"Practice will be unable to achieve its goal unless sustainability is recognized as a paradigm-shifting concept, not merely a technical add-on... Sustainable design thinking must be assimilated into the students' mindset... An emphasis is placed upon envisioning and actually constructing work, with an emphasis on incorporating sustainable technologies and relating to actual communities."	Design-build work offers the potential to consider technical issues such as control layer continuity, but it is not clear to what extent such issues are consistently raised.

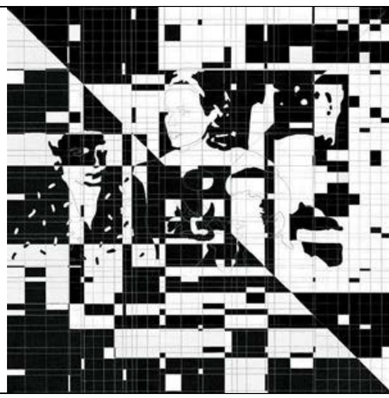
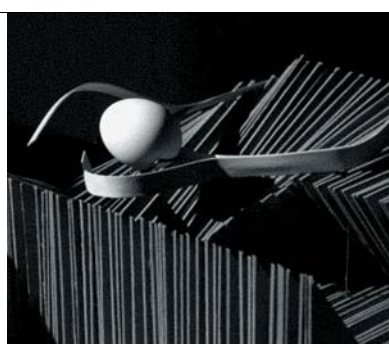
52		"The unfortunate effect of beginning with this abstraction is that it suppresses the fact that architecture is inseparable from its material manifestation. To fully engage in the act of designing architecture, students must integrate the investigation and understanding of making, building technology, and materiality in their early studies...The students are expected to demonstrate understanding that materials and assemblies are not merely subject to whatever form the design supposes, but that the complex layers of building assemblies – structural, thermal, protective, and expressive – are inherent in the final experience and performance of the architectural work."	This studio makes explicit the need to consider technical issues, including control layers and their interactions, not as "add-ons," but as fundamental to the creation of architecture.
53		"Our curriculum is pushing the technical aspects of architecture to be introduced earlier so they can be understood by students from the start of their education." Using local case studies: "The students were asked to: Calculate sun paths and daylight factor...Draw and identify the passive and active thermal systems for the selected building ...Calculate thermal loading for the selected building. Analyze acoustics for one space in the selected building."	Issues of technology are raised early in the design sequence, but the idea is still that they not disturb "the prioritization of conceptual development..." Control layer issues are not explicitly mentioned in the paper; instead, the technical focus is on "systems." Local case studies may or may not reveal useful strategies for building enclosure.
54	No student work illustrated.	"...one must look to our educational system as a means to reconnect the practice of architecture to contemporary cultural discourse... The idea of manual competency, one encompassing both the physical acts of making and the intellectual engagements necessary to facilitate those acts of making, is, perhaps, an appropriate foundation upon which to build an architectural pedagogy."	Not directly relevant to the question of teaching building technology; fostering an "intellectual" basis for manual competency could engage such issues, but there is no specific discussion in this paper of how this might happen.
55	No student work illustrated.	"...a technology against itself may be	Not directly relevant

		able to focus our humanity (bios) found in culture, history, and the capacity of language to say something otherwise. This, I believe, can engender a sense of our shared engagement through poetic thinking and making in beginning design. In doing this there is no need to abandon technology since that would be unethical but instead one should struggle to temper its reign."	to the question of teaching building technology, as "technology" is understood in a very general manner rather than in its specific manifestations. Yes, it is possible to address the "poetic" while still engaging technological issues, but those issues still need to be fully understood and prioritized.
56		"Finding common ground between the electronic and hand drawing/sketching areas in architecture curricula can be achieved."	Not directly relevant to the question of teaching building technology.
57		"Manual drawing and modeling plays an important role in teaching students to see space in terms of scale, proportion, proximity, and context. Teachers need to see that students have mastered visual spatial thinking prior to unleashing them into the infinite space of modeling software... Another measurable outcome of this studio is an intuitive understanding of the behavior of form and material. The explorations by students in this studio build an intuitive knowledge for the way material behaves structurally."	Not directly relevant to the question of teaching building technology: "tectonics" is used as a code for structural intuition, and abstracts from consideration of control layer issues.
58		"Through an investigative understanding of spatial cognition, it may be possible to utilize current technologies (drawing software, immersive virtual environments, gaming applications, and the like) to [increase the] ability to grasp and develop visual and spatial capacities."	Not directly relevant to the question of teaching building technology.
59	No student work illustrated.	"When supposedly neutral performative parameters are used to	The author raises an interesting question:

		generate expressive forms, the invisible hand of function is once again justifying formal originality. Our students are learning to select certain preapproved empirical data such as solar orientation, spatial efficiency, air flows, and by myopically privileging extreme analysis, generate what they believe are sought after visual and sculptural effects... What is missing from any further investigation is the actual construing of craft experience as a generative basis for design thinking."	what is "the relationship of style to building well"? However, the question isn't answered, and the primacy of control layers in contemporary building technology is not mentioned.
60		"What is society's relationship to the environment? What does natural mean? What is nature? How is humankind's relationship to nature conceptualized within one's culture? Where exactly are the wild things?"	Encourages an attitude about surface and form that abstracts from technical considerations relevant to building surfaces.
61		"...an expanded definition of sustainability provides opportunity for exploring poetry, conviction, and ecological practices at the very early stages of design... Student teams spend three weeks with a prescribed set of materials designing and constructing a collapsible passageway that they install in a specified site in the design studio."	Not directly relevant to the question of teaching building technology.
62		"We believe the dynamics driving ecosystems such as behavioral and cultural adaptation under evolutionary pressure apply to innovation and learning in art and design, and can guide thinking about the development of design learning processes and curriculum."	Not directly relevant to the question of teaching building technology.
63		"In response to calls for 'zero waste design,' I would like to propose four specific trajectories to inform the teaching of beginning design: the matter of making, eccentricities and excess, and operations of resistance."	Not directly relevant to the question of teaching building technology.

64		"Powerful modeling tools allow designers to directly manipulate freeform models without considering the constraints of the building process. Therefore, we are left with designs that are often not able to be realized in the physical world... how does one teach beginning design students the difference of immaterial and material design while providing them an immediate experience and hands-on knowledge of materials and construction?"	Considers "material" and "tectonics" but abstracts from consideration of control layer issues in actual buildings.
65		"This paper investigates how first year students can be exposed to the production of dynamic, responsive architectures, by embracing the idea of material as an ever-changing condition."	Considers "material" and various "boundary" issues, but abstracts from systematic consideration of control layer issues in actual buildings.
66		"This paper will present examples from three years of introductory studios from a 5-week summer program... Designed for students interested in architecture, the program is intense but broad and attempts to address how buildings may carry meaning."	Not directly relevant to the question of teaching building technology.
67		"We are no longer living in the age of pure mass reproduction, but of customized singular production. What we thought about owning personal computers in the 1980's is now parallel to how we look at home digital fabrication methods; it is only a matter of time before we are printing prototypes at home."	Not directly relevant to the question of teaching building technology and control layers, as it focused on "interior design" issues.
68		"Generative programs are urban programs that have the potential to impact the community beyond its site or organizational typology."	Not directly relevant to the question of teaching building technology and control layers, as it focused on "urban design" issues.

69		"Students sometimes perceive environmental strategies as being at odds with spatial considerations... Environmental strategy and response can be directed and given purpose the by desires for spatial configuration."	Although environmental issues, light, and heat loss are considered, no systematic examination of control layer issues is evident.
70		"Clearly, the challenge with freshmen, is when what is represented defaults to weak 'building' conventions vs. an ontological opening of the media of architecture in material, space, light, and time."	Although some built projects address issues of rain and sun, a systematic consideration of control layer issues appears to be missing.
71	No student work illustrated.	"The paper discusses the question of a sustainable grounding from a standpoint, which is taken by an artist/architect who understands the phenomenological perception as a way of understanding and being in the world. This paper invites us to understand location as a phenomenon and suggests a strategy to transfer it into studio praxis."	Encourages an attitude toward site and sustainability that abstracts from technical considerations.
72		"The function of the ground in the beginning design studio far precedes the question of how built form meets earth, how steel or concrete feet slip into dirt. The ground is for the architect what the page is for the writer."	Not directly relevant to the question of teaching building technology and control layers.
73		"...a more useful conception understands site as a construction that emerges from the act of making. Architecture designed within this framework in fact borrows from landscape architecture, a discipline that conceives spaces with an understanding of their continuity with their surroundings."	Not directly relevant to the question of teaching building technology and control layers.

74		"The design process attempts to balance two opposing forces: one pulling the designer away from site matters and towards formal abstraction, and a second pushing back in the direction of contextualization. One way to probe this delicate process – and encourage students' sustained attention to both object and landscape in design – is to study the analogous problem of the figure-ground in the visual arts."	Not directly relevant to the question of teaching building technology and control layers.
75	No student work illustrated.	"This presentation will consider the role of observation in an interdisciplinary practice that seeks to comprehend the experiential nature of place and, thereby, unfold a more acute view of the world."	Not directly relevant to the question of teaching building technology and control layers.
76		"If beginning studio is focused on compositional and formal design, then the introduction of the ground plane must be one of the elements considered."	Not directly relevant to the question of teaching building technology and control layers.
77	No student work illustrated.	"Topoi...contain underexplored correlations that are highly relevant for architectural design. Design projects typically originate out of some combination of three constitutive elements: the site or 'context,' the program or 'use,' and the intentions of the architect, his/ her 'project.' If architectural procedures are reducible to one of these topoi alone, the full ecology and, therefore, potentiality of rhetorical invention is lost."	Not directly relevant to the question of teaching building technology and control layers.
78		"Parametric design can be defined as a series of questions to establish the variables of a design and a computational definition that can be utilized to facilitate a variety of outcomes... By framing projects and curricula from the beginning as parametrically derived, it puts less pressure on the designer to generate the right design and more pressure on them to ask the right questions."	Parametric thinking could be directed towards building enclosure and control layer issues; that is, the "right questions" relevant to these issues could be asked. However, they do not seem to be considered in this paper.

79		"...the pursuit of 'lightness' in structure can manifest into a purely formal and material investigation without addressing the greater question of what it means to 'tread lightly.'"	Not directly relevant to the question of teaching building technology and control layers.
80	No student work illustrated.	"Projections, which have been quietly guiding the geometry of architecture for centuries, have remained an untapped design resource for too long."	Not directly relevant to the question of teaching building technology and control layers.

Source: These images and quotes are taken from the 80 papers in the Proceedings of the 27th NCBDS (National Conference on the Beginning Design Student), University of Nebraska, Chairs: Lindsay Bahe, Peter Hind, Brian Kelly (2011)

Endnotes

[1] Many of the underlying ideas in this paper derive from my previous investigations into the relationships between technology and design.

- The potential independence of technology and design (of "science" and "architecture') is explored in: "Separating Science from Architecture: Why Technology is Taught Outside the Design Studio," *The Architecture of the In-Between: Proceedings of the 78th Annual Meeting of the ACSA*, 1990, San Francisco, CA, March 17-20, 1990.

- I examine the interplay of reality and abstraction within the technical history of brick wall construction in: "On the Disappearance of Monolithic Walls: Meditations on a Brick," *Making Environments: Technology and Design*, (Washington, DC: ACSA Press, 1992), proceedings of the 1992 ACSA Technology Conference, San Diego, CA, Feb. 6-8, 1992.

- The changing relationships between building materials and the expression of heroic form is examined in: "Disembodied Technology and Design," *Body, Technology, and Design* (Washington, DC: ACSA Press, 1993), proceedings of the 11th Annual ACSA Technology Conference, Phoenix, Arizona, Jan. 28-30, 1993.

- I criticize the ideal of integrative pedagogic strategies (combining "technology" and "design) since "the 'cutting edge' of design long ago severed all ties to rationality," in: "Dis-integrating technology and design," 1999, unpublished essay at http://www.ochshorndesign.com/cornell/writings/Tech-design99.html (accessed 9/24/13)

- The underlying causes of nonstructural building failures (leaky roofs, cracked slabs, and so on) are examined in: "Designing Building Failures" *Proceedings of the 2006 Building Technology Educators' Symposium*, University of Maryland, College Park, August, 2006. Preliminary suggestions for an appropriate architectural pedagogy and strategies for a probabilistic approach to the design of buildings can be found in the concluding section.

- A more detailed examination of a risk-based approach to building design can be found in: "A Probabilistic Approach to Nonstructural Failure," *Architectural Engineering Institute 2013 Conference* (ASCE), Penn State University, April 2013.

[2] I'm not denying the possibility of creating an abstract or conceptual architecture on the basis of intuition, or any other unselfconscious mode of creation. The point is that, in the final analysis, all architecture has a conceptual basis – that is, some abstract qualities – no matter how its designers understand or articulate their own design process.

[3] Jean-François Lyotard, "Answering the Question: What is Postmodernism?" Thomas Docherty, ed., *Postmodernism: A Reader*, Columbia University Press, New York, 1993: "...modern aesthetics is an aesthetic of the sublime, though a nostalgic one. It allows the unpresentable to be put forward only as the missing contents; but the form, because of its recognizable consistency, continues to offer to the reader or viewer matter for solace and pleasure. Yet these sentiments do not constitute the real sublime sentiment, which is an intrinsic combination of pleasure and pain: the pleasure that reason should exceed all presentation, the pain that imagination or sensibility should not be equal to the concept." He continues: "The postmodern would be that which, in the modern, puts forward the unpresentable in presentation itself; that which denies itself the solace of good forms, the consensus of a taste which would make it possible to share collectively the nostalgia for the unattainable; that which searches for new presentations, not in order to enjoy them but in order to impart a stronger sense of the unpresentable." (p.46)

[4] For a discussion of Le Corbusier's five points, see: Alan Colquhoun, *Modern Architecture* (Oxford: Oxford University Press, 2002), 146-149.

[5] For a concise history of innovations in glass manufacturing, see "Chronology of Advances" in the "History of Glass," Wikipedia, http://en.wikipedia.org/wiki/History_of_glass#Chronology_of_advances.5B33.5D (accessed 9/25/13).

[6] Glass as "void" was not the only abstract category in which glass appeared within modernism: aside from its transparency, its reflectivity was also valued at times, as was its potential to let in sunlight or – when tinted – various colored lights.

[7] Modernism, especially in its "brutalist" phase, exploited the "heroic" quality of materials like concrete, steel, or brick.

[8] It is interesting to note, in this regard, that the funerary building types (pyramids, and so forth) or unbuilt Cenotaphs that can be seen as precursors of abstract modernism had little or no need for natural ventilation.

[9] An informal and Canadian-centric "history" of the development of these control layers into pressure-equalized rain screen systems can be found in Joseph Lstiburek's "But I Was So Much Younger Then (I'm So Much Older Than That Now)," BSI-065, *Building Science Insights*, at: http://www.buildingscience.com/documents/insights/bsi-065-i-was-younger-then (accessed Oct. 24, 2013).

[10] Joseph Lstiburek, "Vapor Barriers and Wall Design," *Research Report 0410*, November, 2004, http://www.buildingscience.com/documents/reports/rr-0410-vapor-barriers-and-wall-design (pdf accessed Oct. 25, 2013).

[11] Most cladding systems must be fastened through those control layers that are placed between the cladding itself and the structural substrate that supports it, but there is at least one exception: certain polymer-based exterior insulation and finish systems (EIFS) are light enough so that the lamina constituting the "cladding" of such systems is adhered directly to rigid insulation boards without mechanical fasteners.

[12] Control layer problems emerged at Peter Eisenman's Wexner Center: "...it would seem embarrassing for any architect, let alone one as prominent as Peter Eisenman. You design a museum - your first large-scale work, a breakout project whose exterior scaffolding design, a virtual celebration of impermanence, sets the architecture world buzzing. Within just a few years, however, cracks start to show. Quite literally: the skylight leaks. The glass curtain wall lets in too much light, threatening to damage delicate artwork. The interior temperature swings by as much 40 degrees some days." (Robin Pogrebin, "Extreme Makeover: Museum Edition," *New York Times*, Sept. 18, 2005.

Different control layer problems plagued Frank Gehry's Stata Center: "MIT has settled its 2007 lawsuit against the architects and builders of the Ray and Maria Stata Center... MIT’s lawsuit cited design and construction failures in the building. These included masonry cracking and poor drainage in the amphitheater; 'mold growth at various locations on the brick exterior vertical elevations'; 'persistent leaks' throughout the building; and sliding ice and snow." John A. Hawkinson, "MIT settles with Gehry over Stata Ctr. defects," *The Tech, online edition*, March 19, 2010.

Joseph Lstiburek also examined control layer problems at the Stata Center: "Lstiburek speculates that the Stata Center's leaks are caused by 'fishmouthing' of the waterproof membranes, discontinuities between the roof and walls, and poor design of the window-to-wall connections. But he claims something else is wrong – something even more basic. During a 45-minute, PowerPoint-aided lecture, he shows me MIT's own photos of the center being built. 'You see the yellow stuff, gypsum board. And you'll see the membrane going over this and then the brick. The insulation that is put on the inside should have been put on the outside. They just have them in the wrong order.' In the winter, when a building like this is heated, explains Lstiburek, who wrote the U.S. Department of Energy's handbook on moisture control, water vapor 'sweats' through the wall into the insulation and is trapped there by the waterproof membrane, just like your T-shirt gets sopping under a leather jacket. This erodes the wall, causes mold, and even makes the insulation smell like dirty socks." Anna Kamenetz, "Lost in the Funhouse: The Battle Between Starchitect Frank Gehry and MIT Reveals the Widening Chasm Between Design and Down-to-Earth Craft," *Fast Company*, first published February, 2008, updated at http://www.fastcompany.com/641146/lost-funhouse (accessed Nov. 10, 2013).

[13] Photo credit: Ibagli, 2009, public domain, at http://commons.wikimedia.org/wiki/File:OSU_Wexner_Center.JPG (accessed Oct.25, 2013).

[14] Photo credit: Tafyrn, 2006, public domain, at http://en.wikipedia.org/wiki/File:MIT_Strata_Center.jpg (accessed Oct.25, 2013).

[15] Peggy Deamer, "First Year: The Fictions of Studio Design," *Perspecta 36* (2005), p.2.

[16] *Proceedings of the 27th NCBDS* (National Conference on the Beginning Design Student), University of Nebraska, Chairs: Lindsay Bahe, Peter Hind, Brian Kelly (2011), online at http://novicedesign.org/NCBDS/27/27.html (accessed 7/18/14).

[17] Leslie Johnson, "Matter Matters," *Proceedings of the 27th NCBDS, ibid.,* p. 337.

[18] Claire Alyea and Nancy Yen-wen Cheng, "Online / On Target: Reflective Practice through Blogging," *Proceedings of the 27th NCBDS, ibid.,* p. 154.

[19] Brian T. Rex and Marti Lea Gottsch, "From a Sandbox of Objects to One of Things," *Proceedings of the 27th NCBDS, ibid.,* p. 26.

[20] Richard L Hoag, " Cumulative Learning in the Act of Design," *Proceedings of the 27th NCBDS, ibid.,* p. 47.

[21] Maria Vera, Jonathon Anderson, Ming Tang, and Shai Yeshayahu, "Re-Tooling the Logic of Design," *Proceedings of the 27th NCBDS, ibid.,* p. 100.

[22] Rima Al Ajlouni, "Biomimcry Studio: Nature-Inspired Sustainable Design Thinking Approach," *Proceedings of the 27th NCBDS, ibid.,* p. 118.

[23] Lohren Ray Deeg, "Introducing Multidisciplinary and Multi-scale Thinking Into a Beginning Design Project," *Proceedings of the 27th NCBDS, ibid.,* p. 138.

[24] Lohren Ray Deeg, "Introducing Multidisciplinary and Multi-scale Thinking Into a Beginning Design Project," *Proceedings of the 27th NCBDS, ibid.,* p. 142.

[25] Christopher Romano, Nicholas Bruscia, and Shadi Nazarian, The Living Wall: A Project of Many," *Proceedings of the 27th NCBDS, ibid.,* p. 93.

[26] Troy Nolan Peters, " Starting with Integration. Using Hybrid Techniques for Zero Energy Design," *Proceedings of the 27th NCBDS, ibid.,* p. 126.

[27] Jodi La Coe, " [re]Constructing the Sustainable Imagination," *Proceedings of the 27th NCBDS, ibid.,* no page number.

[28] The "art" and "science" of architecture produce a tension between the "freedom" of abstract thinking and the "pragmatics" of actual construction: "It is widely perceived today that there is an intrinsic tension between freedom of ideas in architectural education and the pragmatics of negotiation in the building process. Architecture remains one of the few professions that still allow dreams, but all designs, banal or avant-garde, must endure constraints of reality and seemingly unbearable compromises when put to realization. To their credit, architecture schools largely privilege abstract thinking in the design studio. This discrepancy between the education of architects and the practice of architecture produces an obscure yet revealing dynamic between the two realms, and it is this disjunction that enables the distance necessary to stretch and expand the boundaries of the architectural vocation." Angela Pang, "Implementing Architecture: Cornell and the Education of Architects," *Architecture and Urbanism* (A+U), May 2006, p.9.

[29] Seng Kuan and Angela Pang (interviewers), "Education in Process: New Directions at Cornell," *ibid,* p.18.

[30] Jonathan Ochshorn, "Designing Building Failures," *op. cit.*

[31] Not considered in this paper are the types of "passive" technologies related to the orientation and position of a building on a site: in particular, the influence of sun and wind. While the damage done by abstracting from such issues is real, it is of a different sort from the literal damage caused by control layer failure. Poor decisions about orientation, functionality, and so on create added costs and inconveniences for building users, building owners, and for the larger society, but the building itself may remain intact.

[32] "Perhaps the most important conclusion derives from the fact that, for unusual (peculiar or complex) architectural designs, the interaction of materials, systems, geometries, environmental conditions, installation methods, and so on, is rarely systematically tested or theoretically grasped. Conventional construction details and methods, on the other hand, have at least a track record of generally successful (or unsuccessful) application. While the lack of a consistent measure of reliability applies to such conventional systems as well, there is at least an informal understanding of how such systems perform over time. For this reason alone, one can state that *nonstructural failure will generally increase as the peculiarity or complexity of the architecture (i.e., the deviation of its design from well-established norms) increases*." Jonathan Ochshorn, "A Probabilistic Approach to Nonstructural Failure," *op. cit.*

[33] Tony Tufariello, "Synthetic Stucco Failures," *Gen Re Connect*, undated, at https://www.facworld.com/facworld.nsf/doc/stucco (accessed Nov. 7, 2013)

[34] Marshall, Robert R. "2001 Building Failures Study." *CMHC Technical Series 01-140* (2001): *1-4. Conceptual Reference Database for Building Envelope Research*, cited in Ochshorn, "Designing Building Failures," *op. cit.*

[35] Robert Campbell, "Learning from the Hancock," *Architecture*, March 1988, p.68, cited in Ochshorn, " Dis-integrating technology and design," *op. cit.*

[36] An example of such "pre-building" research can be seen in the glass enclosure system developed for La Cité des Sciences et de l'Industrie in Paris as described in: Rice, P. and Dutton, H. (1995) *Structural Glass*, E & FN Spon, London, New York, cited in Ochshorn, "A Probabilistic Approach to Nonstructural Failure," *op. cit.*

[37] Casius Pealer, "Professional liability insurance: When to get serious," *Architectural Record*, Dec. 2007, at http://www.architecturalrecord.com/articles/6964-professional-liability-insurance-when-to-get-serious (originally accessed Nov. 7, 2013; new link provided Nov. 24, 2015).

[38] Suzanne Frank, *Peter Eisenman's House VI: The Client's Response*, New York: Whitney Library of Design, 1994, p. 64.

[39] Peter Eisenman, "House VI," originally published in *Progressive Architecture* 58, no. 6 (June 1977) and reprinted in Frank, *ibid.,* p.21.

[40] I discuss the role of competition in driving and defining fashionable architecture in an unpublished essay written in 1983: "Fashionable Building: The Purpose of Architectural Education," at:

http://www.ochshorndesign.com/cornell/writings/fashionablebuilding.html (accessed Nov. 8, 2013).

[41] The origin and meaning of "defamiliarization" is explained in countless texts, all of which credit the term to a 1917 essay by Viktor Shklovsky translated as "Art as Device" or "Art as Technique": see, for example, Svetlana Boym, "The Poetics and Politics of Estrangement: Viktor Shklovsky and Hannah Arendt," Alastair Renfrew and Galin Tihanov, eds., *Critical Theory in Russia and the West*, Routledge, New York, 2010, p.101.

[42] Joseph Campbell, *Pathways to Bliss: Mythology and Personal Transformation*, Edited by David Kudler. Novato, California: New World Library, 2004, pp. 132, 133.

[43] Much of this material on the "heroic journey" is taken from my online essay, "Critique of Milstein Hall: Nonstructural Failure," at http://www.ochshorndesign.com/cornell/writings/milstein-critique/nonstructural-failure.html (accessed Nov. 7, 2013), including the following evidence that some architects really do proudly wear this "badge of honor":

"'There's not an architect I know that doesn't have problems with important buildings,' Mr. Eisenman said in a recent interview in his New York office. He cited a comment that Frank Lloyd Wright is said to have made when a client called to complain that a house was leaking: You mean you left my building out in the rain? 'Do you know any architect that's been free of that? I don't know any,' Mr. Eisenman said. 'Frank, Rem — they all do,' he said, referring to Frank Gehry and Rem Koolhaas. 'Wright, Corbu, Mies. Look at Mies and the Farnsworth House — enormous problems.'" Peter Eisenman quoted in Robin Pogrebin, "ARCHITECTURE; Extreme Makeover: Museum Edition," *New York Times*, September 18, 2005, at:

http://query.nytimes.com/gst/fullpage.html?res=9F07EEDE1131F93BA2575AC0A9639C8B63&sec=&spon=&pagewanted=all (accessed June 9, 2010).

Frank O. Gehry, referring to suit brought by M.I.T. over leaks, cracks and drainage problems at the Stata Center, said: "These things are complicated and they involved a lot of people, and you never quite know where they went wrong. A building goes together with seven billion pieces of connective tissue. The chances of it getting done ever without something colliding or some misstep are small." Robin Pogrebin and Katie Zezima, "M.I.T. Sues Frank Gehry, Citing Flaws in Center He Designed," *New York Times*, November 7, 2007, at http://www.nytimes.com/2007/11/07/us/07mit.html (accessed June 9, 2010).

The heroic attitude was articulated brilliantly by Piet Mondrian in 1925: "If one takes technique, utilitarian requirements, etc., as the point of departure, there is a risk of losing every chance of success, for intuition is then troubled by intelligence." *L'Architecture Vivante* (Autumn, 1925), p.11; referenced in Collins, Peter. *Concrete: The Vision of a New Architecture*, 2nd edition. Montreal: McGill-Queen's University Press, 2004, p.281.

[44] Chen, S., et. al, eds. (2010) *Forensic Engineering 2009: Pathology of the Built Environment*, American Society of Civil Engineers, Reston, VA., cited in Ochshorn, *A Probabilistic Approach to Nonstructural Failure*, *op.cit.*

[45] Hannes Meyer in the essay, "Bauen," quoted in K. Michael Hays, *Modernism and the Posthumanist Subject: the Architecture of Hannes Meyer and Ludwig Hilberseimer*, MIT Press, Cambridge, MA, 1992, pp.158-159.

[46] The images and quotes in Table 1 are taken from the 80 papers in the *Proceedings of the 27th NCBDS, op. cit.,* numbered in the order of their appearance, as follows:

1. Leslie Johnson and Catherine Wetzel, "Liquid Containers"
2. Brian T. Rex and Marti Lea Gottsch, "Boxing Form: 12 Years of Playing in the Sand"
3. Charles Graves, Jr. and Thomas Sofranko, "Perenial Questions, Persistent Cubes"
4. Jim Sullivan and Tom Sofranko, "Mining The Ncbds Archive: Steps Towards Disciplinarity"
5. Brent Freeby, Michael Lucas, Brian Kelly, JoAnn Moore, Bryan Ridley, and Keith Wiley, "Power [Tools]: Parasite's Progress"
6. Richard Hoag, "Building Conceptual Frameworks: Cumulative Learning in the Act of Design"
7. C. A. Debelius, "Integrating Technology: Reflections On Pollan's A Place of My Own: The Architecture of Daydreams"
8. James Bassett, "The Form of Context"
9. Donna Kacmar, "Changing Curriculum"
10. John Folan, "Or+And"
11. Shannon Criss, "Working with Contradiction"
12. Christopher Romano, Nick Bruscia, and Shadi Nazarian, "The Living Wall: A Project of Many"
13. Catherine Wetzel, "Building on Mies, Integration at IIT"
14. Maria Vera, "Re-Tooling the Logic of Design"
15. Michael McGlynn, "Blurring Boundaries: Integrated Design, Architectural Technology, and the Beginning Design Student"
16. Christian Dagg and Justin Miller, "Recalibrated: Approaching Integrated Design via Curricular Shifts"
17. Rima Ajlouni, "Biomimcry Studio: Nature-Inspired Sustainable Design Thinking Approach"
18. Troy Peters, "Starting with Integration. Using Hybrid Techniques for Zero Energy Design"
19. Katrina M. Lewis, "Bridging Disciplines and Cultures: From Beginning Design in the United States to Integrated Humanities in Bangladesh"
20. Lohren Ray Deeg, "Introducing Multidisciplinary and Multi-Scale Thinking into a Beginning Design Project"
21. Roderick Grant and Keith Rushton, "The Color of Experience"
22. Nancy Yen-wen Cheng and Claire Alyea, "Online / On Target: Reflective Practice through Blogging"
23. Raymond Quek, "Parallel Lines -The Mirror of Architectural Creation and Belief in Textual and Visual Realms"
24. Samantha Krukowski, "Rhyme Blue"
25. Daniel J. Butko, "Word Design"

26. Michael Lucas, "The Write Stuff: Stealth Theory for Beginners"
27. Brian Ambroziak, "Scriptorium [Space of the Night Scribe]"
28. Susannah Dickinson, "Digital Design Communication"
29. M. Saleh Uddin, Robert Tango, and Arief Setiawan, "Fold in Architecture: A Form-Making Strategy in Foundation Studios"
30. Brian M. Kelly, "Found Object/Material in the Design Process: More Than Just Visual?"
31. Justin Miller, "Re-Envisioning: Analysis Tools in Beginning Design Studios"
32. David Hill, "Primary Sourcing: Defining a Role for Physical Archives in Teaching Digital Media"
33. Jeff Balmer, "The Diagram & Beginning Design Education"
34. Julia Granacher, "The Synthetic Diagram and the Creation of Form"
35. Jonathon R. Anderson, Ming Tang, Maria Vera, and Shai Yeshayahu, "Parametric Thinking [Not Modeling] as a Generator"
36. Jonathan Mills, "Digging Up Ideas: Visually Exposing New Directions"
37. Eric Oskey and Dennis Playdon, "Making of Place"
38. Jodi La Coe, "[Re]Constructing the Sustainable Imagination"
39. Anthony Cricchio, "Beginning Connections: Mythology and Collage for Beginning Architecture and Design Students"
40. Kristopher M. Palagi, "Body as Site"
41. Glenn NP Nowak, "Beginning of the Never-Ending: Design Investigations"
42. Bradley Walters, "Out of Thin Air"
43. Maria V. Miller, "Why Wait? Integrating Social Problems into the Beginning Design Project"
44. Kate O'Connor, "Sustaining Through Design Curriculum"
45. Peter Olshavsky, "Ethical Rehearsal: Storytelling as Design Praxis"
46. Dariel Cobb and Theodore Sawruk, "Weaving Walls: An Alternate Narrative of the Essence of Architecture"
47. Julia Granacher, "Unlocking the Intuitive; Towards a Codified Generative Design Approach"
48. Beth Bilek-Golias, "Democratic by Design: Architecture Teacher Leaders Building a Liberal Arts Foundation to Support Transformative Curriculum Leadership"
49. Glenn NP Nowak, "A New Beginning Design Student: From the End of High School Toward the End of Careers"
50. Shonali Bose; Gregory Kessler, "Design Thinking and the 3+ Graduate Architecture Student"
51. Shannon Criss, "Embedding Sustainable Design Thinking into the Architectural Curriculum"
52. Leslie Johnson, "Matter Matters"
53. Donna Kacmar, "Conceptual Systems: Technical Foundations for Beginning Design Students"
54. Thomas Cline, "The Necessity of Manual Competency"
55. Peter Olshavsky, "A Technology Against Itself: Poetic Engagement in Early Design Education"
56. William Batson and Arsenio Rodrigues, "The Hand and the Vector: Graphic Communication"
57. James Eckler and Karl Wallick, "Thinking Manually, Working Digitally"
58. Jennifer Barker, "To Sustain Learning: Developing Spatial Awareness in First-Year Design Students"
59. Frank de Santis, "Reconciling the Poetic and The Prescriptive: Negotiating Architectural Form"
60. Kathryn L. Bedette, "Where Are the Wild Things? Introducing Environmental Theory in First-Year Design Studio"
61. Ann Sobiech Munson, "Ecological Material Practice as Fundamental Habit (Or, Dumpster Diving Poetics)"
62. William R. Taylor and Jennifer Wall, "Design Ecology: Waste Happens"
63. Bradley Walters, "Materialisms And Excess"
64. Jonathon R. Anderson, Ming Tang, and Maria Vera, "Representation and Realizing: A Hybrid Process of Immaterial and Material"
65. Manole Razvan Voroneanu, "Material Performance"
66. Kevin H. Moore, "Scenarios: Participatory Environments in a Pre-Architecture Program"
67. Jennifer Hamilton, "Students Investigate Digital Fabrication as Means for Elevating Designer-Client Relations"
68. Matthew Battin, "Generative Program Creates Context"
69. James Eckler And Karl Wallick, "Rationalization and Reconciliation"
70. Jim Bagnall, Brent Freeby, Michael Lucas, Joann Moore, Byran Ridley,And Keith Wiley, "Triple Grounding"
71. Henning Haupt, "Architectural Design Between Bound and Unbound Criteria"
72. Nora Wendl, "The Earthbound Observatory: Grounding Beginning Design"
73. Jeffrey L. Day, "Surrounded Not Grounded"
74. Sanda Iliescu, "Field-Making: Ways to Re-Imagine the Figure-Ground Problem"
75. Peter P. Goché, "Vernacular Grounds: A Process of Observation"
76. Charles Macbride, "Engaging The Ground: A Process, or, the Suspension of Disbelief"
77. Steven K. Holmes And Lauren Mitchell, "A Throw of the Dice: Aleatory Procedures as Design Beginnings"
78. David Karle And Brian M. Kelly, "Parametric Thinking"
79. Bruce Wrightsman, "Integrating Structures"
80. James Spiller, "Interrogating Perspective"