The Evolution of the Full-Scale Artifact in Architectural Academia

Under the influence of digital technologies and the virtual realm, the architectural model has radically mutated, not only in its appearance and method of fabrication but in its function. It's no longer just a scaled object to glance upon and imagine how the spaces might be at their true size. Instead, the full-scale artifact has regained an important place in academia and practice due to both technological advances and current events.

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INTRODUCTION

According to Michael Speaks in Design Intelligence, the field of architecture faces unprecedented challenges in a world increasingly dominated by globalization, technology and a knowledge-based economy. Thus, design should be about innovation and the creative process, not just the result of a single product. The aim is cheap, quick and adaptable prototypes, research and design performed by the act of doing. These goals for architecture on the whole incite new values and modes of thinking about design and the status of the fabricated model. It's no mere mode of representation but rather a physical reality to inhabit and a significant part of the process that interweaves the role of design and construction.

Since the Renaissance, a rift has grown between design and construction in architecture. But over the past thirty years, technological developments have led to increased experimentation in the field mending this gap. These digital advances have catalyzed the popularity of the design-build digital fabrication approach in the profession and in the university setting. The physical models and digital representations in these studios have a unique role in the design discussion. Often the result is a prototype, a manifestation of a design at 1:1 scale, which incites a transparent discussion of the artifact and how it may be inhabited. Because the model is true to scale, there can be no miscommunication, no misunderstanding of the effect of each design decision. These models become architectural artifacts in their own right and from this design/build process, students begin to connect not only the hand and the eye through the act of creation, but the hand, the eye and the thought behind an architectural design.

Technology is the norm in the office and the academic studio. Students and professionals design with three-dimensional digital tools, and, through these means design and construction are inextricably woven together in a continuous feedback loop. Recent university design-build programs have aligned more closely with the model of the Dessau Bauhaus by employing the latest technologies and materials to find new ways to conceptualize and construct architecture. Some programs use traditional building methods, but increasingly, more and more are engaging digital craftsmanship. Students use digital tools for design and construction to create a portion of a building or a full scale model to demonstrate a process or method of building. These experiments are representative of the what is possible and indicative an allegiance to parametric design and the pursuit of research as a design tool.

In architecture, theory (design) and practice (construction) have not always assumed equal status. But, historically, the master builders of cathedrals such as Chartres, St. Paul's and Amiens worked on the design and supervised construction simultaneously, directly connecting the designer and the craftsmen. The act of design and the act of making were seamlessly linked and the unification of these two principles continued sporadically over there years. At the Brion-Vega Cemetery in Treviso, Italy, the artist and architect Carlo Scarpa directly involved the workmen in the design process. He understood the value of integrating these craftspeople directly into the process and described this benefit as an integral part of his work.[1] Antoni Gaudí also used this practice for the Church of La Sagrada Familia in Barcelona by asking the workmen to contribute to design ideas during construction.

For a number of architectural academic programs, design-build courses and full-scale models are now integral to the curriculum. In an article called "Learning from Construction" in Architecture Magazine these courses were described as "intended less as surveys of the popular alternative delivery method than as hands-on clinics to teach students about sites, structures, materials and joinery. Academic design-build programs remove design projects from the studio vacuum and push students to reconcile their drawings with the reality of structures they can build, weld wire and plumb. This process encourages students to work as part of collaborative teams, resolving conflicts, managing finances, and communicating with clients."[2] Thus, these course are about cognition, about understanding. There are multiple ways of comprehending a drawing or a model, but when students construct a full-scale prototype, they begin to realize how the space they design is manifest in the real world. The conversation about a project is more productive since it is about the reality of the constructed object and the methods used to achieve it rather than the imagined interpretation. Models are big and easy to understand by anyone, be they reviewers, clients or other designers. This enhanced transparency allows for increased comprehension of problems and thus better solutions.

THE BAUHAUS: THE ORIGINAL DESIGN-BUILD STUDIO

To understand the role of full-scale models today, we need to examine the roots in the Dessau Bauhaus paradigm. As established by Walter Gropius in 1919, the school fostered a cyclical and fluid design process and a forward-thinking pedagogy evolved from industrial design and mass production.[3] Students of the school were encouraged to build in order to further explore design intentions. This model spawned the design-build strategy as a delivery method that offers faster paced production and more cost-effective buildings than the typical architect/contractor coordination.

In a lecture at the ACSA National Meeting in 1959, Gropius explains the goals of the design-build studio as an educational model. The Bauhaus touted research as the precipitant necessary to further educational aims. A revolutionary concept at the time, the Bauhaus focused on teaching students to put stock in process over given information and to value the experience gained through live projects:

> "In an age of specialization, method is more important than information. Training should be concentric rather than sectional with an emphasis on relations.
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> Design knowledge only comes by individual experience, where feedback on one's own work is of paramount value. Through the feedback students receive when trying to build their designs, they quickly learn to account for constraints. The aim is to provide a rich and deep learning environment, facilitating a student to design and build ubiquitous computing, not only within human capability constraints, but also for human enjoyment, spirituality, etc.
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> At the start, basic design and shop practice combined should introduce the students to the elements of design and simultaneously the ideas of construction. In succeeding years, the design and construction studio should be supplemented by field experience. Construction should be taught with design, for they are directly interdependent.
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> …Students learn to design better when first encouraged to explore, try, reflect upon, and integrate design and construction."[4]

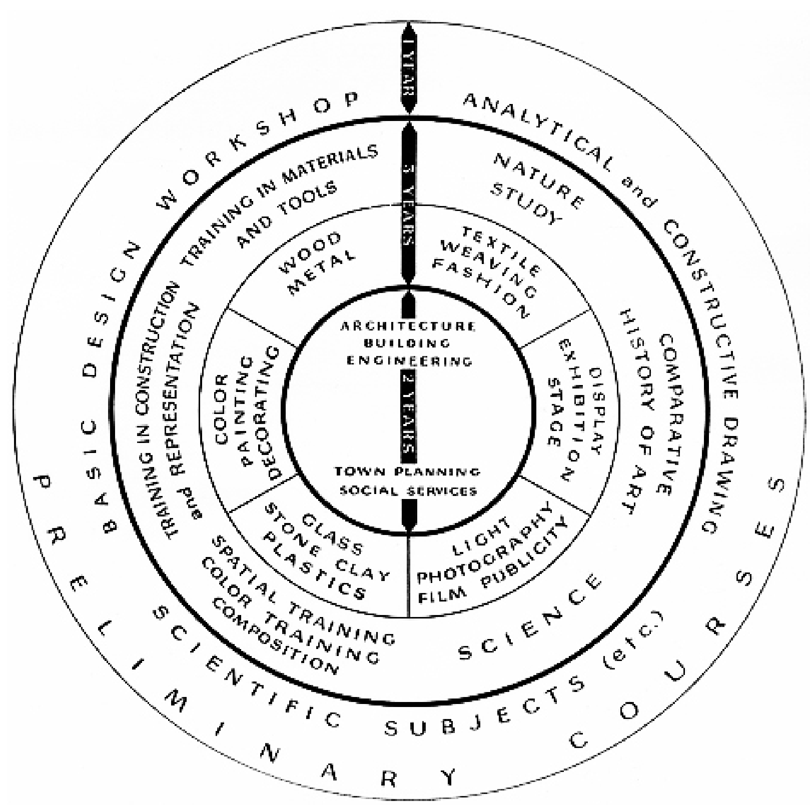

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Figure 1: Dessau Bauhaus, *coursework breakdown*

The Bauhaus program aimed to connect the craftsman with the artist and shift construction to the center of the architect's training. Gropius explains this emphasis on hands on teaching: "Starting with the simplest tools and least complicated jobs, [the student] gradually acquires the ability to master more intricate problems and to work with machines, while at the same time, he keeps in touch with the entire process from start to finish."[5]

In the "learning-by-doing" workshops taught by Johannes Itten and Josef Albers, students were allowed to experiment with materials in an open-ended format, emphasizing rigorous process and intuitive design methods. The decision to abandon basic instruction, in which students merely paint and draw, in favor of a systematic study of materials, of their constructional, functional and economic requirements and possibilities, was didactically significant. Albers explained that the objective of his course was "the ability to invent through construction and to discover through observation is developed, at least at first, by undisturbed, uninfluenced and unprejudiced experiment that is a playful tinkering with concrete goals and experimental work."[6] Thus, central to the focus of the school was a process-based method using the opportunity to explore new ways to fashion architecture.

Despite the fact that many American schools formulated their programs using the Bauhaus as a model, the practice of building full-scale prototypes and studying details in the tectonic realm did not originally translate. Instead, the focus was on a representation-based pedagogy of scaled three-dimensional models and drawings in plan, section, and elevation. In the last twenty-five years, the inclusion of a design-build component in architecture programs has moved from the fringe of architectural academia to a compelling didactic tool. The work in these courses interrelate design ideas and fabrication. Concepts are tested and new possibilities and solutions are revealed through the process of making. Examining the evolution of the full scale model of the design-build approach reveals much about and the future potential of digital fabrication techniques through innovation rather than problem solving.

TRADITIONALLY CRAFTED WHOLE FULL-SCALE PROTOTYPE

Full-scale traditionally constructed design-build was initiated in the United States via **Yale University's Building Project** (established in the 1960s) and **Auburn University's Rural Studio** (established in the 1990s). The projects retained original building methods, but didn't really push the boundaries of research. The current studios that tend toward this method emphasize cost savings and efficiency over a rigorous design process, therefore elevating the act of construction over design-thinking.

A number of design/build programs follow this long-established format. A few notable examples are **University of Virginia's Community Design + Research Program**, **University of Arkansas Design/Build** and **Auburn University's DESIGNhabitat**. These programs focus on hands-on experience through the act of construction and community outreach to create buildings that fit into their cultural and climatic settings. This is evident in the words chosen to describe their programs. UVA summarizes their collaborative Community Design and Research Center (CDRC) with the intention that "through design and public service, [students] are able to apply their skills to compelling social issues, gaining real–life experience in the process and broadening their conceptions of what professional practice can be."[7] The Fay Jones School of Architecture at the University of Arkansas fixates on building by hand for the community. According to them, students have "sketched, sweated and hammered through some 16 design/build projects."[8]

Auburn retains its original concentration, but a recent AIA paper by Justin Miller and David Hinson reveals DESIGNhabitat's expanding aspirations to target design-based research objectives. The ambition is that DESIGNhabitat projects should fulfill one of two goals, (1) to test hypotheses or (2) to demonstrate the effects of integrated design strategies.[9] Simulation becomes a crucial apparatus in scrutinizing a design from component to full working prototype, as students probe the limits of digital tools and technologies.[10] They evaluate the performance of preliminary designs to analyze the potentials before any actual building phase. But, still, the program has its limitations; the evolution of programmatic phases over the past eight years centers on climatic concerns, energy conservation strategies and construction by hand.

TECHNOLOGY AND DIGITAL FABRICATION IN ARCHITECTURAL ACADEMIA

Design-build programs of this traditional type have often been critiqued because the architects (or students) restrict themselves to technologies that are, for the most part, outdated. The incorporation of digital fabrication and automated con-

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struction invigorates the architectural process from concept to production. By informing learning objectives with cutting-edge ideas, the efforts of design-build programs are expanded to more varied results and these studios advance educational outcomes.

Fittingly, the word technology is rooted in the Greek word techne, which refers to both "art" and "skill."[11] Thus, it follows that the utility of digital tools can redefine the relationship between them, strengthening their bond and reaffirming the base meaning of the term technology. Through the use of these technologies, students design in three-dimensions from the beginning, incorporating considerations of how best to fabricate. This can only be approximated in chipboard and graphite on trace paper. The late Marco Frascari comes closest to qualifying the potentials for the bond between construction and thinking in "The Tell-Tale Detail." He describes learning as "an exchange between the construing and the construction and a balance between the thinking about and the making of an artifact."[12] The use of technology in the creative revealing of ideas through construction facilitates this "exchange" and strikes a harmony between design and construction.

Figure 2: DESIGNhabitat, *habitat2*

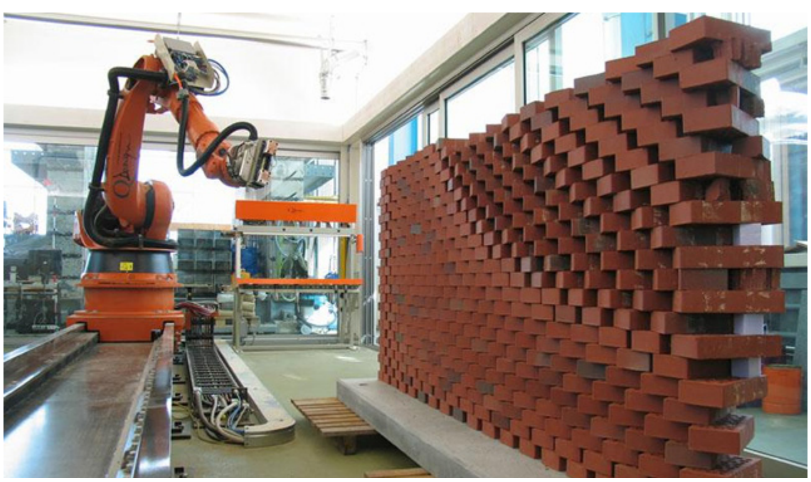
Several academic programs take advantage of digital tools to formulate projects to construct full-scale models that can come in several different forms: a method of assembly, a section, or an entire structure.

DIGITALLY CRAFTED FULL-SCALE PROTOTYPE: METHOD OF ASSEMBLY

Incremental full-scale models give students the opportunity to design complex buildings via elaborate means. This prototyping method analyzes the potential of a building strategy chosen by the students. Research is fully engaged as students use technology to examine a process of design and fabrication. This kind of artifact construction is reminiscent of Jean Nouvel's design of metal sunscreen units with active diaphragms for L'Institut du Monde Arabe. Because these increments can be duplicated infinitely in a field condition, utilizing this unit-based approach allows students to focus on a particular aspect of design or method of construction rather than a particular structure.

The Programmed Wall was a project for a course at the **Swiss Federal Institute of Technology, Zurich** (ETH Zurich) in 2006. This four-week workshop in which students design brick walls to be constructed by an industrial robot is an example of ingenuity in the digitization of assembly. It shows the potentials for translating parametric design to automated construction. Students mastered a method of design by manipulating the positioning of an object in a field, thus allowing for computer-aided assembly and formation of tessellated walls.[13]

The course is described as a step toward future building practices: "if the basic manufacturing conditions of architecture shift from manual work to digital fabrication, what design potential is there for one of the oldest and most widespread architectural elements -- the brick?"[14] The students explored a process that could be the future of masonry construction. Unlike a brick mason, the robot can position each brick precisely, without reference or measurement, and therefore, can work quickly and efficiently. Students exploited this ability by "developing algorithmic design tools that informed the bricks of their spatial disposition according to procedural logics."[15] Designing parametrically with software in this fashion links a part with the whole through a set of defined geometric relationships. This process fosters the potential for the design of a module that acquires multiple variations as it is instantiated across a field. "Even as the design of the field and the module differ, together they invariably form a tessellated pattern."[16] So, instead of designing the geometry of the wall, the students were able to design the constructive logic that can have many formal architectural applications.



3 Figure 3: Programmed Wall, *5-axis robot building one of the wall scripts.*

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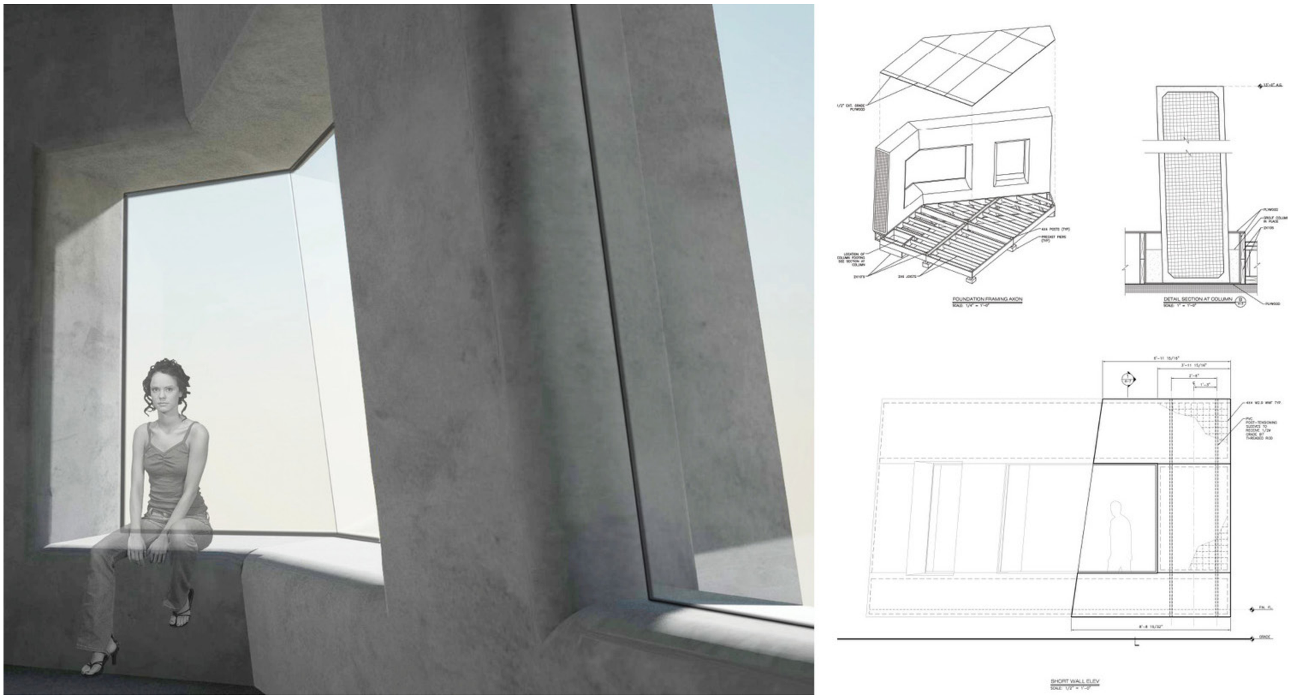

DIGITALLY CRAFTED FULL-SCALE PROTOTYPE: SECTIONAL

The **Georgia Institute of Technology** is one school that employs digital tools and technologies to build sectional models that demonstrate construction techniques. Since joining the faculty as Thomas W Ventulett III Distinguished Chair in Architectural Design in the School of Architecture in 2012, Marc Simmons has pushed his students to explore the cutting-edge. In his Design & Research Studio of Fall 2012, groups of students worked on three separate site-specific buildings for the DUMBO neighborhood in Brooklyn, New York. The objectives of the studio are constituted as: “An analytical and interpretive process may yield a critical design for the building envelope, understood in the broadest terms, and provides ballast for the continued evolution of a set of envelope ideas that quickly emerges into full physical and empirical assessment and development. This question of origination - yielding a set of ideas and positions framing specific envelope designs is profoundly important enabling the realization of technical designs and solutions that not only perform, but engage broader aspects of human experience.”[17] The emphasis for this course was on the development of the building shell through an iterative analysis of context, materiality, systems and performance. The projects were tested through physical models, samples, mock-ups and full-scale prototypes. In the end, the students made extensive use of Georgia Tech’s Digital Fabrication Laboratory to create full -scale testbeds of each specific façade system proposals.

The group that was tasked with the design of a mixed-use development created a complex parametric building envelope. The students built numerous digital models, chipboard scaled models and full-scale styrofoam section models to test their design before fabricating a full-scale segment of the folding facade in the selected material. Because the students chose concrete, they built a formwork from pieces cut using a CNC router, placed rebar and then completed the wall with multiple pours. In the process, they began to understand the complexities of this type of construction in working with consultants and vendors.

Figure 4: Mixed-use development project, *rendering and technical drawings.*

The immediate digital and physical production of models and mock-ups was a critical tenet of the studio employed to interrogate design issues. Each manufactured artifact brought up more questions, begetting the fabrication of the subsequent model to further understand the reality of the projects and aid in decision-making. According to Simmons, the design process is iterative and interwoven: "In a perfect world, it is a continuous, virtuous, spiral-formed cycle of design incorporating and assimilating new information, parameters and understanding."[18] The final review for this studio was part design discussion of architectural choices and of the potential real world issues of the projects, and part field trip in which the jury was invited to see, climb, touch and physically experience the actual spaces created by the students.

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DIGITALLY CRAFTED FULL-SCALE PROTOTYPE: ENTIRE STRUCTURE

Some university programs aspire to create complete structures as prototypes This variety of digital design-build is manifest in complex constructions such as the work done by the Digital Design Fabrication Group at the **Massachusetts Institute of Technology**. For the past decade, Larry Sass has worked with teams of students to rethink building design and construction with the belief that some day, all buildings might be printed by machines run by computers.[19] Through this process, the model becomes the artifact, the building itself. From 2007 to 2008, Sass led a group of students to design a Digitally Fabricated House for New Orleans. Commissioned from the Museum of Modern Art in 2008, this structure illustrates a home delivery system that utilizes CAD/CAM methods.[20] This project was one iteration of yourHOUSE, a reinterpretation of the New Orleans style shotgun house. Each project deployment is composed of recycled plywood friction-fit components, so there is no need for mechanical fasteners.[21] Also, there is no issue of measurement or miscommunication with the contractor, because each of these pieces is drawn to scale and cut by a machine so that it can be put together like a puzzle in only a few days.[22] By applying complex design and fabrication strategies to a project that meets the aesthetic demands of a community, this project provides a plausible paradigm for student design and production of a functioning design-build prototype, a model that becomes a usable structure.

CONCLUSIONS

A research and technology-based approach acts as a linchpin in the design-build process. The very purpose of a design-build program is to explore the limits of

Figure 5: A Digitally Fabricated House for New Orleans, *the final construction in a vacant lot on West 53rd Street near the Museum of Modern Art..*

architecture, teaching students the procedure of converting a design from the virtual realm to the physical as well as establishing a way of thinking. Bernard Tschumi, former Dean at Columbia University School of Architecture, sums up the aspiration of architecture's value of design intelligence in education by suggesting "you want to teach people how to think rather than just to learn the code."[23] Current design-build programs align closely to their Bauhaus lineage by centering on live projects: elastic format designs that encourage research through trial and error. The work is animated and adapts to dynamic external forces. Lisa Iwamoto explains that in her design-build studios "relationships among the design, material, fabrication, and assembly are intentionally kept flexible through the final building stage. The design-build process fosters experimentation, where fortuitous "accidents" may lead to new insights and unintended design consequences."[24] The use of full-scale models via digital craftsmanship in the design studio allows for students to work directly with the intended assemblies and gain real world results when testing ideas. Students are connected to the design process that a practicing architect experiences, as well as a contractor's procedure of building construction. As the studio emulates the flux of real-life experiences, it simultaneously presents a compelling array of concurrent scales and enhanced decision-based thinking.

Architecture is a rapidly changing field. Computer modeling techniques can now be combined with fabrication software, connecting the architect directly to the fabricator. Through CAD and BIM modeling the architect's precise computer model is increasingly an integral mode of representation and construction can be executed directly from it. These advances in technology have also impacted architectural education. Students use the computer to build models and create walk-throughs that simulate the assembly of and the experience of a space. It is essential that these studios continuously evolve in response to technological innovation in which technology transfer, virtual reality, and sustainability set new criteria for performance demands. With this approach, design-build programs result in real-scale products, segments or whole artifacts that form new relationships between architecture and the users. This 1:1 scale experiment is now a significant part of the process as the design community aspires to harness the power of digital fabrication and 3-d print entire houses.

Teaching students digital craftsmanship in the generation of a design and building assemblies is an integral objective for architecture academia. In digital design-build studios, students learn to work through problems with three-dimensional representation tools and production software and better their design process, strengthen the most immediate benefit of design-build projects, the invigoration of the discipline. Positioning digital tools and fabrication within a design-build sequence encourages design innovation at full-scale and pushes the boundaries of architectural education and practice. The use of technology in the production of full-scale prototypes strengthens the bond between design and craft and secures the continual evolution of the field of architecture with universities leading as innovative and boundary pushing epicenters of research and design.

ENDNOTES

1. Kenneth Frampton. Studies in Tectonic Culture, The Poetics of Construction in Nineteenth and Twentieth Century Architecture. (Cambridge: MIT Press, 1997).
2. Joseph Bilello. "Learning from construction: practical hands-on programs teach students about sites, structures, and materials." Architecture Magazine. August 1996: 145-149.
3. Rainer Wick. Teaching at the Bauhaus. (Berlin: Hatze Cantz, 2000).
4. Walter Gropius, ACSA National Meeting, 1959.
5. Wick.
6. Johannes Itten. Design and Form: The Basic Course at the Bauhaus. (London: Thames and Hudson, 1967).
7. University of Virginia. "Community Design + Research." http://www.arch.virginia.edu/research/themes/community.
8. University of Arkansas. "Design/Build | University of Arkansas Fay Jones School of Architecture." http://architecture.uark.edu/281.php.
9. David Hinson and Justin Miller. DESIGNhabitat: design/research + design/build: Expanding the Design/Build Model. American Institute of Architects. http://www.aia.org/aiaucmp/groups/aia/documents/pdf/aiab087197.pdf.
10. Ibid.
11. technology. Dictionary.com. Collins English Dictionary - Complete & Unabridged 10th Edition. HarperCollins Publishers. http://dictionary.reference.com/browse/architect (accessed: September 03, 2012).
12. Marco Frascari."The Tell-Tale Detail." Perspecta 24. (New Haven: Yale University Press, 1987).
13. Fabio Gramazio and Matthais Kohler, Digital Materiality in Architecture (Baden, Switzerland: Lars Müller Publishers, 2008).
14. Ibid.
15. Ibid.
16. Ibid.
17. Charles Rudolph and Marc Simmons. ARCH 6071: Design + Research Studio. Syllabus. Fall 2012.
18. Ibid.
19. Larry Sass. (October, 2011). The House the Larry PrintedL Larry Sass at TEDxBermuda. [video file]. Retrieved from https://www.youtube.com/watch?v=obnhUcetrIo.
20. Ibid.
21. yourHOUSE. Massachusetts Institute of Technology. http://web.mit.edu/yourhouse/project1.html.
22. Lloyd Alter. Home Delivery: Digitally Fabricated Housing. Treehugger. http://www.treehugger.com/modular-design/home-delivery-digitally-fabricated-housing.html. July 7, 2008.
23. Lisa Iwamoto. Digitals Fabrications: Architectural and Material Techniques. (New York: Princeton Architectural Press, 2009), 15.
24. Quatman, 375.