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A Machine for Learning: Materials and Construction in the Beginning Design Studio

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Abstract
An ongoing effort, begun nearly a decade ago by the building technology faculty, seeks to increase integration of the concepts and content taught within the technical courses into design studio work. This has primarily been implemented through lab assignments in the technical courses devised to apply developing technical knowledge to current, or recently-completed design studio projects. This approach has met with considerable success in the later years of the architectural education, after students have acquired a strong foundation of technical knowledge. There is greater difficulty, however, in fluently integrating building technology content in early studios, particularly given a greater fluidity in early design studio content, and a lack of technical knowledge among beginning students.

Disciplines
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Introduction

An ongoing effort, begun nearly a decade ago by the building technology faculty, seeks to increase integration of the concepts and content taught within the technical courses into design studio work. This has primarily been implemented through lab assignments in the technical courses devised to apply developing technical knowledge to current, or recently-completed design studio projects. This approach has met with considerable success in the later years of the architectural education, after students have acquired a strong foundation of technical knowledge. There is greater difficulty, however, in fluently integrating building technology content in early studios, particularly given a greater fluidity in early design studio content, and a lack of technical knowledge among beginning students.

This paper details one attempt to incorporate the exploration of materials and construction within the early architecture design studio. More specifically, the work of the first year, second semester, undergraduate architecture design studio, Arch 202, will be presented. The theme of materials and construction is approached in the studio via the *Machine Project*, a six-week-long "warm up" exercise taught at the beginning of the semester. This project takes a direct approach to technical issues, with a focus on imparting first-hand experience to novice students.

Position of the Studio

Arch 202, taught in the Spring semester of the first year of architectural study, is the third design studio in the educational sequence. It is preceded by Arch 201 in the Fall, and, before that CORE, a basic design studio taken during the freshman year, prior to acceptance into the Department of Architecture. Arch 202 is taught concurrently with the introductory building technology seminar course, conducted as a series of lectures and labs encompassing fundamental issues of materials and assemblies.

A major goal of the Machine Project within the design studio is to compliment this technical content with hands-on exploratory design work utilizing real materials and tools. Another focus of the project is to continue the emphasis on previously-introduced techniques of sketching and technical drawing as integral tools in the investigative and communicative process of design.

The Machine Project

The semester begins with students working in pairs on the six-week-long Machine Project. The work is approached through a structured iterative process with several distinct phases of activity. The process begins with *Discovery* and *Tinkering,* progressing through development of a *Proposal, Prototyping, Testing,* and *Re-construction*.

Fig. 1. Students tinkering.

Discovery and Tinkering

To begin the project, each student pair is assigned one of the following vocations to investigate: physician, astronomer, cartographer, or spy. They examine the particular tools, processes, and methods by which each vocation gathers, organizes, and presents empirical information. These findings are presented and discussed in class.

Concurrent with the Discovery phase, students engage in Tinkering (Fig. 1). Each team acquires a minimum of three mechanical objects having one or more moving part. They disassemble the objects, creating exploded axonometric drawings, attempting to understand, document, and communicate construction and mechanical operation. Using only elements from their disassembled objects, the students must assemble a new hybrid capable of mechanical operation. The Discovery and Tinkering phase of the project concludes at the end of the first week of the semester.

Next, the students receive the Machine Project brief in which they are challenged to:

design, prototype and construct a full-scale instrument to mediate a relationship between the user and the physical environment, while interpreting, heightening, or re-presenting a particular observable phenomenon such as gravity, light, sound or wind. [1]

These instruments are to be “interactive with, or activated by the human body (and to employ) mechanical movement as an essential element.”[1]

Proposal

In the second week of the project, each team begins an iterative ideation process. Exploring emerging concepts through sketches, diagrams, and working models (Fig. 2), they test and develop initial ideas. This process culminates in the creation of a design proposal, in which the students prepare a written statement outlining the intended relationship of their Machine to physical phenomena, human experience, and the nature of the mechanical movement employed.

Prototyping and Testing

Following instructor critique and refinement of the proposal, students develop a working prototype, exploring issues of material and connection performance, mechanical movement, structural stability, interactivity, ergonomics, and experiential effect. After two weeks of development, the prototypes undergo testing. Through a “gallery-style” review, students are able to demonstrate and observe performance while receiving feedback from instructors and peers inhabiting, operating, and interacting with their prototypes.

Re-construction

Based on prototype performance, students spend the final two weeks of the project refining and rebuilding the Machine. The final full-scale and functional machine is accompanied by a measured, exploded axonometric drawing communicating the details and choreography of construction.

Machine Project Intent

The sequencing of tasks is orchestrated to avoid overwhelming the students with the complexity of the entire project at once. The delivery structure divides the project into discrete phases, each with a clearly-defined set of goals and deliverables. Through these activities, students gradually build competence and confidence in new ways of working and thinking, with each phase building toward the next.

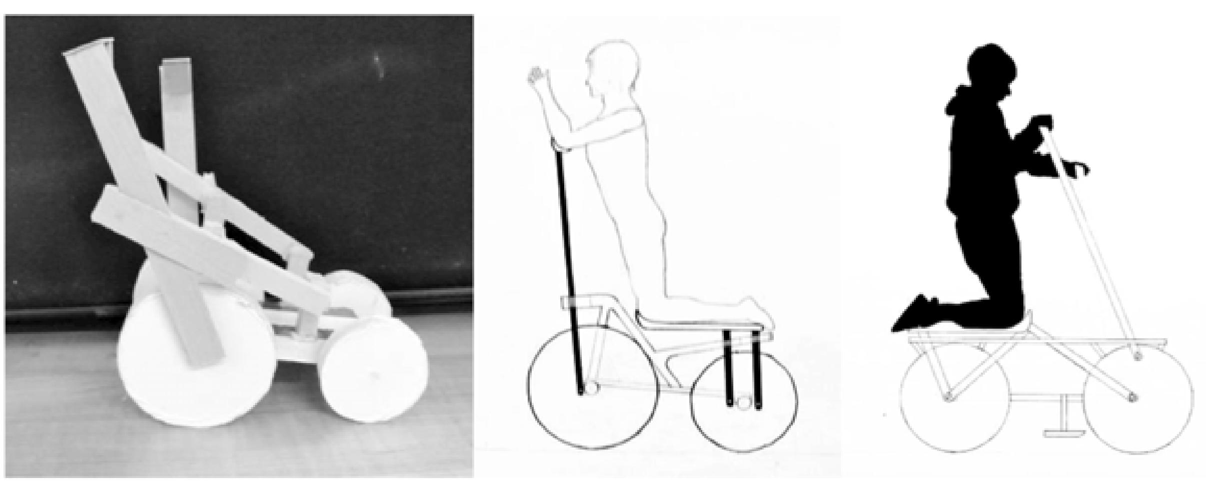

Fig. 2. Developmental drawings and model.

This approach also creates multiple avenues for conceptual engagement. One student group may develop an interest in exploring the techniques and methods used by the vocation assigned to them in the Discovery phase. Another may pursue implementation of a particular mechanical operation discovered while tinkering, while others become interested in creating a particular kind of user experience or interaction with phenomena.

The research, presentation, and discussion of the initial Discovery phase serves to expand students' awareness of the multiplicity of experiential phenomena, and the means by which they are observed, measured, and recorded. These activities also help to create a foundation of shared vocabulary and experience among all students.

The process of deconstruction, documentation, and reconstruction in the Tinkering phase not only introduces students to, but immerses them in issues of materials, connections, and assembly in an immediate and intuitive way. They are challenged to inventory, examine, assess, and inventively recombine physical constructions, but, at this stage, not to *design*. This helps to obviate any "design paralysis" that can affect novice students when confronted with new and unfamiliar concepts and processes.

The awareness and experience gained during Discovery and Tinkering, forms a conceptual foundation, enabling student to "jump in" to the development of their proposals and to continue with the primary work of the Machine Project.

Charles Eames identified one key to design as "the ability of the designer to recognize as many of the constraints as possible, his willingness and enthusiasm for working within these constraints. The constraints of price, size, strength, balance, time and so forth. Each problem has its own peculiar list."[2] Constructing a full-scale, fully functional prototype brings such constraints into sharp focus in a way not possible via the drawing and digital or physical modelling methods typically employed in design studio.

The demonstration of built prototypes in the gallery review provides a venue for students to critically assess their own work and identify critical functional failures. These failures become learning opportunities, illuminating design constraints and serve to inform further development of the design.

Fig. 3. Prototype pre-, and post-collapse.

By first-person observation of performance under real conditions, students are presented with clear and measurable success criteria: the Machines must operate, they must hold together, they must stand up, they must manifest phenomena, they must accommodate human interaction. Students learn to not only accommodate, but, as Eames says, *embrace* these requirements to achieve success. The "all-or-nothing" stakes of the project create a productive, if demanding design challenge, interweaving multiple issues of function and construction with aesthetic, conceptual, and experiential aspirations.

The Re-construction phase requires students to substantially, or completely rebuild prototypes to address not only inadequacies of operation, interaction, or stability (Fig. 3), but to refine connections and improve the craft and the quality of fabrication (Fig. 4).

Many projects proved unstable due to structural or connection shortcomings. Others could not perform their mechanical function, due to issues such as friction, inaccurate fabrication, or wear and tear on materials. Some failed to satisfactorily manifest physical phenomena. Interestingly, a great number of students were dissatisfied with the "user interface" and ergonomics of their machines. Under the lens of actual use, it became obvious that much more consideration for user experience and interaction was required.

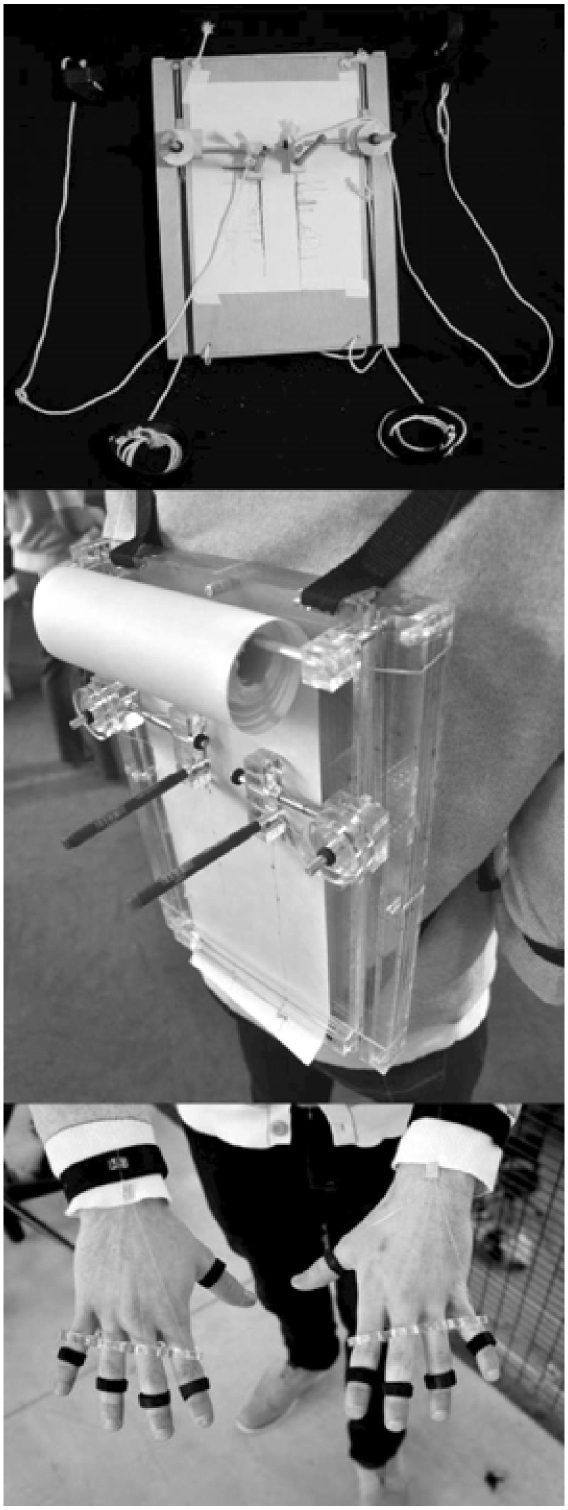

Fig. 4. Prototype (top) and Re-construction with functional and material refinements (middle and bottom).

Observations

Based on faculty observations, The Machine Project has proved wildly successful at generating student investment. Students became extremely invested in making their Machines work. The 'make it work' attitude created a heightened sense of urgency and responsibility and a greater sense of accomplishment when they achieved a successfully operating machine.

The Machine Project has also proven successful at introducing students to a multitude of issues difficult to engage through speculative "paper projects". These include technical design issues such as: material properties, tools and processes, joinery, cost analysis, structural stability, load path, and connections, as well as broader design issues of collaboration, iteration (from conception, to failure, to redevelopment, to success), and human perception/sensation.

In an effort to assess student perceptions, the faculty circulated a brief questionnaire in the following semester, soliciting input regarding the value of the Machine Project and the lessons learned therein. About one third of the class responded, and of those, no negative comments about the project were identified. This general positivity may be due to the disposition of students likely to respond to a non-required request for written work, but we were impressed by the insight and regard for the project that the students demonstrated in their responses.

Regarding the design process, Victor Valadez noted, "It forced me to think more about the entire process of how to design and build instead of just designing a form." This indicates an understanding of buildings, not as objects, but as assemblages, constructed of physical material in a physical process occurring in time and space. The identification of designing more than a form is also an indicator that students are aware of how built realities affect human experience beyond visual inputs. The awareness of the multiplicity of human sensation is one of the primary objectives of ARCH 202, whereby the Machine Project requires a sensation tested design throughout its development and refinement.

Joshua Neff stated, "Drawing can only convey so much. I think that having to construct (the machine) helped me to better understand (the role of) a construction document to explain the design." Similar comments were present throughout the responses, identifying that the students acquired real awareness of the false reality of drawn or modeled space, particularly when the students have a limited knowledge of building science, material technology, and construction practices. Student Alexandra Lunning explained that, "we are taught about materials, construction, and structures in our technology classes, but the machine project was a great introduction into the actual construction of objects and the forces at work within them." Understanding inherent disconnections between theoretical knowledge, drawing, or model, and potential built reality, is a major underpinning of thoughtful and considerate design. The Machine Project develops in students a nascent awareness of these disconnects, ideally enabling them to begin to anticipate such issues in their future work.

Admittedly, the evaluation of outcomes of the Machine Project has exposed some trade-offs as well. There was a very real struggle, later in the semester, to apply lessons learned from the Machine Project to a building design. This is partially attributable to the shift in scale, from object to building. More importantly, perhaps, was the absence of real feedback and productive constraints inherent with the limitations of a paper project. As student Zhaoyu Zhu observed, "Errors occurred throughout the process of (making) the machine. Small errors might not affect a drawing, but one small error can determine whether your machine works or not." Zhu discusses The Machine Project in terms of working or not working. This language addresses obvious physical requirements of structural, material, and mechanical performance, and ergonomics. These issues are unavoidable when dealing with a full-scale, interactive construction. However, when the students are tasked with designing a building or larger structure, the exploration of concepts and physical-spatial proposals is approached by the limited avenue of traditional design representation, conducted at reduced scale, typically in two-dimensions. Designs on the page or screen are not affected by the forces of friction or gravity, so there are no measurable, testable criteria to make manifest failures of physical performance.

Paradoxically, additional difficulties which emerged following The Machine Project typically related to a lack of fluency with these very representational strategies. Despite production of supporting technical drawings, the Machine Project is primarily a hands-on exercise. This focus does not contribute to a foundation of traditional architectural representation techniques in the beginning weeks of the studio, resulting in poorer representations of the more abstract buildings later investigated in the semester. By favoring the tactile, haptic, physical, and measurable, the Machine Project sacrifices development of the students' capabilities with abstraction and representation.

Conclusion

The end goal of Architecture is not representation, but construction, and the Machine Projects serves as a first-person introduction to issues of construction. Material performance and constructional concerns are not readily apparent to inexperienced students, and can be easily ignored when working with pencil, mouse, or model. The Machine Project begins to give students some awareness of the immensity of the gap between the drawing board and the construction site. While almost any imaginable form can be virtually modelled, construction is a physical process, with inherent limitations and potentials. Through this exercise, students gain direct experience with materials, developing an understanding of their particular expressive and performance qualities. They begin to understand that technical issues of material, form and construction can be, and often must be, integral to design concept, and that competent employment of material and form for functional effect often determines the success or failure of a project.

The Machine Project has thrust building science and material technology issues into the heart of the design studio. Moreover, through the Machine Project, practical understanding of design intent, material limitations, and human perception and experience has been set forth as a foundational element of architectural education. This approach could be considered a reverse-engineering of our typical approach to technology labs as overlays or add-ons to the design studio. The project serves to broaden student's awareness of the potential of their designs to be not just an idea or object, conceived and depicted, but physically realized construction capable of creating particular interactions and experiences. Particularly through the building, testing, and re-building of full-scale prototypes, students become aware that a host of additional performance issues, relative to user interface and experience, are critical design drivers. The typical design studio tends to be dominated by conceptual or aesthetic concerns and an often speculative approach to problem solving. The Machine project weights structural, functional, and experiential success equally with concept. As student Zhaoyu Zhu commented, "Concept is only one part of the project. If you have a sweet concept but the machine doesn't work, the concept is not that attractive."

The injection of the traditionally disparate concerns of building technology courses into the beginning design studio through the Machine Project empowers young designers with the knowledge that building performance is a substantial determinant in the success or failure of any project's development in their future architectural careers.

Notes

[1] Rhodes, Patrick. *Machine Project Brief,* ARCH 202, Iowa State University, 2013.

[2] Eames, Charles. *Design Q & A*. Dir. Charles Eames, Ray Eames. 1972. Film.

Figures/Images:

Fig. 1. Spiller, James, photographer. 2013

Fig. 2. Hamman, Michael & Hull, Donald Hull. Machine Model and Drawings, ARCH 202, Iowa State University, 2013

Fig. 3. Spiller, James, photographer. Bannik, Charlotte & Wuest, Laura. Machine Prototype, ARCH 202, Iowa State University, 2013

Fig. 3. Spiller, James, photographer. Lick, Jacob & Pigeon, Will. Machine Prototype and Re-construction, ARCH 202, Iowa State University, 2013