

Kinetic Forms of Knowledge for Design

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Abstract

The introduction of Kinetic design processes, particularly through computer aided programming of input and output relationships has created a unique territory for design. This new design territory offers architects a unique opportunity to rethink discreet typological design by fostering more active engagements and interventions with design. Unlike discrete-typological design thinking, which may be transmitted by books or lectures, these new Kinetic interactions with design are taught by example and are learned by doing, representing new emergent forms of design knowledge which allow us to reengage and reinvent the process of design.

Keywords: Kinetic architecture; Personal fabrication; Action research; Constructivist learning theory; Computation.

Introduction

Recent technological innovations of low cost sensors and actuators are creating many new possibilities for the design and utilization of kinetic elements in architecture. As innovators in the fields of computation and engineering develop the tools and technology for environments to physically change in response to human need, reduce demand on resources, and improve functionality, the potential for reconfigurable architecture is expanding. Therefore, understanding computation, mechanical design, and digital fabrication constitute new forms of knowledge critical for educating the future architects.

Concurrently, development of a new generation of computer technologies presents significant opportunities to transform the teaching and learning landscape. These technologies are enabling us to rethink the traditional use of computers in delivering information by engaging them beyond the flat interface of the screen. Using programmable objects, physical computing, rapid prototyping, and personal fabrication are all powerful vehicles of active and experiential learning in the classroom and beyond.

In addition, while kinetics may have historically been considered a field outside of the more static and stable field of architecture, architects are now finding more interaction with kinetics at many scales. This paper argues that new opportunities for responsiveness in architecture combined with the advanced capacity of computing for education, represents unique possibilities to transform Architectural design process and thus reexamine the functionality of buildings. To substantiate the idea of kinetic responsiveness as an active intervention in architecture through technology mediated learning environments, we will

examine the context and pedagogy of a recent elective class entitled "*Kinetic Architecture*" offered at Florida International University by the co-authors of this paper.

Pedagogical Context

The research for planning *Kinetic Architecture* class began by examining the methodology of *How to Make Almost Anything*, a well-known class at MIT's Center for *Bits and Atoms*, taught by Neil Gershenfeld. This recurring class is offered to the general student body and is open to participation from all disciplines. The class teaches design intended for the market of a single user through personal fabrication utilizing a "bottom-up" technological approach.

The pedagogical model for *How To Make (Almost) Anything* builds on a series of weekly digital fabrication exercises covering a wide range of Do-It-Yourself topics. These include, physical fabrication such as laser cutting, water jet-cutting, CNC-milling, 3D printing, along with programmable topics such as milling programmable circuits board from scratch, laying out electronic components, and connecting input and output devices.

The net combined effect of all of these exercises is to enable students to personally generate designs, which aren't commercially available, that is, something you couldn't buy. Gershenfeld argues that we shouldn't be constrained to large-scale mass-market technologies to develop new innovations, citing the schism between end-user and product (Gershenfeld, 2005). Given the tools and support in the class, students learn many of the fabrication technologies used by large-scale corporations and

manufacturers, reconnecting the end user with the manufacturing of the products themselves. This represents a more personal relationship between user, technology, and products. This is a bottom up approach to innovation that Gershenfeld refers to as "Personal-Fabrication"(Gershenfeld, 2005).

Engaging students with direct and hands on experimentation with materials and technologies leads to a different type of knowledge and judiciousness. In this class it isn't enough to simply have an idea for a design represented by renderings, rather the design must be made to work in order to be successful, a task ordinarily left to other phases of research and development. According to Gershenfeld the humanist distinction between the "liberal arts" and "illiberal arts" separated the making of ideas, from the making of things (Gershenfeld, 2005, p. 7,34). He argues if libraries were historically the places for communities to access information and knowledge from books for the purposes of personal education, fab-labs are the new communal places for accessing a more active and hands-on knowledge for learning how to make anything we specifically want, instead of a product for a mass audience(Gershenfeld, 2005, p.12).In other words, a new type of knowledge is gained directly from the fabrication processes rather than learning from a book or a lecture, a concept the philosopher Manuel Delanda refers to as the divide between "*Knowing That*," and "*Knowing How*" (DeLanda, 2013, p.73).

Delanda describes the philosophical differences in ontology between the idealists, empiricists, and realists, noting that idealists and empiricist philosophers tend to assume that all knowledge is representational, something he calls *Knowing-That*.He argues that both idealism and empiricism fall short of a more active knowledge, a knowledge that he calls *Knowing-How*. '*Knowing-How*' results from more active interventions and experimentations to produce knowledge. "Unlike *Know-that*, which may be transmitted by books or lectures, *Know-how* is taught by example and learned by doing" (DeLanda, 2013, p. 73). This type of more active knowledge gained through direct hands-on experimentation became the pedagogical ambition for our class.

Constructivist Learning Theory

Gershenfeld's class utilizes a hands-on pedagogical model, based on constructivist learning theory. This approach assigns a high educational value to constructing "tangible objects" as a vehicle for learning and sharing knowledge. According to this theory, learning happens from creating or constructing concepts into objects or products that are relevant to students' lives (Warren, 2012).From this point of view, learning is an active, constructive process through which new information, ideas, or skills come together with purposeful ways of engagement with objects and others (Smith and MacGregor, 2005, p.1). Vygotsky, a well-established educational theorist, argues that humans are unique in that they are born into environments shaped by the activities of previous generations. The human capacity to make and use

artifacts is therefore a key component in our ability to learn as we enrich and extend knowledge through an individual's appropriation and mastery of the cultural inheritance (Wells, 1999).

Although constructivist theory has been increasingly recognized across many educational fields in the past decades, it does not introduce a novel approach in architectural education as it essentially describes the architectural design studio model. However, Gershenfeld's approach to constructivism utilizes advanced computational technologies in combination with personal fabrication skills such as machining, and microprocessor programming as a venue for active participation in learning not knowing what the outcome will be. This combination offers valuable lessons for architects, as the personal fabrication model is essentially non-representational, but is rather about the process of realizing a design by actually making it or learning through *Know-How*.

Gershenfeld's relationship to constructivist theory advances the idea of active learning further by what he calls *just-in-time* education. He states that "you let people solve the problems they want to solve, and you provide supporting material they can draw on as they progress"(Brockman, 2013, p. 14).Based on this idea, creation of a "tangible object" should not only relate to the students' life experiences, but also should embody a problem that they want to solve. As is the case in his class, by creating things they desire, students express themselves technologically, and produce things for living in the world they want to live in (Brockman, 2013, p. 14). This personal production represents a bottom up approach for design and a shift from architectural education of the past, which often aligns with *Just-in-case* thinking.

Kinetic Process Design

The relevance of kinetics to architecture raises two questions: first, what is the relationship between motion and buildings that are historically static artifacts? Second, how can architects engage with movement in a meaningful way?

In a comprehensive book on the topic of kinetics in architecture, Jules Moloney suggests that a relative lack of kinetic architecture history is a significant challenge in that it deprives the field from access to sufficient precedents of historically based studies and research. The author states, "The lack of content and a step outside the tradition of static form provide a challenge for this new field of research, as there is no coherent body of theory to reference, nor are there sufficient designs to critique" (Moloney,2012, p.3). Kinetic influence on architecture is a broadly unexplored relationship.

In our Kinetic Architecture class we approached the absence of precedent not as a constraint but as a liberating element. This allowed us to think outside the constraints of historical models, an

Idea that Jan Knippers, explains as the shift “From Model Thinking to Process Design” (Knippers, 2012). Knippers argues that the introduction of computational design processes, recasts the roles across the design team, and offers the opportunity to break from the barriers of conventional model thinking to embrace process thinking and new forms of interaction.

Knippers defines conventional model thinking, as the practice of thinking in discreet typologies, using the example of the hinged arch’s calculability verses that of the cable-stiffened arch. He states that although the hinged arch is not more efficient than the cable-stiffened arch, it has allowed an exact and reliable calculation of internal forces. So even at the end of the previous century, when the limitations of calculability has no longer been an issue, nearly all large exhibition halls still use three-hinged arches. He argues that this is the negative result of *Model Thinking*, which defines individual models as a set of well-defined rules for the development of geometry and calculation of internal forces. Clear boundary conditions and limitations only allow for solutions within a specific framework, in other words thinking in discrete typologies (Knippers, 2012, p. 77).

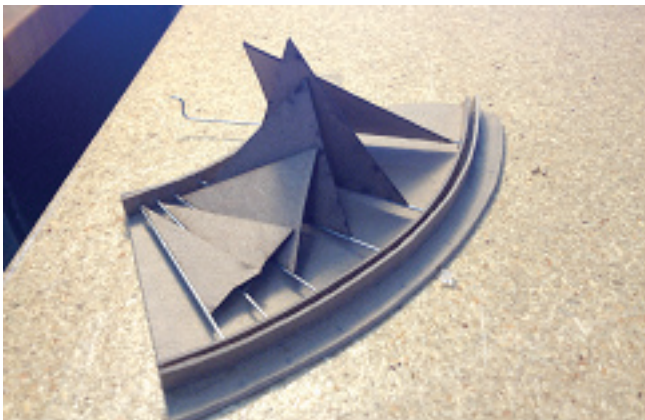


Figure1: First stage in exploration of motion by a student

How could kinetics in architecture allow the possibility to break through the barriers of *Model Thinking* and begin to operate outside the boundaries of discrete typological thinking? Knippers’ response would be that new forms of interaction between the various designers, architects, and engineers would be made possible through computational design and manufacturing strategies (Knippers, 2012, p.81). As there exists a lack of a clear history of kinetic forms of architecture, learning methodology can be directed into different trajectories, and knowledge could thus be attained through direct interaction with the medium, in this case the production of movement.

For our class, therefore, it became important to reconsider how buildings could move and in what capacity the design of movement itself could recast the architectural design process. Posing a series of How-To exercises and having students go about learning through iterative studies of motion suggested a seamless fit with collaborative bottom up learning methodology discussed previously.

Kinetic Architecture Seminar

In the *Kinetic Architecture* seminar, we began by asking students to examine the components of movement and define machines and mechanisms. Understanding that all complex machines are the result of six simple machines, students were then asked to build models capable of rudimentary movement, using one of the simple machines or mechanisms they studied. Students began making quick mockups of these simple machines out of provisional materials like paper and plastic. This was an important step to experiment with the fundamental building blocks of movement and producing movement and motion itself, not the representation of movement as form.

Once students successfully mocked up their simple machines, they experimented with combining multiple mockups into various combinations and assemblies. Their motion experiments became combinations of simple machines, which produced more complex procedures. Students explored six types of motion; Rotary, Oscillating, Linear, Reciprocating, Intermittent, and Irregular that could be converted, from one to the other.(Roberts, 2010, p.23)



Figure2: Second stage in exploration of motion by a student

Motion conversion options allowed these simple machines to act responsively. We asked students to consider how their simple machines could act as mechanical inputs, which could then be converted into other mechanical movements as outputs. Some of the typical combinations of simple machines students worked with included cranks, cams, and followers, and linkages. Students moved beyond developing these more complex combinations of machines, producing various strange mechanisms without any assigned value or work. These included drawing machines, kinetic sculptures, and generally folding and unfolding studies.

The class also provided a workshop for teaching how to use “Arduino”, which is a microcontroller kit of parts for developing software based interactions between sense-able inputs and actuator based outputs. The workshop was designed to help students to transform environmental inputs into kinetic outputs.

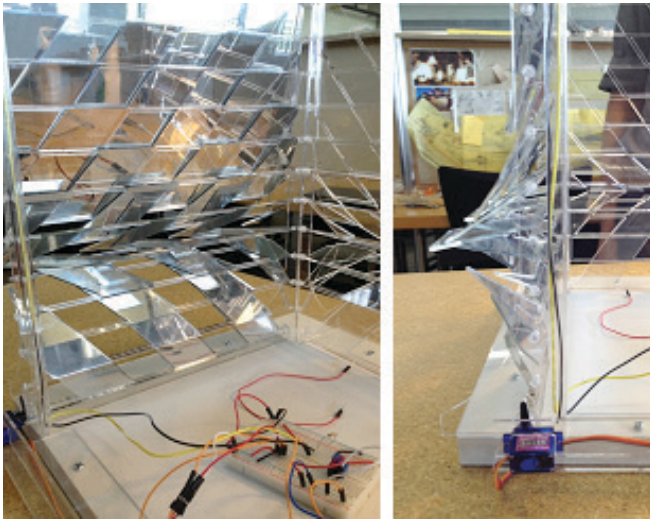


Figure 3: Responsive Facade Device designed by two students

Students were introduced to the component parts that come pre-packaged and add-ons to the Arduino environment. Low-cost Sensors and Actuators can be easily sourced and connected with Arduino, to facilitate analog to digital conversions options using computation instead of physical machine building. Some students had the ambition to produce a type of movement conversion but struggled with programming language to accomplish the movement- a task not familiar to typical architecture design development.

Students were asked to work in collaborative groups of two, combining their individual machines into combined studies for designing new architectural applications. Figures 1-3 show images from the process and the final outcome of an example project from this class. This group of two students produced a prototype for a façade shading device that moved vertically in response to photo-sensors placed on the roof of a building. The device was broken down into a large number of small panels. The movement of each panel was controlled by the movement of the panel directly below as a cascade effect. The movement was initiated by a servo connected to the Arduino board. All panels were shaped as parallelograms, so when they were completely down, they could block the light entirely, by producing an overlapping configuration. When the panels were up they formed gaps through which only partial light entered the building. In the final version of the model the students added a reflective coating to the panels for selective tinting.

Conclusion

Our approach to the *Kinetic Architecture* class is of value to the discipline and pedagogy of architecture for a number of reasons. First, it represents a new design territory which offers architects the unique opportunity to engage in bottom-up, personalized, design know-how, thus recasting the familiar design process by fostering more active engagements and interventions with design.

Second, requiring the physical production of motion, instead of only flat representations of form, is learned through a different form of knowledge, one which isn't communicated in books and lectures, but rather through hands on experimentation and practice. This approach is a shift away from architecture as a discipline, which has become divorced from the means and methods of making. These more active engagements reconnect architectural design with the means and methods of construction, by reincorporating *Knowing-how* into the process of design.

The knowledge of *Knowing-How*, is of particular use in that it allows students to find new forms of design thinking by recasting the process of design. Instead of developing a set of two-dimensional representations as solutions to a well-studied problem, these students were required to use movement to suggest the new problems to be solved. These new problems required practicing and learning through experimentation to build structures which actually moved and demonstrated a proof of concept. This proof of concept suggests a new type of deliverable for architecture beyond the flat representation. Providing students with the Know-How of Kinetics allowed them to imagine in new ways design interventions which challenge contained typological *Model Thinking*, by building new relationships from the bottom up. This Bottom-up approach, while brief in our one-semester class, allows for proposals which are re-imaginative, in that they imagine a new world, instead of only providing solutions to a clearly defined, reductive one.

Lastly, Arduino and other computational environments are increasingly providing architects and designers access to new forms of personalizing design through what Knippers calls *Process Design*. This allows the very process of architecture to be unbundled from its representational *Model Thinking*. With new tools comes the capacity to rethink and re-imagine how we do architecture, and the practice of learning, '*Knowing-How*' instead of the '*Knowing-That*' necessarily requires new formations of design knowledge and process. Although Kinetic Architecture represents only one approach towards considering these new possibilities for architecture and design, it has the capacity to precipitate new collaborations with more active bases of a design knowledge, which is not static, but moving, and in this way Kinetic.

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