Critical Making

Exploring the Use of Making as a Generative Tool

An engagement with the senses is essential to the creation of closeness and intimacy between people and their environment. It follows then that the development of this way of thinking about the built environment should be prominently addressed in the training of future architects. If an architect has the opportunity - or responsibility - to encourage haptic engagement between people and space, then that process would benefit from the introduction of a multi-sensory experience during the design process itself.

Critical thinking, or the reflective practice of reasoning, is frequently employed in the university classroom to assist students in solving problems. However, within the design professions, amongst others that have a close relationship with the manipulation of matter, there is another construct to utilize in the process of problem solving: critical making. Critical making is positioned at the intersection of the 'scholarly' work of thinking and the material work of making; it serves as a catalyst for design, embedded in a process of craft, material, and exploration.

This paper outlines the pedagogical basis for the use of critical making in the educating of novice architecture students and demonstrates its applicability in the architectural design studio. Through this reflective process, students are presented the opportunity to gain insight into both their work and the materials of design and construction.

Education…becomes an act of depositing, in which the students are the depositories and the teacher is the depositor. Instead of communicating, the teacher issues communiqués and makes deposits which the students patiently receive, memorize, and repeat. This is the 'banking' concept of education…. (p. 58)

In this passage, Paulo Freire (1970) describes the typical, and unfortunate, reality of many curricular structures at all levels of education. In this learning environment, teachers preach facts, theories, and other information to students isolated in windowless classrooms or, in a contemporary construct, sitting at home on their computer in an online forum. The students hear the words (or read the powerpoint), but they seldom see and very rarely do anything to reinforce or extend the depth of the information received. With regard to this practice, John Dewey (1938, p. 26) would likely comment: "How many students…were rendered callous to ideas, and how many lost the impetus to learn because of the way in which learning was experienced by them?"

Mike Rose illustrates a similar issue, but from the opposite perspective, in *Mind at Work: Valuing the Intelligence of the American Worker.* Rose (2004, p. xv) states "our testaments to physical work are so often focused on the values such work exhibits rather than on the thought it requires… It is as though in our cultural iconography we are given the muscled arm, sleeve rolled tight against biceps, but no thought bright behind the eye, no image that links hand and brain." It is the perceived disconnect between the head and the hand that binds these two passages. There have been considerable efforts put forth over the last century to separate acts of thinking from acts of doing both in the classroom and in the workplace (Crawford, 2010). Currently, higher education places great emphasis on what Matthew Crawford (2010, p. 161) describes as universal knowledge, or "knowing that," over individual experience, or "knowing how." While universal knowledge can easily be conveyed in the classroom, online, or in any other forum due to its detachment from experience and place, the practical knowledge of knowing how to do something is always tied to the individual experience of the person who is learning. This latter form of learning must be attained through embodied interaction with reality; a practice that is not always embraced as a curricular priority.

Freire (1970) argues that in order to combat this disconnected pedagogy, a shift must occur that centers learning initiatives on the development of "critical consciousness" within the student. Critical consciousness is established, according to Freire, through the personal engagement with and the active exploration of abstract concepts. This process is one of experiential learning: the "process whereby knowledge is created through the transformation of experience (Kolb, 1984, p. 38)."

Experiential learning includes a wide range of methods that put the learner in direct contact with the realities being studied (Kolb, 1984). Arthur Chickering (1977, p. 86) explains that experiential learning "turns us away from credit hours and calendar time toward competence, working knowledge, and information pertinent to jobs… It reminds us that higher education can do more than develop verbal skills and deposit information in those storage banks between the ears." These ideals allude to a learning environment very different than the one outlined in the opening quote; one in which the mind and the body are united in a search for knowledge, a premise reinforced by current research outlined in the study Bodies of Knowledge (Claxton, Lucas, & Webster, 2010).

Although many different methodologies have been employed in the delivering of experiential learning content, all center on the idea that this style of learning is focused not on a product or deliverable, but on the development of a working process. Within experiential learning pedagogy, ideas are not seen as fixed. Instead they are allowed to develop, evolve, and reform based on the experiences of the learner (Kolb, 1984, p. 26). Jean Piaget went as far as to conclude that intelligence itself is not innate, but "arises as a product of the interaction between the person and his or her environment (Kolb, 1984, p. 12). Within this mode of thinking, the process of developing intelligence is the critical factor, not the physical result of the activity undertaken.

Designer Thomas Heatherwick (2012, p. 22) illustrates just such an engaged working process through a brief narrative:

While I was studying, I developed a particular way of thinking through making. Instead of always starting with a drawing or a discussion, I used the making of test pieces in the workshop to find ideas. Adopting a spirit of purposeful aimlessness, I was trying to avoid needing an outcome. Although giving myself permission to experiment, I remained open and receptive to the possibilities that the materials in my hands were offering, ready to convert them into something useful. Making them, I was wondering how each one might translate to the scale of a building or piece of furniture…

Heatherwick's process highlights the development of ideas over product while engaging with material construction. Experiential learning, as Heatherwick describes, in which engagement takes place through "kinesthetic, hands-on/minds-on" activity is typically referred to as active learning (Smith, Knapp, Seaman, & Pace, 2011, p. 3). Active learning engages the mind through the activation of the body, fully absorbing the student in the pursuit of knowledge.

Active experiential learning activities such as Heatherwick's, bring together two modes of engagement that are often held separate: the conceptually and theoretically based practice of critical thinking and the goal and material based practice of making (Ratto, 2011, p. 253). The process can be classified as one of critical making: a pedagogical construct that can help students develop Freire's critical consciousness. While engaged in critical making, abstract concepts are explored through the creation of physical things. Through this process driven learning strategy, students can develop new ways of seeking knowledge.

But critical making - and experiential learning in general - has the ability to develop more than just student intelligence. This is particularly true in the fields of architecture and design (although certainly not exclusively) where critical making has the potential to create a sense of nearness and intimacy between the student and the tangible elements of a curriculum or profession. In *Hapticity and Time,* Juhani Pallasmaa (1999, p. 2) argues passionately for the promotion of the haptic in the design of the built environment:

Our culture of control and speed has favoured the architecture of the eye, with its instantaneous imagery and distant impact, whereas haptic architecture promotes slowness and intimacy, appreciated and comprehended gradually as images of the body and the skin. The architecture of the eye detaches and controls, whereas haptic architecture engages and unites. Tactile sensibility replaces distancing visual imagery by enhanced materiality, nearness and intimacy.

Haptic, which typically refers to the sense of touch, is gradually transforming into a "synonym for the emotive and multisensory experience of architecture" (Mallgrave, 2011, p. 189). It can be argued that if an engagement with the senses is essential to the creation of intimacy between people and their environment, then the development of this thinking should be prominently addressed in the training of future makers, designers, and thinkers. For example, if, in the process of design, an architect has the opportunity and responsibility to encourage engagement between people and space, then that process would benefit from the introduction of inspirational haptic experience into the design process itself. Critical making can provide that opportunity.

Recent studies have shown that the brain may be wired to put 'doing' before most other commands, even 'thinking' (Claxton et al., 2010). As such, students must be encouraged to occasionally move outside their comfort zone, stop overthinking, and engage in embodied exercises that offer alternative avenues to knowledge. This paper first analyzes the constituent components of critical making: thinking and making. It then outlines the potential opportunities available to students when these two traditionally disparate methods are utilized in the same classroom, illustrating the resultant potential of this pedagogical construct.

Although the conclusions made about critical making can be applied to students in many disciplines, this discussion focuses specifically on a study of the utilization of critical making in the architectural design studio. The use of critical making as a generative tool in the design studio has the potential to not only develop architecture students' abilities to engage with, critically and creatively work through, and ultimately solve design problems, but also to help instill within these same students a better understanding of the relationship between people and their environment.

PROCESSES OF THINKING

Although there are certainly numerous modes of thinking that are of value to students, two are of particular interest for this study: *critical thinking* and *lateral thinking*. William Graham Sumner (1940, p. 632) believed critical thinking involved "the examination and test of propositions of any kind which are offered for acceptance, in order to find out whether they correspond to reality or not." Michael Scriven and Richard Paul (2013) expand on Sumner's message:

Critical thinking is the intellectually disciplined process of actively and skillfully conceptualizing, applying, analyzing, synthesizing, and/or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action. In its exemplary form, it is based on universal intellectual values that transcend subject matter divisions: clarity, accuracy, precision, consistency, relevance, sound evidence, good reasons, depth, breadth, and fairness.

A more structural definition cites critical thinking as an act of reasoning; when an individual critically thinks, he or she "actively links thoughts together in a way that allows [him or her] to believe one thought provides support for another thought" (Hughes, Lavery, & Doran, 2010, p. 19). Critical thinking involves the positioning of arguments, also known as inferences, in which one or more statements - the premise(s) - are claimed (or inferred) to support another - the conclusion (Hughes et al., 2010, p. 21) (Figure 1). In this construct, there can be valid arguments (called syllogisms) or invalid arguments depending on the logical or illogical construction of the argument.

Three key tasks are involved with the creation or analysis of sound arguments. First, the critical thinker must determine the meaning of the argument. Without this clarity, the soundness of the argument linking the premise and the conclusion would be difficult, if not impossible, to ascertain. In order to accomplish this task, the thinker must learn how to interpret the types of statements and arguments presented (Hughes et al., 2010, p. 26). In academia, a student must clearly understand a given problem statement, delineating opportunities and constraints, primary and secondary considerations, contextual issues, and other relevant data. These practices of observation, organization, and interpretation require the development of a formal and experiential knowledge base, which happens over the course of the education of the student. At this point, the student must also understand the language of the given problem or find a means of learning it from the variety of sources available including the instructor, classmates, and course texts and readings. In addition, this student must develop a strong understanding of the assumptions and point of view - the context - under which the problem is being contemplated. The instructor, the class, and the individual student will all make assumptions about the problem which will significantly affect the argument's meaning and the process of critically thinking through it.

Second, the critical thinker must verify the truth or falsity of the statements of the argument as an argument can only be sound if the premises and conclusion are true. This procedure can be difficult as false premises may lead to a true conclusion, and vice versa. To accomplish this task, the critical thinker will need to develop a skill set in verification (Hughes et al., 2010, p. 26). In a purely objective sense, through the logic of positivism, the verification process would be a finite procedure

Figure 1: Diagram of the Typical Critical Thinking Process

that is conclusive and absolute (Stevens, 1990). A verification of this type would confirm a deductive argument, or one in which there is a guarantee of truth in the conclusion. However, many arguments are not purely objective. These more subjective arguments, in which the truth of the premises makes it reasonable to believe that the conclusion is also true, are called inductive arguments (Hughes et al., 2010).

With regards to architectural study, rarely is a studio problem the proof of a deductive argument; instead, due to the relative subjectivity of architectural design, it is the development of an inductive one. Each student creates a design to solve the given problem. The design (the what, the solution) is the conclusion and the time on the project is spent developing an argument to support that conclusion. Theoretically, in a critical thinking model, the reasoning (the why and the how) of each chosen design move provides structural links. Each sub-argument helps to bond the initial premise (the given problem) with the conclusion (the ultimate design), strengthening the overall argument. This argument takes the form of the design strategy and is centered on a cohesive series of smaller, interrelated design moves.

This process characterizes the third component of critical thinking: the ability to reason or infer connections between statements. The process of reasoning draws heavily from the principles of logic: the study of the relationships between premises and conclusions and the normative principles that structure how one makes or assesses these relationships. As opposed to a description, which is an attempt to accurately represent something, normative principles are standards of assessment that provide the underlying structure for reasoning (Hughes et al., 2010, p. 28).

Whereas critical thinking works with these normative principles that guide our choices, *lateral thinking* helps to break down normative thinking patterns and to realize new opportunities. Architectural design, for example, encompasses many normative principles (structural conditions, building codes, standard details, etc.) that must be considered in the development of a project. But design is rarely purely methodical, precise, or logical. The process of design in the academic architectural studio may be linear as an overall structure, but the day-to-day work of design is iterative and repetitive. Each step requires the posing of multiple ideas for evaluation and reflection, a process undertaken throughout the course of a project.

Lateral thinking is a method by which the thinker poses different approaches, concepts, or points of entry into a given problem; it is a process of exploration. Like brainstorming, lateral thinking asks the thinker to suspend judgment of 'correctness' or 'validity' in favor of opening up possibilities for 'what might be.' Critical thinking is a logical, step-by-step process; it is constantly attempting to move forward. Lateral thinking, on the contrary, steps sideways with the goal of revealing a series of ways to engage the problem from widely divergent perspectives (Figure 2). Where critical thinking is analytical in nature, lateral thinking is provocative (de Bono, 1970, 1992).

These two tools are complementary and can be used in tandem when problem solving. Students use lateral thinking skills to develop a creative process and generate iterative conceptual ideas about the problem or its components. Critical thinking skills are then employed to analyze the iterations and to select the most appropriate solution with which to move forward. In this spirit, lateral thinking is a generative tool, while critical thinking is a selective tool (de Bono, 1970, p. 39); lateral thinking opens up pathways that provide potential opportunity, while critical thinking allows for the selection of a best path of travel to move the project forward. The "crux of the creative process resides in the interplay of the divergent (lateral) and convergent (critical) stages of thought" (Morthland & McPeek, 2010, p. 86). If these processes of thinking are used individually, a student would end up with a significant void

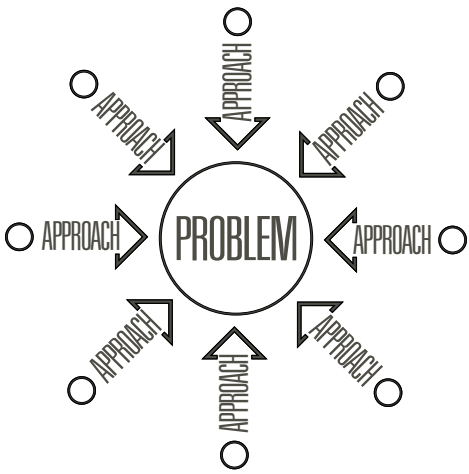

Figure 2: Diagram of the Typical Lateral Thinking Process

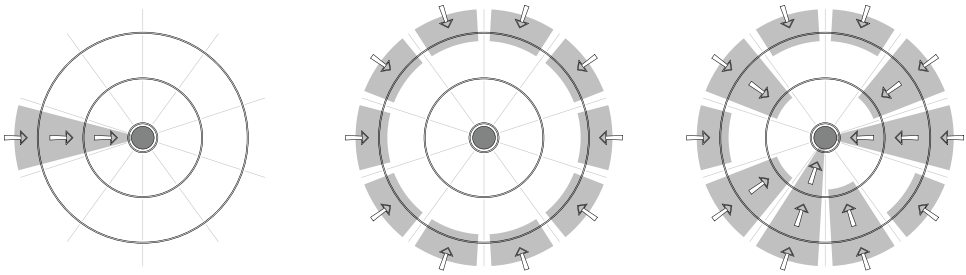

Figure 3: A Comparison of the Impact of Critical and Lateral Thinking on Problem Solving

in his or her solution. Critical thinking alone creates a deep, but relatively narrow exploration of a problem; lateral thinking alone creates the opposite condition - a broad exploration of ideas, but no depth in the resolution. When students are taught to use these means of thinking jointly, however, the opportunity arises for breadth and depth of exploration (Figure 3). Within this structure, a working process can be developed that is both provocative and analytical.

PROCESSES OF MAKING

With respect to this study, making refers to the creation of a tangible object, good, or element through the forming, modifying, joining, or assembly of various raw materials or components. Traditionally, making is a goal-based process that results in a tangible product. For making to occur, the maker must have a "systematic encounter with the material world" (Crawford, 2010, p. 21).

This encounter is an embodied practice, one requiring the maker to use his or her body to generate a set of movements (known or unknown) in order to achieve the desired form or result of the made object. If the movements are known, the process likely has a logical structure; this type of making frequently strives for efficiency and a vertical step-by-step approach to making a pre-conceived product (i.e. an assembly line). Conversely, unknown movements liken the process of making to that of lateral and critical thinking. This process explores avenues for manipulating the material at hand (lateral thinking) and investigates the best ways to use the material to achieve the desired results (critical thinking). Either process, however, possesses the core characteristic of embodiment. Despite arguments from Rafael Cardoso (2010) and others who state that making in a digital era should include digital manipulation as a core component. The relative lack of embodiment occurring within these processes, however, tends to push virtual creations outside of this definition of making. So, what, then, do architects really make?

Traditionally architects are categorized as designers. "Design, broadly defined, is an all-inclusive way of looking at and addressing problems…" (Pressman, 2012, p. 16). The process of design is "an effort to arrive at what will be obviously fit and true," a useful and productive solution (Lethaby, 2010). As opposed to making, designing is the generation of ideas through a rigorous process involving investigation, conception, intuition, and iteration. This process often leads to the practice of making, but design, on its own, is not a tangible entity. Instead, designing is the process of generating a plan for action. In order for this plan to become tangible, it must be represented. Sam Ridgway (2009, p. 268) defines representation as "the presentation of one thing (the signified) in or by another (the signifier). One thing is presented again in another." By this definition, architects do not make anything concrete. They do not create the spaces we dwell in; they create drawings and models that are at the same time representations of the building yet to be built and abstractions of the conceived design strategy (Schwartz, 2013).

Most everything that is generated in the typical architectural studio refers to something else and only very rarely is an object made which is itself the tangible and physical goal (Guthrie, 2005). Architecture students, like architects, deal primarily in the making of drawings, models, renderings, and the like. These elements are all critical products of the design process. They are typically made for two reasons: as a means of working through a design idea or as means of

explaining a design to others. In either situation, the process of making is rarely about adding value to the materials used or about helping to realize the true potential of the made object. They are instead the physical manifestations of developed (or developing) ideas. In the future, the students will use this process of representation to define a strategy for constructing a project. They will use the representations to communicate this strategy to those who will build it. The architect's "drawings are not an end in themselves, a work of art, but simply a set of instructions, an aid to the craftsmen who construct his buildings" (Rasmussen, 1995, p. 14).

However, Donald Sch□n (as outlined in Krupinska, 2014, p. 118) proposes that design can suggest "the designer's negotiations with the real materials involved in each situation." As architecture students traverse their education, they will benefit greatly from experiences that ask them to negotiate with real materials in addition to the development of these typical representations. Connections to the realities of materiality and construction will help them "understand the possibilities and limits of the materials and crafts, and [to] communicate their ideas and intentions to the specialist craftsman, whose hands become the designer's surrogate hands in the execution of the work" (Pallasmaa, 2009, p. 63).

Crafting is a specific form of making. David Pye believes that craftsmanship is "workmanship using any kind of technique or apparatus, in which the quality of the result is not predetermined, but depends on the judgement, dexterity and care which the maker exercises as he works" (1978, p. 4). Crafting, therefore, is the practice of skilled making and is delineated by certain features: personal vision, mastery of a medium, bodily presence, physical exertion, skill, and direct involvement with materials and materiality (Cardoso, 2010, p. 329). Unlike making, which anyone can do, crafting requires informed expertise and practice. As craftsman George Nakashima (2011, p. xxi) states: "The woodworker, applying a thousand skills, must find that ideal use and then shape the wood to realize its true potential." Skill is utilized to refine the process of making and direct it toward finding the ideal potential of the raw material. For Peter Zumthor (2006b), the skilled making of buildings is an art, one that asks the maker to create "a meaningful whole" out of many discrete parts and pieces. Regardless of the means of assembly or quality of transformation, making and crafting are processes of exerting human will on material.

Making, then, has the potential to be a process of adding value (or taking it away). Adolf Loos (2010, p. 116) positions that all materials are, of themselves, equally valuable to the artist (the maker). Despite the significant economic impact of material choices in most making practices (especially architecture), when most people assess the value of made things, it is rarely the material that carries value, but the work of making embodied within the object. Skilled making, therefore, can be seen as a process of adding value to the raw materials with which the maker works. "There are a thousand different possibilities in one material alone" (Zumthor, 2006a, p. 25); the making process is about embracing the right possibility at the right moment. Constantine Brancusi (as cited in Pallasmaa, 2009) stresses, however, that one cannot just make what is desired out of a material; one must make what the material permits you to make. Each material has its own language, as does the process of making. The maker must learn to speak the language of a material through the embodied process and, in turn, allow others to understand this language as well. Making is, therefore, not just a language, but a narrative; it is a story of the material's transformation.

Bob Sheil (2005) offers his own definition for making: to form something through the performing of required movements. The narrative of making is embedded in the working process, each gesture adding to the tale. Many have argued that the process of making is as critical an element as the product itself (similar to the theory of experiential learning). Kieran & Timberlake (2004, p. 7) state that the encounter with making is a designed process in itself and can have significant influence on the made object: "the design of how we go about…making circumscribes what we make." Robert Morris (1995) also describes the process of making as having as significant of 'forms' as the end product made. These forms are behaviors that guide the interaction between the maker's actions and the materials of the environment. While informed by these learned behaviors and at times necessarily logical in its progression, the process of architectural making can also be messy, chaotic, unstructured, and intuitive - a parallel to the juxtaposition of critical and lateral thinking.

Despite the prevalence of making in the architectural design studio though, the question persists as to the significance of its role in the exploration of architecture. Making, in this environment, shares many similar traits with the

traditional definition. It requires the development of expertise, practice, and skill. It has a rigorous process that possesses the potential to significantly impact the product (representational or not). It is messy, chaotic, and can be very intuitive while still being informed by a wide range of structured rules. Undeniably though, the primary use of making in the architectural studio is an act of representation; a significant purpose on its own, but there exists the potential for more.

THE PROCESS OF CRITICAL MAKING

As previously stated, processes of making are used on a regular basis in the architectural studio. These processes, however, are typically used to depict, demonstrate, develop, test, or convey design ideas. As opposed to practices frequently utilized in the fine arts, in an architectural curriculum acts of making are rarely charged with the task of generating ideas and often they are left out of the primary iterative loop of idea conception altogether (Figure 4). They are instead the representation of ideas already conceived. Often, it is difficult for students, especially those in the first few years of their education, to engage in making without knowing what they are going to make prior to beginning. There is a significant difference, for instance, between the making of a model of a design and designing a project through the making of models. Tentative to make a leap without a plan in place, they sit and ponder, sometimes very unproductively. In *What an Architecture Student Should Know*, Jadwiga Krupinska (2014, p. 153) outlines strategies for instigating design used by several contemporary architects: Steven Holl's watercoloring, SANAA's model brainstorming, Jean Nouvel's writings, and Santiago Calatrava's kinetic force analysis. Critical making provides another way of initiating a project. Utilizing the complementary tools of making and thinking, this construct has the ability to act as a generative device for sparking the design process.

Matt Ratto (2011) has outlined three stages to a critical making process, any of which he believes can serve as a starting point for critical making:

One stage involves the review of relevant literature and compilation of useful concepts and theories. This is mined for specific ideas that can be metaphorically "mapped" to material prototypes, and explored through fabrication. In another stage, groups of scholars, students, and/or stakeholders jointly design and build technical prototypes. Rather than being purposive or fully functional devices, prototype development is used to extend knowledge and skills in relevant technical areas as well as to provide the means for conceptual exploration. A third stage involves an iterative process of reconfiguration and conversation, and reflection begins. This process involves wrestling with the technical prototypes, exploring the various configurations and alternative possibilities, and using them to express, critique, and extend relevant concepts, theories, and models. (p. 253)

The review of literature stage begins with a thoughtful reading of the problem statement and the objectives for the course. Just as with critical thinking, understanding of the problem's 'premise' is important. This stage centers, however, on the analysis of a provocative reading or set of readings that can conceptually drive the investigation. These readings present abstract ideas and assist in the development of Freire's critical consciousness. The grounding of the project in a set of existing ideas also provides a framework for the process to move through and gauge itself against.

The building of prototypes (in this paper referred to as constructions) stage is the nexus of making within this process. In the architectural studio, this making may take the form of a preliminary assignment, an introductory task of a given problem, or any number of other forms. The goal of this stage is to manipulate material, but, unlike the processes of making outlined previously, here

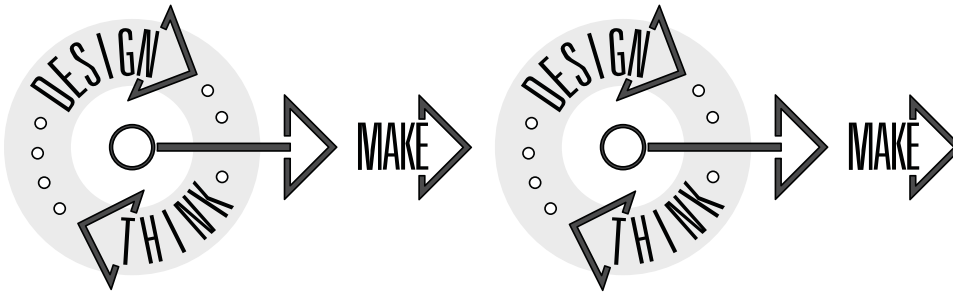

Figure 4: Diagram of a Traditional Working Process with Making as a Representative Tool

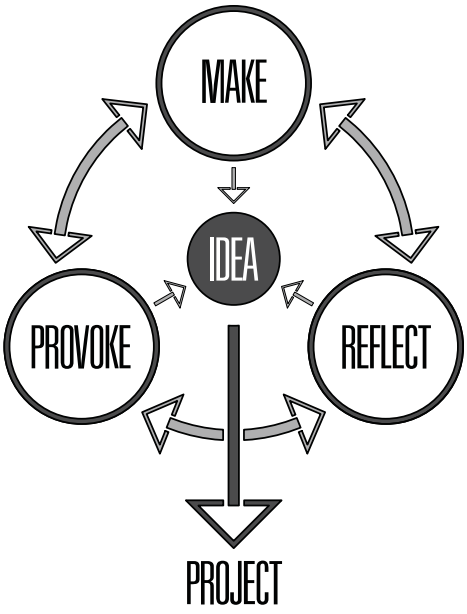

Figure 5: Diagram of the Typical Critical Making Process

the goal is not representation or product. Instead, the goal of this stage is to use making to generate ideas - of making, of building, of creating space, of joining assemblies, of detail, of material properties, of proportions and scale, of the fundamentals of architecture - which will be used as a point of departure for the assignments to follow. It is process driven, not product driven. In a fashion similar to that presented by Thomas Heatherwick, here making is a catalyst (Figure 5).

Zumthor (2006b) discusses a similar working process in Thinking Architecture. He states that in his studio, all design work starts with real materials: "The drawing of scale plans also begins with the concrete object, thus reversing the order of 'idea-plan-concrete object', which is standard practice in professional architecture. First the concrete objects are constructed, then they are drawn to scale" (p. 67). For both Zumthor and Heatherwick, processes of making centered on engagement with materials serve as generators of inspiration and design. In both examples, making is exploited as a lateral thinking tool and is used to open up and explore new avenues into the given problem; each reconstructs the typical design diagram, allowing making to become an integrated component of the generative cycle (Figure 6).

In the third stage, that of reflection, the constructions are discussed. In the architectural studio, dialogue is initiated between teammates working on the same construction, between classmates working on the same project, and between student and instructor. This dialogue can (and should) occur at any point; a construction does not have to be 'finished' in order to debate its merits, embedded ideas, or contributions to the project. Discussion leads to changes and further making as ideas are flushed out and the constructions are worked and reworked. In this stage, critical thinking plays the primary role and the students are tasked with creating connections (inferences) between abstract ideas embedded in the made constructions and the larger questions or problems posed to the studio. This stage is one of communication and interaction between those involved in the project.

These three stages are iterative and repetitive; the critical making process cycles through them, typically in a non-linear fashion. The maker moves from literature review, to making, to reflection and back, often engaging multiple modes simultaneously. This rigorous process embeds making within a cycle of lateral and critical thinking. Making and thinking support each other, allowing the students the potential to gain more perspectives of the given problem. Ratto (2011) believes that the entire process of critical making needs to be experienced within a collaborative environment. This philosophy echoes that of Robert Morris (as cited in Cardoso, 2010, p. 329) who believed that the practice of craft should be a shared tradition, experienced by a "network of makers, freely exchanging their wares." Offering a different perspective, Nakashima (2011) expresses his belief that

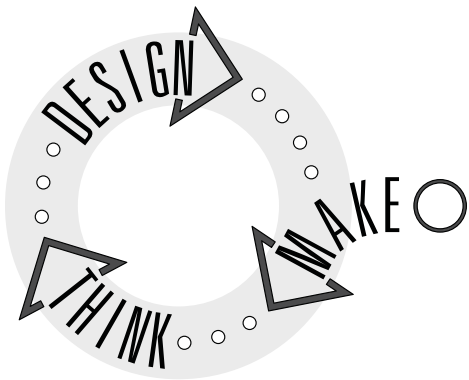

Figure 6: Diagram of a Critical Making Process with Making as an Integrated Tool and Catalyst

despite the strong collective of craftsmen in his studio, the act of craft is a meditative practice. "Craftsmanship is a silent skill. People who talk excessively cannot take part" (p. 121). In the architectural studio, moments for meditation, alone with the material, can be important for many individuals working in the critical making process. However, in order to generate the most productive learning environment and to properly provide the basis for critical reflection and mutual support, it is necessary for this process to occur in a collaborative (or at least cooperative) setting.

Fundamentally, critical making draws from the study of embodied intelligence or embodied cognition. Embodied cognition "seeks to explain how the way we think depends on what we are doing with our bodies and how we are interacting with the physical environment" (Claxton et al., 2010, p. 4). This line of inquiry finds that many people think more clearly and more productively when their bodies are active (doodling, jogging, showering, talking with their hands, etc.). The research has also shown that thinking may have evolved from bodily interaction and that the mind and the body are very closely linked. The adage that the brain is the control system of the body is outdated; the brain can be more closely described as a modulator of the body's behavior (Claxton et al., 2010).

Architecturally, embodied cognition is closely tied to the understanding of the built environment. Pallasmaa (2009, p. 13) states that "[e]mbodiment is not a secondary experience; the human existence is fundamentally an embodied condition." Humans are connected to the world through their senses. Pallasmaa urges that the senses are not passive, they are actively engaged with the world and structure our understanding of it; they are storehouses of our knowledge of the environment. Phenomenological philosopher Maurice Merleau-Ponty (as outlined in Mallgrave, 2011) adds that the physical body is unmoved during the act of perceiving. It is, instead, the phenomenal body which perceives; it serves as a receptor for external sensory stimuli, creating a strong argument for the intertwining of mind and body.

Claxton (2010) has also found that when working with physical materials, the maker is significantly more absorbed in the work than if he or she was just thinking through a problem. The belief is that while making, different sensory, motor, and cognitive events integrate in complex ways. These complex integrations promote engagement and, in turn, the potential for experiential learning and the development of knowledge.

By introducing critical making exercises into an architectural curriculum, there exists the potential for enhanced learning through the development of students who are more intimately and immediately connected to and engaged with their work. The results from past design studios taught by the author which have included critical making exercises have supported these conclusions (Figures 7 and 8). Through instructor evaluations, students in these courses stated that they believe they have learned more working in these classes than they have in other design studios using more traditional pedagogy. Multiple students have asserted their appreciation for the hands-on experience, believing that it not also allowed for the development of ideas used in other projects, but that it has also affected their perception of the built environment. The results of these evaluations also revealed a strong reception by the students

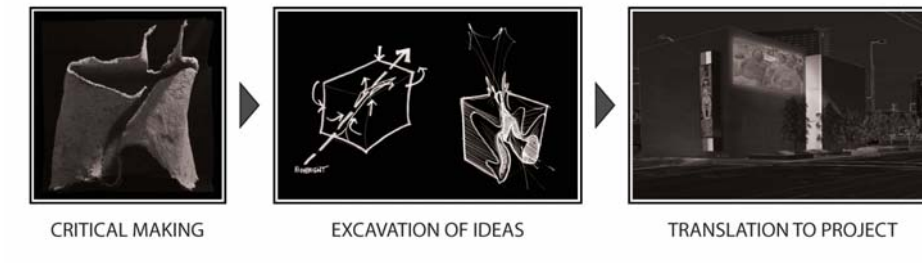

Figure 7: The Critical Making Process - Fall 2010 - D. Edwards

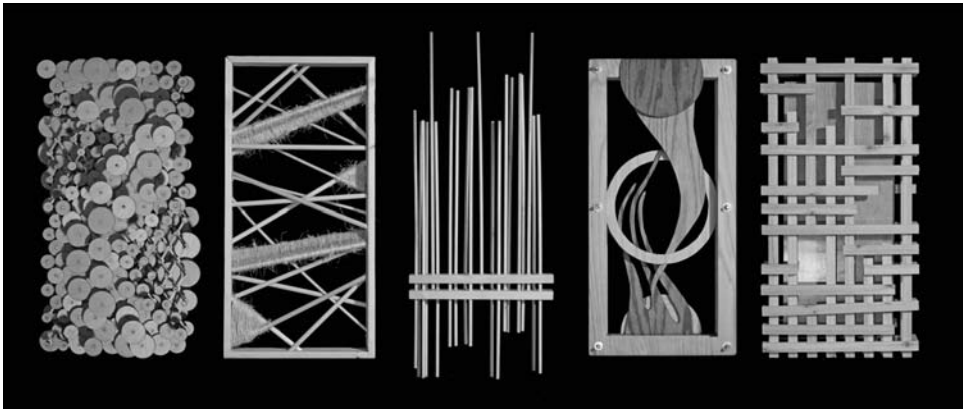

Figure 8: Examples of Panels Generated Through a Process of Critical Making - Fall 2012 - M. Ollmann, A. Steiskal, K. Patrick, D. Thomason, S. Dale

of this pedagogical stance as the groups assessed both the course quality and educational experience of the studios at a 99% (average of 4.95 out of 5.0). Although far from conclusive, these results do demonstrate the eagerness of the students to engage in learning through critical making and through haptic connections with the materials of construction. In future iterations of these studio courses, the hope is to develop better means of documenting the critical making process and its effects on the development of design ideas.

DISCUSSION

Experience does not go on simply inside a person. It does go on there, for it influences the formation of attitudes of desire and purpose. But this is not the whole story. Every genuine experience has an active side which changes in some degree the objective conditions under which experiences are had. (Dewey, 1938, p. 39)

Education should be transformative; each bit of knowledge gained should contribute to the development of an individual. In a traditional classroom setting, it is not unusual for knowledge to be momentarily gained, only to be quickly forgotten after the final exam. John Dewey (1938, p. 35) believed that experiential education was based on habit and that habit is based on the belief that "every experience enacted and undergone modifies the one who acts and undergoes" as well as the quality of his or her future experiences. Education, then, when rooted in experience is not transitory; the experience creates a lasting imprint on the person. Students are not only permanently transformed by first-hand experience, but participation in these learning activities changes the way in which that student will interact in future activities as well.

Issues of transformation appear again in the work of Earl Kelley (as outlined in Raiola, 2011, pp. 181-182) who believed that "[e]xperience… is the process of undergoing the contact with the concrete, the working out of the project circumstances." One of Kelley's primary concerns with the educational system was that knowledge is often presented as absolute prior to the process of learning instead of the result of working through a lived experience. These thoughts are channeled in the more contemporary theory of Crawford's "knowing that" versus "knowing how" mentioned earlier in this paper. Life-lasting knowledge is gained through the performing of real actions in real time; by creating knowledge, rather than having it preached to you; and by living lessons, not watching them.

This immediate and personal experience, according to Kurt Lewin, is the focal point for "giving life, texture, and subjective personal meaning to abstract concepts" (as outlined in Kolb, 1984, p. 21). Here Lewin discusses the transformation of the concepts themselves as they are explored and embodied in real constructs through experiential work. These embodied experiences have the ability then to serve as catalysts to spark their "own process of inquiry and understanding" (Kolb, 1984, p. 11). It is within the notion of the catalyst that the pedagogy of critical making is rooted. Louis Sullivan (1967) acknowledged that every seed

has a *germ* that functions as the "seat of identity" for the plant it will become. This germ must be nourished to allow its simple working idea to blossom into all that follows. Critical making can act as the seed germ, as the catalyst for action. It can transform the representational nature of made things into a generative one. Making processes, when coordinated with critical and lateral thinking, create a learning structure that promotes inquiry, exploration, and knowledge building.

Critical making encourages not just the generation of ideas, however, but also nearness and intimacy with the physical makeup of the examined world. With respect to the built environment, Kenneth Frampton (1998) acknowledges that the most powerful connections one can develop involve a wide range of sensory input:

It is symptomatic of the priority given to sight that we find it necessary to remind ourselves that the tactile is an important dimension in the perception of built form. One has in mind a whole range of complementary sensory perceptions which are registered by the labile body: the intensity of light, darkness, heat and cold; the feeling of humidity; the aroma of material; the almost palpable presence of masonry as the body senses its own confinement; the momentum of an induced gait and the relative inertia of the body as it traverses the floor; the echoing resonance of our own footfall. (p. 28)

Space is defined by more than visual cues; imagine the feel of a gentle breeze from an open window versus the stagnant air of a long sealed tomb, the aroma of fresh cut cedar versus the antiseptic palette of a hospital room, or the echo of a heavy door slamming at the end of a long hallway. Given the impact of the full range of senses on our experience of architecture, what impact do the senses have on the training of architects?

CONCLUDING THOUGHTS

Architecture is one of the only arts in which the maker does not manipulate the material of the made product directly. The addition of the critical making process to an architectural curriculum has the ability to remedy this aberration (to a certain extent) and to connect the architecture student more intimately to the realities of the constructed environment. Critical making can actuate the senses of young design students; it can create within them empathy and understanding for the practice of construction that they will be intimately connected with in the future. For example, a student who has had the opportunity to work with concrete in the design studio will have a better understanding of the innate properties of the material and how to exploit them in future designs as well as a better understanding of the steps the contractor must take to ensure the concrete is fabricated correctly and how to tailor designs to assist in that process. These advantages, potentially nurtured by a critical making process, can have significant aesthetic, material, and financial implications for future work.

But the effectiveness of critical making can stretch well beyond the architectural design studio.

Every good craftsman conducts a dialogue between concrete practices and thinking; this dialogue evolves into sustaining habits, and these habits establish a rhythm between problem solving and problem finding. The relation between hand and head appears in domains seemingly as different as bricklaying, cooking, designing a playground, or playing the cello… (Sennett, 2008, p. 9)

Critical making links the head with the hands - thinking with making - through a dialogue between maker and material. While engaged with the material, the supporting literature, and those around him or her, a novice student has the potential to open up new avenues of thought about the project or problem at hand. Jerome Bruner (1966, p. 159) believed that it is the "task of the curriculum maker and teacher…to provide exercises and occasions for…nurturing" the students engagement with a body of knowledge. We must not just present a knowledge base, but also teach how to seek out knowledge. Critical making is just one of many ways that students can become versed in ways of inquiry. It can teach students that knowledge does not have to be preached to be gained. Knowledge is lived; it is performed; it is hammered and chiseled, brushed and molded. Finding knowledge is an active pursuit, a pursuit that can simulate a lifetime of learning for anyone willing to get his or her hands dirty and start making.

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