Material Misadventures: Lessons in Failure

It should be noted that fingers are not born with brains, these develop gradually with the passage of time and with the help of what the eyes see. The help of the eyes is important, as important as what is seen through them. That is why the fingers have always excelled at uncovering what is concealed. Anything in the brain-in-our-head that appears to have an instinctive, magical, or supernatural quality—whatever that may mean—is taught to it by the small brains in our fingers. In order for the brain-in-the-head to know what stone is, the fingers have to touch it, to feel its rough surface, its weight and density, to cut themselves on it.
— Jose Saramego, *The Cave*

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INTRODUCTION

Our first-hand experiences are instrumental in the understanding of the world around us. Learning occurs not only through visual or auditory means but also through tactile engagement. Jose Saramego's words are particularly pertinent for the building design field in that cutting oneself on stone provides critical knowledge in comprehending the parameters of working with the material. The value of working hands-on with materials and physically engaging matter must also account for the potential of stumbles along the way.

It is significant to examine the distinction between explicit and tacit knowledge in architectural design education. There is a cultural shift of thinking in our students that often only focuses on successes; however, it is the failures that are more revealing in the developmental learning process. The typical studio design work that is done on paper or in the computer can easily mask potential mistakes where as those errors cannot be hidden when confronted with the physical presence of the real thing. In professional practice, the desire to experiment is often stripped away. There is too much at stake to fail with issues of budgets, schedules, life safety, and liability looming over each project. Design education is an ideal time to take risks and learn from mistakes where one cannot be penalized or held liable for naïve propositions.

In many Architecture programs, materials and methods of construction courses are typically lecture oriented; however, design students would gain an added dimension of knowledge through an active tactile experience than learning exclusively through audio and visual means of lectures, images, and readings. This paper will examine the student outcomes and work produced in a material workshop seminar where students experimented hands-on and at full scale with building materials. What do students learn from the process of physically working with building materials? How does one expand beyond explicit knowledge and teach the nuances of materiality to nurture tacit knowledge for the benefit of developing design processes? With the attention on active engagement with material studies, the intention of this paper is to investigate different modes of failure encountered to evaluate their merit in cultivating building design knowledge.

MEDITATIONS ON MATTER: A METHODOLOGY

With the advancement of digital design tools, it is inevitable that the design process in architecture education is increasingly reliant on the computer. As students become more absorbed in the digital program, there is a concern that they will become further removed or disconnected from physical matter. Often, it is easy to detect in the output of digital drawings and renderings when materiality is an afterthought rather than a factor impacting design decisions. In an attempt to counter this trend in our design studios at the University of Florida, a materials workshop seminar was offered in Fall 2012 and Spring 2014 where students confronted material realities through full-scale physical constructions. The product of this workshop was not a freestanding installation or a building as conducted in typical academic design-build projects; instead, the goals of the course centered on incorporating 1:1 material studies into the design process. The students designed and built components and assemblies at full-scale but focused primarily on experimenting with material behaviors and characteristics, processes of working with the material, and methods of assembly or joining of materials. Engineering new materials or creating practical watertight assemblies was not an objective for the course. Instead, the process intended to encourage discovery and instill a sense of play when working with materials.

The 16-week course had 15 students and each student chose one or two materials to investigate. In the beginning of the semester, they primarily learned general techniques of working with the materials. If a student chose concrete, the consistencies of concrete mixtures and also methods of constructing formwork had to be addressed. If a student chose metal, the forms and types of metals were researched and processes of manipulating metals were investigated. As they became more comfortable with the material, they engaged an iterative process of making that sought to challenge the material. In every attempted study, variables were changed to empirically test constraints and parameters of materials with the potential of uncovering new and possibly innovative ways to work with the materials. For the remainder of the semester, the students focused on assemblies and generated larger constructs derived from their earlier experiments. Throughout the process, drawings and diagrams were utilized to analyze results, to speculate on new proposals and to interrogate the potentials. The workshop established a laboratory environment whose objectives were to experiment with materials at 1:1 scale, to gain knowledge of material behaviors to enhance their understanding of materials and to cultivate a thorough process that mediates between design thinking and built realities.

All the students enrolled in the workshop had completed two semesters of Materials and Methods of Construction courses that are predominantly lecture–based with required readings. The majority of enrolled students had no experience working hands-on with materials and construction, so they struggled in their initial interactions with the materials to take the information learned and implement it at full-scale. The students had to develop a comfort level and a design process engaging matter and accommodating the failures that inevitably accompanied these material studies.

CATEGORIES OF FAILURE: FINDING THE POSITIVES IN THE NEGATIVES

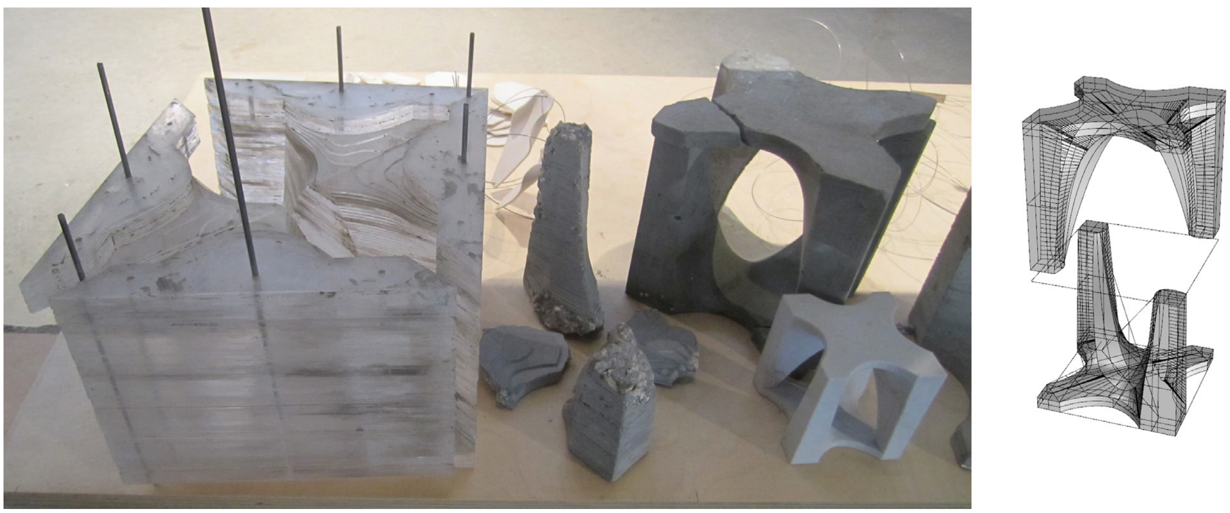
Throughout the process, students in the workshop had to constantly adapt and readjust their ideas on methods of handling their materials. Every time they experimented and the results failed to perform as expected, the students were overwhelming disappointed with a lack of success. However, the failures they encountered were not categorically the same. In reflecting on the extents of each mishap, there were different types of failures that revealed critical learning opportunities that consequently enhanced their understanding of the impact of matter in design. Students needed to learn that each failure was not a regrettable incident but instead it propelled their research in unexpected and positive directions. The attempt to categorize these failures intends to identify significant issues meditating on matter that contributes to the development of the students' thinking and design processes.

False intuitions - Since most of the students had not physically worked with materials such as concrete and wood, they began with naïve ideas and propositions that demonstrated a lapse of understanding material logics. They of course had studied concrete and wood in their Materials and Methods courses, but when confronted with task of casting concrete, they struggled to implement their knowledge of materials and construction into the physical realm. An unexpected hurdle that had to be addressed at the start of the semester was getting students to commit to a research focus. The majority of the students had an initial reluctance to persevere through failures. In the aftermath of a disastrous attempt, they instinctively wanted to abandon the project and select new materials rather than make the effort to adapt or readjust. They were more inclined to try to seek easier paths that would ensure success rather than head in riskier directions.

At the University of Florida, we teach students design skills that utilize digital tools, hand drawing and model-making skills. All design students learn to work in physical models using representative materials such as Plexiglas and chipboard for their maquettes. In the workshop, many students directly translated these representative materials to full scale. Acrylic and glass are two very different materials, yet there was the assumption that Plexiglas's transparency made it equivalent to glass. Their shared characteristic of transparency was enough to ignore all other dissimilar properties. The building materials they were accustomed to using in their studio design work could no longer be used in the full-scale realm. Representative materials could not replicate behaviors and characteristic of materials that could be used in actual constructions.

The Breaking Point - Every material has its weaknesses. The potential for a material to be used in innovative ways requires a thorough understanding of the parameters that limit the material. The point at which a material fails is a critical aspect for design students to comprehend the fragility and durability of materials that are essential for field of architecture. In their material studies, students were encouraged to see how far a material could be pushed. Initially, many students hid their broken pieces - ashamed of their outputs - but not realizing that the experience contributes to developing a tacit knowledge that helps them to be weary of potential failure in the material and the assembly.

One of the students who was interested in the potential translucency of porcelain tested how thin and flat she could make porcelain. She had accumulated a box full of porcelain shards and then realized that the thinner the porcelain tile, the less likely the tile would remain flat after firing. She then began making porcelain tiles that intentionally incorporated curvature to work with the material's tendencies. Another student who was working with concrete designed a proposal for a modular unit and built a formwork for it (Figure 1). In the process, he was unable to remove the concrete in one piece from the formwork. He recognized that the size of the aggregate in the concrete mixture has to be proportional to dimensions of the cast. The aggregate size was preventing the concrete mixture to properly bind causing weakness in the concrete unit. In addition, he had used Plexiglas for the formwork material and assumed that the concrete would not stick to the slick surface of Plexiglas. However, the layered construction of the Plexiglas formwork created a texture that was desirable in appearance but created a surface to which the concrete could lock into. In both the porcelain and concrete examples, pushing the materials capabilities allowed the students to find ways to achieve their design objectives while also preserving the integrity of the material.



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Obstinate Materials - Materials are not always willing to perform to expectations. When working against the nature of the material, there is the risk of the material rebelling and then consequently failing. Theses failures occur not only in creating breakage, but also in generating instances of resistance. Understanding behavioral tendencies of the materials helps to anticipate potential resistances and to prepare strategies to counteract defiance. For example, the structural integrity of formwork is critical when casting concrete in order to resist the forces exerted by the weight of concrete in its liquid state particularly at the bottom of formwork. The experience of withstanding the outward force generated by concrete enhances the understanding the material's behavior and sets parameters for the most appropriate processes and techniques of working with the materials. All material types and materials in different forms cannot be treated the same. Each material has specific characteristics that limit the processes that can be applied to the material. Knowing when to push and when to yield to the material is part of a tacit knowledge that enhances one's consideration of materials in design thinking.

The students experimenting with wood in the course struggled to find the right processes to manipulate the materials. When attempting to laminate veneers into curved forms, the students had to test methods of steaming the wood to push the material to yield more, techniques in applying adhesive, and strategies to secure

Figure 1: Concrete module with preliminary formwork and castings (Stefan Oliver)

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Figure 2: Material failure in laminating wood veneers (Taylor Tofal)

the materials while setting (Figure 2). If they didn't apply pressure evenly to keep veneers together, then layers of veneer would peel away where there was the space to expand. If the adhesive was applied unevenly, then it affected drying time and the surfaces depending on the veneer thickness would spring back. In these material studies, the students were learning to gauge their actions and treatment of the wood. Through this experience, they acknowledged the nuances that shape the skills of millworkers. These subtle distinctions are qualities that are learned through active experience and are difficult to teach beyond generalities through receptive learning methods.

Materials Misbehaving - The discovery that generated the most significant impact on students' design thinking was the realization that there was a disconnect between their speculative drawings and built realities. In drawings, material assumptions are idealized. Material behavior affects outcomes and it is not necessarily easy to predetermine. The work of post-minimalist artists, such as Robert Morris, Richard Serra, and Eva Hesse emphasized the process of working with materials and material behaviors as the subject of their artwork. In reflecting on his Felt Works series, Robert Morris writes that in his process the "unpredictable behavior of the felt meant that form could not be anticipated through drawings or models"2. Morris's studies with industrial felt experimented with variables regarding thickness of the felt, cuts made in the material, and methods of hanging the felt. These qualities could be anticipated but factors of pliability, gravity and heft were difficult to simulate in drawings or maquettes, consequently, adding complexity and unpredictability to the studies. Throughout the workshop, drawings were used to interrogate, clarify and propel the students' materials research, but in drawings, the students did not have to contend with gravity or physical resistances in matter. The drawings idealized material components into static representations.

A student who was interested in creating an assembly with rubber and wood began with drawings investigating possible strategies of joining a flexible material with a more stable material. She proposed larger assemblies derived from the rubber and wood joint studies and in drawings, she speculated on the possibility of creating a flat screen that could be adjusted where areas of the screen would curve in and out. Once she built a prototype, she found that her assumptions of a flat assembly were difficult to achieve because the rubber bended as it pleased and torqued the wood assembly (Figure 3). The quality of material flexibility is difficult to factor into the drawings. In general, students thought they would be able to design everything before even touching the material. The act of physically engaging and assessing material qualities and behaviors provides insight during the speculation process.

Happy Accidents - Particularly when failures occurred, students were asked to reflect on and analyze what went wrong. Each experiment was interrogated and often the failed studies lead to discoveries and created new unexplored questions to ask of the materials. On many occasions, the failures in the experiments opened the students' eyes to ideas and curiosities that they had not considered before. Consequently, this lead their materials research into unexpected directions.

A student experimented with the use of plaster and spandex using the MATSYS project, P-Wall as a starting point. In speaking with Andrew Kudless, he learned that the weight of each panel was a particularly difficult project aspect requiring reconsideration. So the student decided to test methods for make lighter panels by adjusting plaster mixtures and integrating other materials such as perlite and Styrofoam. In one attempt, he tried to displace the plaster using water balloons to lighten the quantity of plaster. This attempt was not particularly successful in reducing the weight of each plaster piece, but it prompted a new question on whether he could make two-sided panels with the same surface effect. This led to experiments in developing techniques and processes that ultimately used centrifugal force to produce two-sided panels. With each experiment, it was critical to encourage students to look past the failures to seek opportunities of uncovering new possibilities.

The Refining Process - In trying to achieve their objectives, students needed to critically understand the value in an incremental process of improving upon failed attempts. Each failure was a moment to analyze the situation, readjust concepts and adapt new variations in an attempt to improve upon it. The process of refining helps to generate a more intimate understanding of the material. In the design process, it is rare to produce the perfect design solution in the first attempt. Studies that were comprehensive in examining all variables that impact the material – equipment that can be used, the processes that can be applied, methods and components of assembly - not only created an intimate understanding of the material but also helped to develop a thorough design thinking process that was more likely to achieve successful results.

One student focused on casting metals was interested in aluminum foam panel products and the cast bronze panels used in the American Folk Art Museum. He wanted to find a way to cast aluminum panels that were perforated but, unlike aluminum foam, could be easily handled without gloves. The student first experimented with numerous iterations using various processes of casting metals like sand casting and lost wax methods. Then he tried different ways to achieve the desired perforation in the panels. Each failed attempt was analyzed and adjustments were made to variables in the process and he finally settled on a technique using ice and dry ice as a formwork material. Once he could produce perforated panels with consistency, he then started to question how the panel could be part of a building assembly and experimented with fastening methods (Figure 4). This methodical process of working allowed the student to intimately learn how to work with aluminum in a casting process to then contemplate its potential as a building component.

THE SIGNIFICANCE TACIT KNOWLEDGE

Instead of classifying all mishaps uniformly as 'failures,' these categories emerge from analyzing and reflecting on each material experiment as a means of understanding the gaps in development of material thinking. These failures stimulated the production and research in the students' active engagement with matter. They helped to identify the critical moments of awareness when integrating materiality into the design process. Educational theorist, David A. Kolb, states that "learning is by its very nature a tension- and conflict-filled process"3. If an active learning experience is a smooth and effortless process, then it has less of an impact on the individual's developmental learning. The various failures encountered established tension needed in the course to challenge the students.

John Dewey, Jean Piaget and Kurt Lewin, pioneers in theories on experiential learning in the developmental process, emphasized the value of hands-on experience and direct engagement and argued that our active experiences expand the knowledge base and also create a scaffolding for an individual's structure for learning. The methodology of the materials workshop parallels Lewin's experiential learning model of a four-stage cycle:

> Concrete experience is the basis for observation and reflection. These observations are then assimilated into a 'theory' from which new implications for

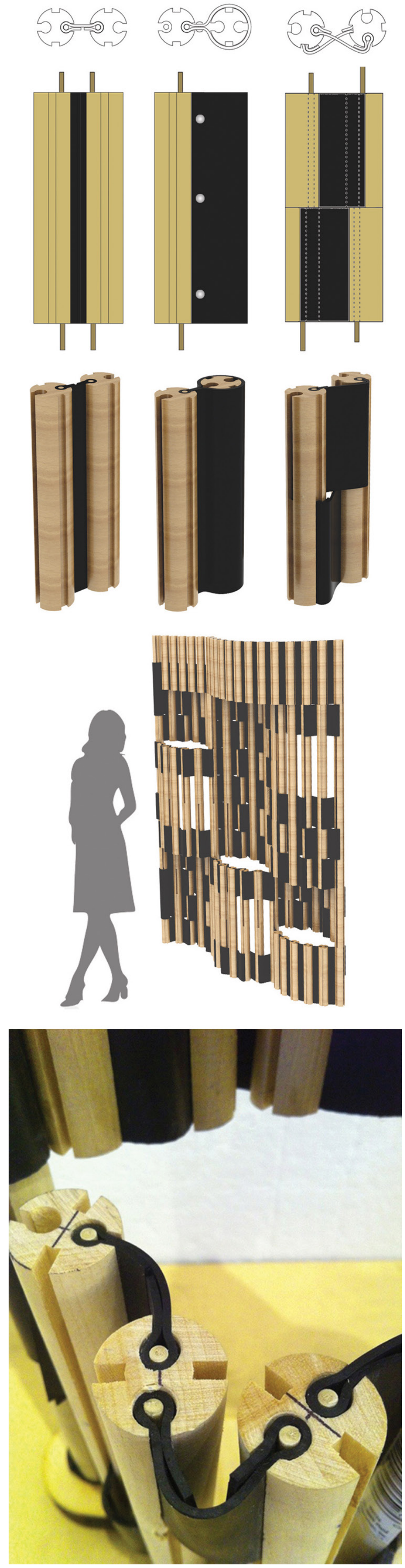

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Figure 3: Wood and Rubber studies (Huajing Huang)

action can be deduced. These implications or hypothesis then serve as guides in acting to create new experiences.4

The students in the workshop engaged in a cyclical process with their materials research. They first established actual physical experience through testing techniques of working with materials. The results of these active experimentations were observed and reflected upon through drawings and analysis that was then formulated into new abstract concepts and generalizations. The implications of these concepts were then tested in a new situation leading to the start of a new cycle. This iterative process of making reconciles between successes and failures.

The tacit knowledge gained from this experiential learning process provides insight into material issues for consideration in design. The direct contact between the hands and the materials cultivates an awareness and connection to materials that enhances design thinking for future practice. The mishaps that were encountered helped to define working parameters. Throughout the process of the course, observations and reflections encouraged students to ask more of the material and challenge conventions. The instructor's role was to facilitate this process of inquiry, bring up questions for the students to consider, and promote awareness by prompting the students to think beyond their comfort zone. In addition, learning through action and failure encouraged students to develop strategies of adaption. The ability to quickly readjust their thinking and approach provided the means to achieve their research goals.

CONCLUSION

In the context of design-build, this materials workshop did not emphasize an experiential learning process through the design and construction of a building project. Instead, the course focused on developing a process of working and thinking through design and construction that mediates between material issues and built realities. The primary purpose of these design-build experiments was to provide an opportunity for students to develop an intimate understanding with a material and become conscientious of the presence of matter in their design work. In each case of failure, the students became more aware of the impact material behavior has on their designs. It is not necessary for students to be expert craftsperson with every material. Just the experience of working with a material at full-scale brings their attention material issues to anticipate in an effort to avoid potential pitfalls in their design proposals.

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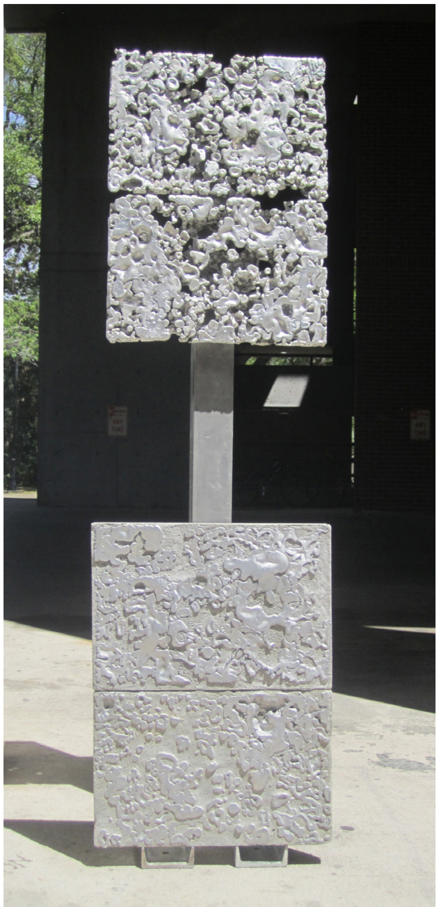

ENDNOTES

1. Saramego, Jose. *The Cave*. (New York: Houghton Mifflin Harcourt, 2002), 67.

2. Morris, Robert. *Continued Projects Altered Daily: The Writings of Robert Morris* (Cambridge, MA: MIT Press, 1993), 73.

3. Kolb, David A., *Experiential Learning: Experience as the Source of Learning and Development* (Englewwod, NJ: Prentice-Hall, Inc.: 1984), 30.

4. ibid, 21..

Figure 4: Cast aluminum studies (Calvin Di Nicolo)