STUDENT-DRIVEN DESIGN IN ARCHITECTURE: INTERACTING WITH RECLAIMED MATERIALS AND PASSIVE SOLAR TECHNIQUES

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ABSTRACT

Automobiles are ubiquitous for transportation in most developed countries, and increasingly in developing countries as well. Because global climate change is now widely accepted as imminent, it is time to seriously reevaluate the use of fossil fuels. This reevaluation also provides an opportunity to rethink the infrastructure in which automobiles reside. This infrastructure extends to the idea of garages that can support off-grid recharging of electric vehicles. The full-scale design/build project discussed in this paper stemmed from a community-run sustainability competition and was organized and implemented by students at Virginia Tech in Blacksburg, Virginia. The project sought to demonstrate a new form of infrastructure for electric vehicles focused on reusing reclaimed or refurbished materials. In their design for the garage, students recovered construction materials from scrap heaps generated by larger-scale projects, deconstruction of older buildings, and post-consumer materials. By taking these materials out of the waste stream, students recovered their embodied energy, giving them a new purpose and avoiding the expenditure of energy to make materials.

Undergraduate and graduate students in architecture and urban design partnered with the Electrical and Computer Engineering Department at Virginia Tech to purpose-build a structure to house an electric-powered maroon Corvette. The garage for the Corvette is a test of a design concept for small solar structures that use a repetitive structural frame with pallets as a structural diaphragm. The Solar Garage had a small budget of $5,000, which in part necessitated the use of repurposed materials. The project allowed the students to have hands-on experience with architecture and design, and also to develop new ways of thinking and engaging the architectural profession and clients. This project will be joined with the 2002 Virginia Tech Solar Decathlon House and its photovoltaic array. While the vehicle is charged by the panels, the building itself relies on passive solar techniques. It receives morning light, but is shaded from afternoon and evening sun, requiring no electrical lighting during the day. The garage is a part of the students' plan to revitalize the 2002 Solar House and surrounding area.

While led by a student from Architecture, the design team included students from English, Electrical and Computer Engineering, Aerospace Engineering, Material Science Engineering, Chemical Engineering, Animal and Poultry Science, and Industrial Design. The belief is that the interactions and boundaries between disciplines provided insight and potential for other research and design beyond the Solar Garage. In this paper two students will discuss their experience thus far with the Solar Garage and its impact on their design work the challenges and benefits of working with an interdisciplinary team, and importance of self-discovery to create a rewarding learning experience.

Keywords: Architecture; design research; reclaimed materials; student research; vegetated assemblies.

1. INDRODUCTION

This Solar Garage project stemmed from a community-run sustainability competition, and seeks to be a proof of concept for small solar structures that use a repetitive structural frame for electric vehicles focused on reusing reclaimed or refurbished materials. The partnership and budget from the Electrical and Computer Engineering Department necessitated the use of repurposed materials from larger-scale projects, and deconstruction of older buildings.

This resulted in hands-on experience with architecture and design, and new ways of thinking. The purpose of the project is to join the project with the 2002 Virginia Tech Solar Decathlon House and its photovoltaic array to revitalize the area. The vehicle is charged by the panels, while the building uses only passive solar techniques. It receives morning light, but is shaded from afternoon and evening sun, requiring no electrical lighting during the day. The garage is also a part of the students' plan to revitalize the 2002 Solar House and the surrounding area.

In this paper two students will discuss their experience thus far with the Solar Garage and its impact on their design work, design/build organizational skills as a team and how this interaction informed the tectonics of the project and how discovering for themselves leads to a more rewarding learning experience.

2. BACKGROUND

2.1 Areas of Inquiry for the Solar Garage

The study has four major concepts that combine to make a basis for inquiry into the Solar Garage. These include the adjacent possible, passive solar techniques, reclaimed materials, and aesthetics. The concepts, as well as the Solar Garage project are reviewed from a phenomenological perspective, that experiences are unique to the individual based on observations of the world in the context of our own thinking.

First, the adjacent possible, a concept of Stuart Kauffman, and explained by Steven Johnson: "The adjacent possible is a kind of shadow figure, hovering on the edges of the present state of things, a map of all the ways in which the present can reinvent itself," [1]. Only specific changes can happen based on these combinations and this number is finite, however this number is vast. The Solar Garage serves as the impetus, the catalyst for these changes. The materials and techniques used in the project are informed by the materials and skills around it which in turn gives rise to these combinations and potential.

Second, passive solar techniques, are used to decrease the need for artificial lighting during the daylight hours. These passive techniques rely on the site conditions in an effort to decrease the active or mechanical loads on a structure [2, 3]. In the Solar Garage, these techniques are aimed at not only reducing potential lighting loads, but also increasing the comfort zone of the structure as much as possible. Some of the techniques that are used in the Solar Garage include low angle sun in the winter and morning to heat the space, with shading in the hotter summer and afternoon.

Third, reclaimed materials, is part of a larger concept called unbuilding. This process is systematically taking a building apart instead of demolishing it to reclaim materials that are still useful in other capacities. This is an economic gain for those who do it and is good for the environment by keeping waste out of the landfills and reusing embodied energy of the used materials, among other benefits [4]. While the use of unbuilding and reclaimed materials takes more time, the benefits in the form of reduced cost for the Solar Garage made it a necessary and desirable method. In the Solar Garage, materials were reclaimed from previous projects such as the Research and Demonstration building on the site, the 2005 Virginia Tech Solar House, and a proof of concept structure for the Solar Garage.

Fourth, aesthetics is an overarching theme to the project and design as a whole. Though aesthetics is a large and subjective area of inquiry, it can be simplified for this study as a method of thought regarding beauty, and of the perception of beauty. There are many different ideas and thoughts of this beauty ranging from the ranging from Kant's subjective experience of beauty [5], to Friedrich Schiller, were it was the most perfect reconciliation of the sensual and rational parts of human nature [6].

3. RESULTS

3.1 Results of the Student's Work: Kenneth Black

The Solar Garage was conceived out of the previous work by the Design with Friends group, based on the lessons learned from the two projects below, a prototype deck and planter for a sustainability competition and a proof of concept for a modular, repeating pallet wall section for small structures.

Fig. 1: Left: prototype of the deck and planter; Right: the proof of concept for the pallet wall section

The Solar Garage went through a series of different sections trying to bring light further into the space. These two sections show different roof angles and the represented differences in light. In the constructed section the roof angle was lowered and the upper portion of the pallet section was removed to allow more light into the space based on the full-scale mock-ups of the wall sections. The complexity of the joints and connections would also be simplified.

Fig. 2: Different sections and studies of the potential Solar Garage wall section.

After the light studies, the full scale construction began in the fall of 2013. The images below are from the beginning of the project starting on the upper left, to the most current image in March after a snow. This is the site towards the existing solar house and the main RDF building. In the two weeks prior to starting construction, the site had been cleared of summer overgrowth which was about 5 feet in height over most of the site and a caution perimeter was established. From then on it has been a tremendous amount of experience and learning constructing at full scale.

Fig 3: Process pictures of the Solar Garage from August 2013 through March 2015

3.2 Results of the Student's Work: Thomas Doorn

The Renovation to the 2002 Solar House

Virginia Tech's 2002 Solar Decathlon House was designed and built by a team of faculty and students from the architecture and engineering departments. The Solar Decathlon competition has a myriad of criteria, the most important of which emphasize sustainable and energy efficient design choices, beautiful and livable spaces, and a building that can be moved to a site and assembled in a few days. The 2002 house now has a permanent place at the Research and Development Facility (RDF) near Virginia Tech's campus. Over the thirteen years following the house's placement at the RDF it has received little care. The work undertaken by Thomas Doorn, with guidance from Ph. D. student Kenneth Black and Virginia Tech professor Elizabeth Grant, began with a revitalization of the exterior shown in figure 4 followed by a plan to renovate the interior shown in figure 5.

Figure 4: Above: proposal for exterior renovation; middle: deck construction detail; bottom: layout diagram

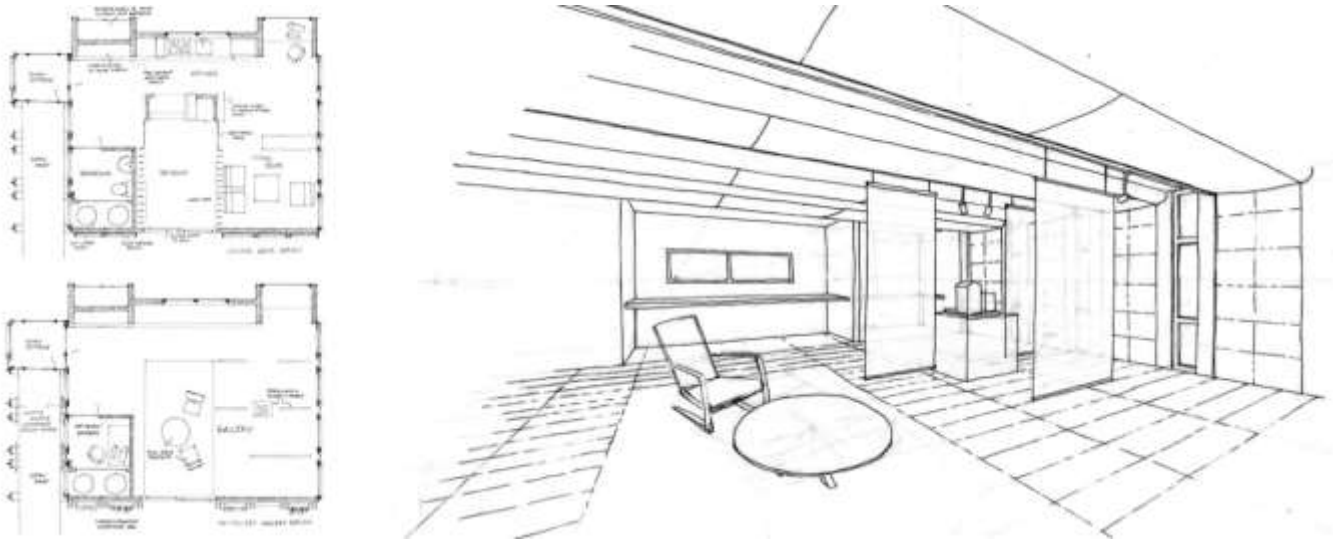

Figure 5: Left top: original plan; Left bottom: new plan; Right: new gallery in the large interior space of the house

The renovation for the 2002 Solar Decathlon House focuses around a central gallery space beginning within the house's central space and extending to the deck and patio outside the house. The renovation relies on the design choices made in the house, leading to an examination of the goals and limitations of the original design. The renovation also responds to the current goals of the RDF and aims to improve awareness of the opportunities present there, with the ultimate goal of attracting more students to the possibilities of self-driven, team-based design and construction.

4. METHODOLOGY

4.1 Student-Driven Process in Discovering the Solar Garage

This project started from a community-organized sustainability competition which stipulated the use of pallets in the design. At first Ross McFarland and Kenneth made a deck and planter made of pallets and a wide variety of reclaimed materials. This then morphed into a proof of concept for pallet cross-section for full-scale construction with a vegetated roof [7]. This proof of concept was seen by a professor in the Electrical and Computer Engineering

Department and asked if it could be made into a building, specifically the Solar Garage [8].

This process of steadily building on previous ideas and experiences lead to some of the first experiences to present and publish work. This process of not only completing, but also reflecting on the work by studying the phenomena of the spaces and ideas constructed, determined the philosophical mindset of the design group in phenomenology. By using the systematic study of previous experiences, a few students created Design with Friends (DWF), a design group dedicated to the idea that full-scale construction and the process of making was valuable to design education. While this mainly pertains to the building envelope, the larger question of building design and construction is always in the background. In DWF, the students propose design projects and then seek funding in order to build them.

DWF started out organized as a series of research-oriented studios to begin studying how the Solar Garage could be constructed from architectural drawings. This process of starting out in architecture and then expanding into other disciplines, beginning as a multi-disciplinary team and then transforming into an interdisciplinary team, led to the most interesting advances in the concept of the Solar Garage and the 2002 Solar Decathlon House by combining expertise.

By thinking about how students could lead their own design process, this led to the incorporation of vegetated assemblies and design support frameworks in Kenneth's Master's research [9, 10]. The diagram, figure 6, is adapted from [10]. This process of organizing and understanding the carport studies, later called the Solar Garage, is part of a larger methodology of how vegetation and architecture interface at the building envelope. This served as the mapping of decisions that would be used in formulating an overall methodology for how a series of inquiry relates the Solar Garage to vegetated assemblies and passive solar strategies by studying the Solar Garage as an immersive case study. The Solar Garage began as an independent, tangential project by DWF that was then brought back to a larger question of design thought as a "wicked problem" [11, 12].

4.2 Reviewing the Adjacent Possible in Multi-disciplinary Design Research

The multidisciplinary team was conceived under the adjacent-possible mindset. From this mindset of combining adjacent possibilities found, DWF began the process of finding students who were interested in the Solar Garage. This research took the perspectives of many students into account when beginning to conceptualize constructing the project as a designed response to the site. This design response takes universalized concepts and injects some form of specialized response whether from the site or larger cultural context. At the same time, phenomenology is used to understand the method of engaging the world in relation to the senses.

There were a number of disciplines involved in the project. The multi-disciplinary team (one that has a number of viewpoints that may not understand each other completely) that existed at the beginning of the project transformed into an interdisciplinary team (comprised of individuals who understand multiple viewpoints simultaneously) through the sharing of experiences and expertise between the members.

This project's development included architecture, materials science, animal and poultry science, civil engineering, electrical engineering, English, and industrial design. Other

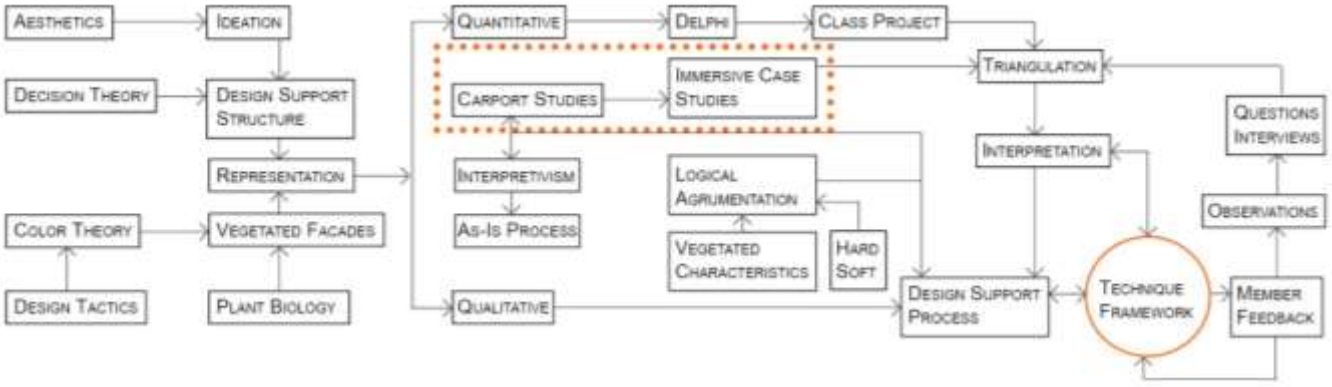

Fig. 6: Theory Map for the framework and DWF methodology; the dotted rectangle shows the work of this study

disciplines were present during construction, including chemical engineering and aerospace engineering. Architecture derived the form and conceptualization of the Solar Garage using passive solar strategies. Materials science worked to explain what materials to choose based on specific properties. Animal and poultry science served to educate us on plants that would not injure animals should livestock get loose and eat the vegetated walls. Civil engineering worked with us to determine water drainage plans as the site originally was a depression that pooled multiple inches of water during rain events. Electrical engineering explained more in depth how solar panels worked and the performance characteristics based on material choices. English explained how writing about and developing a program for an exhibition space would be beneficial to the efficacy of the Solar Garage in the longer term. Finally, industrial design showed us the value of user interactions with the car as a showroom, that the Solar Garage and electric car could be an exhibition space for research.

5. CONCLUSIONS

5.1 Defining Our Student-Driven Design Research

The "Guide on the Side" mentality, combined with the driven nature of students created the opportunity for the Solar Garage. This application of the adjacent possible, of ideas and concepts merging, is designed to break limits, instead of creating them. The work began with the Solar Garage, and led to the expansion of the site into a deck system and new entry for the 2002 Solar Decathlon House as shown in Thomas Doorn's work. From this step and the ideas generated from Design with Friends, the potential for the 2002 Solar Decathlon House to become a future indoor-outdoor exhibition space, utilizing the complex created by the deck system and Solar Garage to show how design and research are part of a larger continuum. The continuum of iterative design builds on itself and the potential found in the adjacent possible in every situation. This strengthens and continues exploration in research and studio.

Specifically, this process of interacting consistently with other disciplines impacted the designs made for the Solar Garage and the renovation to the deck system. In the Solar Garage this led the design to become more a showroom for the vehicle with a raised tiled floor, combined with edible or non-detrimental plants on an associated vegetated wall assembly. This also led to the inclusion of a transparent wall for viewing the vehicle, serving a dual purpose as a source for early morning daylight. The deck system for the Solar Decathlon House utilizes the lessons learned from earlier shipping pallet projects and of the Solar Garage itself. The system shown in Figure 5 is a result of the process of learning through initial designs followed by the actual construction. The most significant and lasting influences on the deck's design came from the lessons learned from the construction phase of the planter and Solar Garage projects.

An independent study grew out of the effort to revitalize the 2002 Solar Decathlon House's exterior, with guidance from Ph. D. student Kenneth Black and Virginia Tech professor Elizabeth Grant. The independent study, as opposed to the exterior revitalization, focused strongly on the origin of the 2002 Solar Decathlon House's design and used the design intent of the original house along with the desires for the development of the RDF to establish a new use for the 2002 Solar Decathlon House's interior. The interior of the house is treated as a gallery for the display of completed and ongoing projects at the RDF, so the use of the building has a strong tie to the future of the RDF.

Much like the Solar Garage, the original design and construction of the 2002 Solar Decathlon House was an interdisciplinary endeavor including architecture- and engineering-related fields. The exploration into the origins of the 2002 Solar Decathlon House lead to a heightened understanding of the results of interaction of disciplines in the field of architecture. There was a tension within the design of the 2002 Solar Decathlon House, defined by the confrontation between the desire to create a comfortable and livable house with beautiful interior spaces and the necessities demanded by the 2002 Solar Decathlon competition's high standard of efficiency and transportability. This tension came to define the house and lead to a positive outcome in which the limiting factors of the design became its strongest elements.

The independent study led to a possible renovation for the 2002 Solar House, but, more importantly, lead to a greater understanding of the results of interactions between professionals from many disciplines. Limitations for the 2002 Solar Decathlon House's construction, such as maximum building weight and maximum building height, posed the greatest challenges but also, in the end, the strongest ideas within the project. Alternative perspectives provided by professions other than architecture introduced

opportunities in the house's design that would have been otherwise overlooked.

5.2 Process of making and thinking

The process of making allows for a different method of engagement, research, and design philosophies. Students, when given the correct conditions and opportunities can self-direct and self-implement research and design projects. The Solar garage is a step in the process of discovering what is possible when many different perspectives are combined. This then exposes new possibilities for exploration in the surrounding area by re-evaluating places that others have chosen to ignore or avoid. From a pedagogical perspective, it shows that students are capable of rising to the challenges set for them. Granted these challenges need to be achievable, but not allowing or hindering exploration is even more of a negative result.

By connecting ideas by working with others we can create more, rather than protecting and removing ourselves and our ideas away from others. By shifting through material and ideas lost to time or forgotten, we have come to the conclusion that new ideas can spring from the old, providing opportunities in the very places deemed as undesirable. As we explore and continue to explore the boundaries of these adjacent possibilities, we have found that those boundaries expand, and that with creativity we can continue to learn and experience more than what we can do alone.

This continuous exploration leads students to find a lifetime of questions that can lead to life-long learning. This boundary of exploring the interface between the environment in the form of the sun and vegetation with the building envelope is but the first step in a series of systematic inquiries into the nature or architecture. This system or process of inquiry through iteration and representation is not new, and by building upon this history we were able to find potential in the Solar Garage. The environment created by working at full scale allowed us to be innovative in our thinking and engagement, breaking out of the standard educational model. By taking all of these steps and thoughts into consideration and then recombining them we generated the Solar Garage.

5.3 Continuation

The adjacent possible continues to show new avenues for discovery, and its concepts will serve the research of the students well into the future. The lessons learned from the continued work with the Solar Garage and its surroundings hope to create an indoor-outdoor exhibition space for student work that will revitalize the area surrounding the 2002 Virginia Tech Solar Decathlon House. This work will also be continued in the teaching method and techniques used to combine education and research in the studio environment. This will be done not only by bringing lessons learned to the studio, but also creating an atmosphere where students can research topics that interest them and infuse these ideas in their designs.

5.4 Acknowledgements

We would like to thank other students for working with us to explore these concepts, and the work they provided is invaluable to understanding the architectural design process that fuses research with studio.

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