Learning by Doing: Knowledge Sharing through Design Pedagogy and
Decision Support Systems

Kenneth Allan Black

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James R. Jones, Committee Chair
Mario C. Cortes
Elizabeth J. Grant
Alexander X. Niemiera
Shelli B. Fowler

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ACADEMIC ABSTRACT

This study into the architectural profession reviews developed decision support frameworks (graphics to inform and improve decision making through access to more information) as knowledge sharing devices. These developed frameworks first, influence decision makers: the students and their decisions in their personal architectural design process and second, develop a framework on vegetated assemblies (building assemblies that incorporate plants such as green roofs and walls) as vegetated assemblies relate to color theory and its implications in design methodology.

This decision support framework assists students in their design process in studio and studio-like educational environments. The purpose of this decision support framework is to influence the students in using vegetated assemblies in their future design inquiry. After implementation, the purpose was to determine the worth of the framework as a mechanism for knowledge sharing. Both purposes were reviewed in developing the framework using immersive case studies, classes both in traditional studios and studio-like courses, website development and member feedback.

The evidence of the resulting improvement of decision making or design work was found through the use of surveys, student reflective writing, and personal interpretation of student works and my own immersive design studies, classes, and development of the framework and its website. The surveys and reflective writing were collected from multiple years of involvement in traditional studio and studio-like classes to refine the framework and its use.

The results of the study suggest that students do have a larger body of knowledge to make decisions about utilizing vegetated assemblies than before the use of the framework and go on the continue using vegetated assemblies in design work. The framework presents the various factors that impact decisions into vegetated assemblies and develop future designs. By influencing and improving knowledge of such factors on the design of vegetated assemblies early in a student's education, improves decision making in future designs and later professional work.

Future work would be targeted at refining the framework and potential courses to include other topics of interest in relation to vegetated assemblies. Finally, the framework could be adapted into a more codified, interactive tool in the future.

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PUBLIC ABSTRACT

This study looks at how graphics and representation can improve the making of decisions on the basis of access to more information across different learning environments. This process of gathering and then sharing information with others can develop into knowledge sharing devices. These devices also known as decision support structures are a scaffold or framework for influencing decision makers: the students. The influence is on their developed design process, how students go about designing, and on their knowledge of vegetated assemblies, which are parts of buildings that incorporate plants such as green roofs and walls, and color theory, which is a method for using color in design.

This decision support structures assists students in their design process in studio and studio-like educational environments. The purpose of this dissertation is to review how decision support structures can be used various learning environments to assist students in exploring lines of inquiry. These lines of inquiry are a deliberate process of exploring an idea or family of ideas. This use of the decision support structure was reviewed using immersive case studies, classes both in traditional studios and studio-like courses, and the development of a website.

The results of the study suggest that students do have a larger body of knowledge to make decisions when using the developed decision support structure. This work presents the various factors that impact decisions into developing future designs based on vegetated assemblies and color theory as topics. This work also improves decision making in future designs and later professional work.

Future work would be targeted at refining the developed decision support structure and potential courses to include other topics of interest in relation to vegetated assemblies. Finally, the framework could be adapted and expanded in the future.

Dedication

We commonly learn from those around us. This method of knowledge through experience is how I have been able to learn more about architecture and myself as an academic.

The opportunities that others have given me to learn and show my knowledge continue to humble me. Without continued support much of this work would be impossible. For their help I am forever grateful.

To my advisors
Who guided me though the process and looked out for me.

To my family
Who encouraged me to continue when given a choice.

To my students
Who learned alongside of me when testing the framework.

To Kathleen
For patiently listening to my rants about plants every day.

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Chapter 1: Introduction

1.1 Preface

The idea for this dissertation came from a class that I took a few years ago. This general professional practice course had a project to make a firm based on a specialized idea. It was simple enough: give a presentation to anyone in design (or not) about your new firm. Our group, as many of the groups, had difficulty conveying our ideas to others, let alone finding a unique idea to center our work around. It ended in a less-than-ideal manner, leaving me frustrated about why this was so difficult. This experience later combined with a part of a graduate class about communicating science. Had I been taught techniques for how to convey my ideas before presenting them or representing them to others, would it have made the previously described experience more fruitful?

From this combination of experiences, I wanted to ease the relationship between learning, teaching, and doing. I was in a meeting with an advisor a few years later where he described an educator as being a node for information exchange rather than a repository. It is important to be an expert, but not be so narrow. But what happens if the professor or mentor is not around to help the student? We realized that providing a visual representation of your thought processes would be helpful as a decision support system.

Allowing new designers to work together with other types of experts and to integrate ideas in studio is incredibly important for their future success. This is the combined work from many different projects, sources, and lines of inquiry. I had started these thoughts on a dissertation with a project called the Solar Garage. This was supposed to be the totality of the work. Turns out, the project would take on a life of its own. The dissertation in fact could not and should neither end with just a particular project, nor

simply reside inside my own mind. The worst would be that the dissertation would only show itself as a tome which could never be read.

The dissertation is organized into three main parts. The first section is focused on the "pre-design" of the work. This is the introduction, the philosophical grounding, the vegetated assemblies, and color theory application. In a more traditional sense this first book is the introduction and literature review. The second section focuses on the framework's development and application in a website for students. This describes the vast majority of what was done and what were the results of the work performed. These are the traditional methodology and results portions of the dissertation.

The third section discusses the validation and possible implications of the framework on teaching, learning, and the profession, what the purpose of such a framework is, and what the future impacts of the framework could be. The validating of the framework included: immersive case studies, professional and peer review of the framework, classroom use in studio environments and in studio-like environments. These sections focus on the validation, discussion, conclusions, and continuation of the work.

A supplementary book will be developed in the future as a succinct summary of the dissertation with the full vegetated framework which is used in part as an example throughout the books.

1.2 Introduction to a framework of mind:

Overview

How do we take ideas and create a body of knowledge for others in frameworks across various media such as print and digital content? Frameworks in the context of this dissertation are a written down mental process that guides and develops a person's designs and design process as a knowledge-sharing device. A framework is grounded in a set of philosophical beliefs chosen by the designer to guide their work, develop experience serving as a decision-support system. Over time, decision-making is improved not only by using the framework itself, but also results in a more informed design process, controlled by the designer.

While I use the terms 'designer' and 'non-designer', it is only a distinction between formal training, of experience. We all are designers in one way or another. I hope to share what I have learned over time with a series of inquiries that became greater ideas as I engaged the world and the people around me. This is not just about where these ideas came from, but also what they mean for you.

Introducing the formation of ideas and design with frameworks

Design is only as strong as the process that grounds it. It is the process that becomes the guiding factor in learning, making and doing. You and I have abilities in common: thought, speech, and representation. This becomes how we can communicate our thoughts to others. Communication of ideas is important, but how do we know what ideas to share, let alone how to have them? The critical questions we often ask ourselves are also very simple ones. Who? What? When? Where? How? Why?

- Why use the studio method in explaining and showing others our work?

- Why is organized thought important to a framework and to us?

- Why does our topic, drive our scholarship or professional direction?

- Why is it difficult to introduce new ideas to others using full technical manuals?

- Why don't we get it sometimes?

You might be asking yourself some questions right now:

- What if I am not a 'designer'?

- How do I even know where to start?

- What is this about a framework and why would I use a one?

- What is it; isn't this just another flow-chart?

- Why use frameworks at all?

Frameworks can help how we engage a new idea. They do not show the whole process of engaging an idea, nor should they, as you and I have the ability to make the final decisions in our process. These frameworks are not set in stone, and change constantly depending on our experience and intent. These frameworks can guide newcomers through an idea until they are ready to explore the idea or topic at a deeper level. They are not a black box. Instead, they are a part of a series of decision support processes that can help us to design, without taking the decisions from us. The use of frameworks is not exclusive to designers; rather the process can be implemented in many project-based learning situations, both in academic and professional settings.

The following is an example of creating such a framework to visually represent and share knowledge, ideas or processes. The summarized framework proposed by the dissertation is presented and serves as a single graphic for the entire following

dissertation. Starting on the upper left and following two interconnected paths, key points are illustrated in the diagram, such as the general framework of a design process on the left-hand side, and on the right a process for analyzing and processing research topics in a design project and how the two interact.
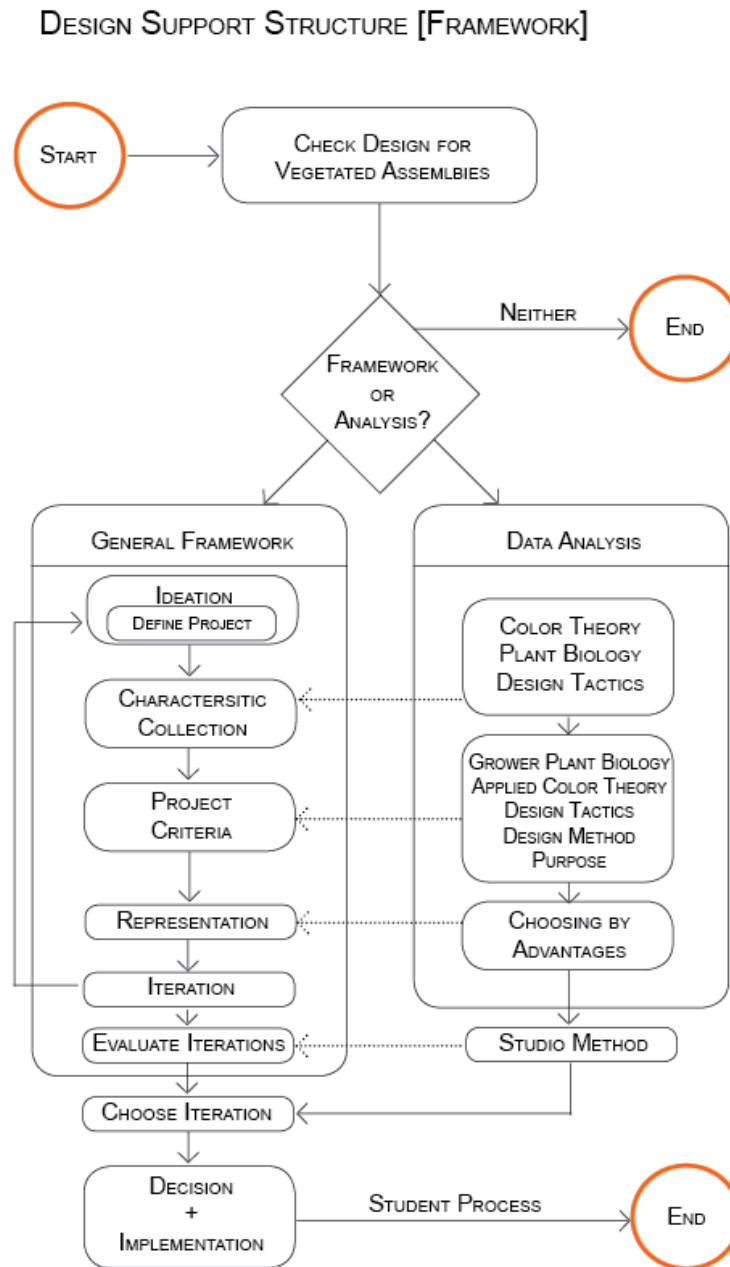
Figure 1: The summarized decision support framework developed during the course of the dissertation.

Figure 2 is the first example of how to graphically represent the dissertation as a framework. By starting with an idea, the framework would be reviewed using multiple methods to validate and refine its content and use by students. This process combines design and research, another key aspect of the dissertation.
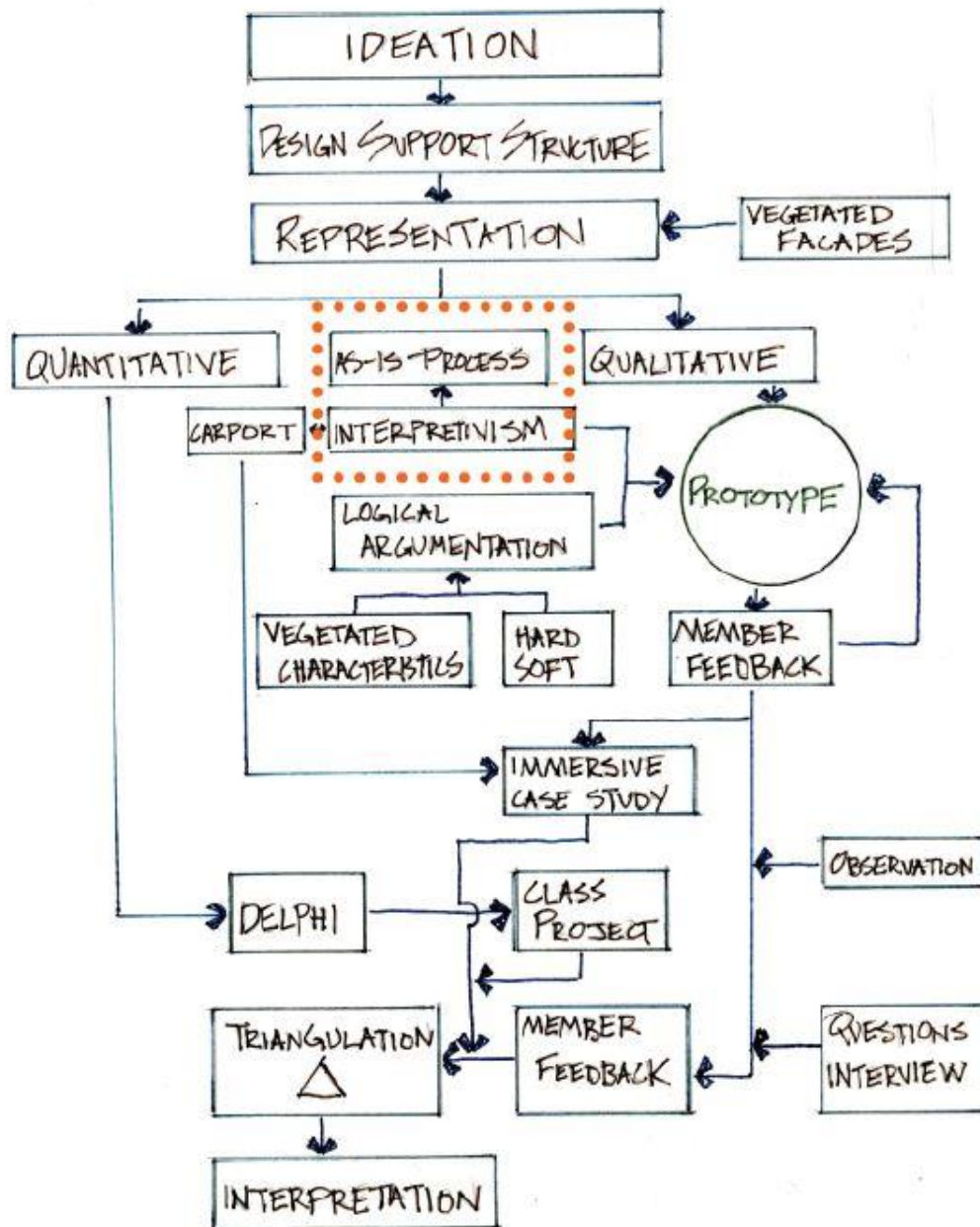
Figure 2: The dissertation represented graphically as a framework from the process of ideation (formation of ideas) to the result or outcome such as a prototype.

A brief summary of the steps of the graphical representation and its implementation:

1: Ideation - Ideas come from somewhere, be it your past experiences, interests, or precedents in the discipline. This concept of developing ideas is the foundation for the decision support structure.

2: Decision support structure - a structure or framework that organizes thought in a graphical manner, it is a very robust diagramming system.

3: Representation - a series of methods, techniques and tactics for conveying information to others be it graphic or oral.

4: Quantitative and Qualitative - these are the two main families of what might be represented by the framework. Topics or design should be considered both in a qualitative (more subjective or experiential/categorical) or qualitative (objective or numeric) manner.

5: Triangulation - this is the process of verifying something in a number of different manners. Usually a minimum of three process or methods are used to verify the validity of something. In this framework immersive case studies, member feedback in the form of what would have been a Delphi, but instead was a questionnaire) and interpretation were used.

6: As-Is Process - what is currently happening? In order to study and understand the impact of something on a condition, the baseline or the norm is necessary. From this a process can be applied to determine a new normative process of what ought to be, rather than what currently is.

7: Interpretivism - the process of doing or observing to begin to understand a process, place, or thing. By using your previous experiences and understanding, observations are evaluated and recorded.

8: Logical Argumentation - this process takes what has come before, often in literature to define and argue for certain methods, process or tactics that were used or will be used in a study, or to inform the information that will be pursued in the work.

9: Member Feedback - feedback allows the process or goal of the study to be improved and better serve the intended purpose. In this case students were asked to use the framework using their design process to identify shortcomings and address them.

10: Prototype - this is the object of the dissertation. This is the framework in its paper appendix form that went through three reviews according to different students and class typologies. It went from a single page, to multiple pages, to both analog and digital. This process is explained next in further detail as both the content and representational method was refined and improved.

We will look at both how a framework can be created to implement studio practices in other disciplines as well how frameworks can be used to combine discipline-specific topics or ideas with other topics of interest. We have the opportunity to decide what is important to us and bring this to the development of our own frameworks and resulting designs, products, processes, or results. At the end of this process of using, updating, and understanding our ideas, frameworks become references of our own work and ideas. A framework is not only what we see written on a page to guide our thoughts, but it also can be manipulated in our minds as we create our own frameworks. We become experts through experience, and with experience our knowledge becomes transformed into a new mindset, allowing us to leave the frameworks of others and create our own unique approaches to engaging the world and our ideas.

One of design's, and our own, greatest potentials lies in the convergence of seemingly unrelated and quite frankly odd combinations of topics. To support this exploration, unrelated combinations are all organized by interactions with vegetated assemblies and interactions with other topics. A process can emerge out of experience in design, but that does not mean that all designers must design alone in a vacuum, nor must they receive no guidance from teachers and mentors, or deny themselves the introduction of unique and stimulating viewpoints. Here are some questions to get you thinking about the concept of a framework:

- Is it the frame to which we hold our thoughts?

- Is it the method in which we think in order to understand?

- How do we operate within our place in the world?

Then there are some questions about how to choose a topic for your idea:

- What is your idea, your topic, is there something that is interesting to you?

- Something in your life that has followed you in your mind?

- An underlying interest in many projects or other works throughout the years?

Having an idea to reflect on will help you understand and engage rather than passively reading though the pages. I hope to convey that vegetated assemblies are a way that we can organize nature and nature's interaction with us. Unruly and always seeking favorable living conditions, plants in vegetated architecture are harnessed for their connection to nature while in the built environment.

This process of understanding vegetated assemblies through phenomenology can become a series of designed responses. This process then becomes a mindset that frameworks can convey graphically as a representation of how we can individually view of the world and our place in it. We have the opportunity to move through the whole process of making a framework and seeing how it can relate to design, and the interaction between ideas and people who are in both design fields and non-design fields. By relying on the expertise or interest in different topics, frameworks can be created in relation to the design process that begins to guide the relationship between individuals and design.

Our philosophical positioning within any discipline is important to organizing our engagement with a topic material and subsequently the world. With these things we can begin to form a framework for the material or topic and how ideas can begin to combine with these initial thoughts. The method for doing so and the representations made are often a personal implementation of techniques. Finally, after using the framework, we

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can move beyond the required use of the framework to design and begin to view it as a reference, as we begin to influence the profession with our own transformed experience about our topics. In effect:

- Think about how you want to use a framework.

- How will the framework change or influence your process of design?

- What happens when I become the expert over time?

Very few would begin to make a studio by having a rigid prescribed set of prompts for projects. Doing so would miss what the ethos of studio could or might be. In this sense Studio is not a formula, but rather, Studio is a mindset formed by experience and of about how you engage the world of design. From this mindset, the question becomes not only what is studio, but why would studio be used to teach others about the process of making? Studio hopes to explore some different topics about the studio environment such as:

- What is it about the studio environment that helps to explore ideas?

- How does studio help to teach us about the world around us?

- Why and how does critiques and discussion of design foster the creative method?

- When does the student or professional become a teacher or mentor for others?

- How does this transition help to understand studio and transformative education?

The studio environment or the design laboratory is based on a series of tenets that serve to make a collaborative space. Often there is a personal philosophy that the instructor brings to the studio to make each unique. As with frameworks, each studio is

different based on the interests and experience of each instructor; however every studio strives to incorporate a base set of aspects. These are:

- to foster co-learning where students learn from each other and the instructor;

- to discipline themselves in self-reliance and independent thought; and

- to determine their own course for life-long learning

These three main aspects of the studio environment can be translated to the professional realm respectively:

- working with others,

- being reliable and thoughtfully motivated, and

- continuing engagement in the profession

These questions of studio and the introduction of a line of inquiry into the profession then generate specific questions to guide framework development with a topic and to influence a personal line of inquiry and a personal architectural design process. As such thought has profound effects on how you interact with the discipline as a whole, and where you will sit within it. We can distill these thoughts into how someone can engage the world around them and translate them to useful processes for other disciplines.

There are interrelations between thought, theory, architecture, design and building science. These interrelations can be more universal than we realize by thinking about how these create and establish new ideas and thoughts. This process of distilling information with experience and combining ideas is what forms an individual knowledge base with which your own architecture, or expertise, can flourish. The weaving of thoughts into a position on your framework as an expression or representation of your expertise is critical in understanding and being able to see the interrelations between thought, design and

topical information. These interrelations are where interesting ideas and questions or new areas of study reside. Our inquiry is what can lead to understanding of a phenomena and how we interact with it on a philosophical and experiential level. These interrelations can lead to a larger stance on a profession or expertise, such as bringing the phenomena of nature into architecture. This creates some questions now specific to a topic or idea; although your applied topical questions will differ, are rooted in the same considerations:

- Why nature and how could nature be infused into our lives?

- Why is nature important to our process as designers and professionals?

- Why should we care about sustainability outside the environmental benefits?

- Is there more to this nature than we realize?

- How can we share our experiences with others?

- Is the environment only in nature, or can we bring nature to our buildings?

Other topics can be reviewed in a similar method to the study of vegetated walls. The concept of questioning and the collection of information and learning from others who are admired in their field are all part of creating a personally adapted investigation into your profession. For example, with vegetated walls some questions that arise are:

- What is a short history of the element I am working with?

- What are the benefits to using the idea of vegetated walls to others?

- Are there different types of vegetated walls?

- How do such walls interact with the space around them?

- How do others see vegetated walls in their buildings and representations?

- Why are vegetated walls interesting or why should they be used?

These questions are about the topic at hand, and how information can be shared. From this information we can begin to critically analyze our topic and its importance to our discipline, potentially fusing it with our research, teaching, or professional practice.

So, what are the criteria for how vegetation, our topic, will influence our framework and the different combinations of ideas that we choose to explore? Seeing often helps to show how and why a technique or process is helpful to others. We can write all day that it will and should work, but seeing how it does work is often more concrete. This is the synthesis of thought, design, representation and topical expertise.

A framework can allow us to represent the thoughts that inform our lines of inquiry. These become sources of invention in our systematic approach to a topic of interest. A systematic approach does not mean that it is linear, but rather organized, with a process being applied to bring structure to seemingly chaotic thoughts.

There are an almost limitless number of facts. How can we help or begin to filter information and guide initial ideas and processes, and then allow others to grow outside of face-to-face guidance? These frameworks do not replace our mindset, they augment it. This augmentation visually represents our experience and the memories and knowledge we have maintained. We construct our understanding of the world by utilizing our past experiences to inform our current and future ones. We use objects such as the frameworks to establish a reference for our memory or inspiration from which we develop new inspiration. The conception of the framework as an object of making is central to its use in studio and other environments. This process of making and the framework are the basis from which our ideas can form and combine with.

We need to remember that design is amorphous in scope. With a near limitless number of facts and considerations, design needs to filter or organize this information with a guide to initial ideas and processes. From this initial guide we can grow beyond to other particular questions. Design information is not equivalent to pure technical knowledge. This requires synthesis of situations, processes, and technical information to complete a work. This synthesis is not inherent in someone. What can be considered genius is built from experience, visual input, and the series of inquiry selected from a personal repertoire of interests, often not occurring immediately.

Experience is not just sitting and reading a book, but reading is a part of learning to synthesize new information or ideas. Success is not an accident, and good luck is not providence. Rather these two things are created by habits and thoughts which combine with prior planning to give us new ideas. These ideas are not reproductions of other objects in our world, but are instead our interpretation of our world as it is applied to our design process and skill.

If you are looking for a self-help book that is going to tell you exactly what to do, this dissertation will not be of much use. This dissertation shows 'a' way, not 'the' way, to develop a framework. It shows the sharing of ideas, space, words, material, and interactions to form relations between ideas, which create a narrative for future designs. It is not a rigid step-by-step prescribed process. Instead it is a way to interpret your world and by doing so, engage it as a framework appears.

I want to reiterate that this process of developing ideas can take years. The literal application of the framework and its combination of new ideas is part of a slow process of being engaged in your topic, while allowing for external inspiration to inform you. The

object, the framework, guides a mindset to inform your design within your series of experiences. Experiences, some as simple as a watercolor of poplar leaves, as shown in Figure 3, play an active role in the analysis and interpretation of ideas to make a reaction and a construction of new ideas. This process of making is the progenitor of design.

Figure 3: A watercolor sketch of poplar leaves looking into nature as a form-giver and color. Form and color influence depth in a composition using hue, saturation and value.

1.3 Framing the dissertation as scholarly study

Overview

This more detailed introduction which serves to introduce the dissertation as a scholarly body of work. Framing the dissertation as a scholarly study will include: my position on architecture, the problem statement, the purpose of the study (aside from the concept of idea generation mentioned in the last chapter) the research questions, some general definitions, limitations, a brief excerpt on methods and procedures (more will be explained in subsequent chapters), validation, further study and ethical considerations, and preliminary conclusions.

Position Statement

Architecture exists as an example of personal interactions with the surrounding environment. I choose to subscribe to the idea of man as a metric for the development of space and impression. This belief is not solely dependent upon the individual, but the interface the individual has with architecture and the environment, which informs design. We, as designers, people, and users all have a sense of place and connection to the environment in which we live.

A building that is not responsive to the surrounding conditions of nature is simply a lost opportunity for a more compelling intervention in architecture. This sense of place within the realm of architecture is created by the experiences from each individual and their interpretation of phenomena. Studying and controlling this individual experience and subsequent understanding of the world allows architecture to show its worth by making the individual aware of their environment through architecture and the senses.

This idea of an innate connection to the environment, termed Biophilia by the biologist Edward O. Wilson, is not new. Man first existed in nature and then used architecture to provide shelter and a sense of place. This harmony with nature is not only being sensitive to the environment, but also sensitive to the cyclical methods that nature employs and how these cycles can be integrated into the design of responsive architecture. Architecture is a combination of natural and man-made stimuli to create space as a designed response.

The past, present and future is a continuum for an architect. This creates perspective and context against sentimental historicism, modernism and utopianism. This is not to say that the designer is solely focused in the past, but rather is aware of the past, the past that has become the present and is projected into the future. The way in which a designer operates then influences future interventions in architecture which may or may not be his own.

Therefore, the designed response is not an act but a habit maintained by the designer, ingrained into the design process. This is not to say that a project must be only one pure idea. Design should have many layers that build the intensity of the design, without adding unneeded complexity. When this sensitivity to the surrounding environment is central to the design from the beginning, the response is stronger and more developed. It is this connection with nature and the environment that leads my work in combining color theory with vegetated assemblies. Nature and its color provide an infinite potential for an individual line of inquiry using the study of phenomena to experience architecture and its worth.

Problem Statement

All of the question posed earlier in the introduction can be summarized with two questions: How do individuals interact with, and process sensory input from the surrounding environment?; and how do decision support frameworks serve as a knowledge sharing device?

Sensory information is transformed into useful knowledge. This knowledge is elaborated upon by past experiences while being stored for future interactions ass memory. These memories are called upon in times of need and used again. This process is termed cognition. Cognition can be, and is used for all aspects of living, and in philosophy there is a subset of techniques: epistemology, logic, metaphysics, ethics and aesthetics. The first of these techniques, epistemology, is mainly concerned about the areas that which can be known and their scope (NYU, 2014). Epistemology, combined with another type of cognition, meta-cognition, will prove critical to the development of the design process supporting the framework for vegetated assemblies in relation to color theory. How do we know what we know (knowledge about cognition) and how do we know that we know it (regulation of cognition)? These are the two main components of meta-cognition (Schraw, 1998). Being aware of what we know as designers and how we know it can lead to more complete design decisions. But what are the problems that we and students will face?

The description of design research is explained by Nigel Cross in *Designerly Ways of Knowing*. This method relies on seeing design as a third culture to the humanities and sciences. This third culture can also be called technology, or applied science and organized knowledge combined to address practical tasks. Overall, these sorts of practical

tasks are not necessarily evaluated by analysis alone as in the sciences, but through the synthesis of ideas, and experiences. Design problems are often called "wicked" (Rittel and Webber, 1973). This means that they are not as defined and compartmentalized as other research questions, often acted upon by many different external forces. These problems must be re-defined and re-evaluated by the experience and tools available to the designer. This begins to place limits on the design, generating a possible outcome or design solution. To tackle a small fraction of these "wicked problems" relating to architecture, a topic must be chosen.

If we use the two questions at hand: how do individuals interact with, and process sensory input from the surrounding environment?; and how do decision support frameworks serve as a knowledge sharing device?, we can begin to narrow our focus. Since I wish to share what I am interested in and know, the topic of vegetated assemblies will engage color theory and apply its synthesis to the framework as a knowledge sharing device through the lens of phenomenology.

Phenomenology is a theory of knowing that contends that the observation of phenomena is different from perception and judgment. Instead of discretely evaluating through perception or rationalizing through judgment, an individual experiences ones' surroundings as a world or an object outside the observer and then internalizes these experiences; that we are a summation of our experiences and knowledge. From this basis about understanding cognition and meta-cognition the framework will serve as a method for allowing designers to graphically see and perhaps experience design in a different manner by way of my experiences in relation to color theory, informing their design decision-making process.

With concerns about environmental impact of buildings persisting, new methods and theories of construction continue to develop; however, this concern should not become dominant to the aesthetics of the design. Aesthetics should be in a dialogue with environmental design concerns allowing for each to complement the other. How do we meld the science of plant biology with environmental design? Specifically, how can the use of plant biology and color theory interact with and respond to the building envelope? The building envelope is a very broad topic; however, in reference to nature, one type of building system can be called to the forefront: vegetated assemblies.

The design of vegetated assemblies should be responsive to the site both in vegetation used and in color theory, in order to improve the interaction and experience between the user and the building and climate. However, this study is looking for regional expression by using specific plant biology and color theory for southwestern Virginia. If the study were to encompass all types of plants and their respective biology, it simply would not be feasible. The plants reviewed in the framework will be derived from a combination of commercially available plants in the region and other biotic factors.

So how can a regional interpretation of nature be brought back to the constructed environment, using the very walls that form it? The ancient gardens of the Egyptian and Mesopotamian civilizations and the Chinese in medieval times show the desire to bring vegetation back to the constructed environment (Hongxun, 1982; Osmundson, 1999; Shepard, 1967). Others contend that in more modern time vegetation was used for the wellness and stress reduction of those in the constructed environment (Parsons, 1991; R. S. Ulrich, Dimberg, & Driver, 1991). Biophilia takes this further developing on the

hypothesis that there is a genetic predisposition to nature that creates the innate desire for a connection with nature (Wilson, 1984).

What is the formative role of vegetation on sustainability and green architecture outside of energy conservation? Vegetation has the ability to give a sense of connection back to nature not commonly found in constructed environments. In the urban environment there can be a lack of vegetated spaces for those living in cities. Architects can and have used this opportunity to develop ideas and design concepts applicable to vegetated walls and facades, creating living buildings. These vegetated facades can be both decorative and integral to the building itself. Therefore, this connection, genetic or not, can serve as an underlying driver for the inclusion of vegetated assemblies in the constructed environment, such as walls, buildings, and other architectural structures.

Purpose of the Study

This dissertation study is an exploration into and application of phenomenology in decision support frameworks and their capacity as a knowledge sharing device. This study into the architectural profession reviews developed decision support frameworks (graphics to inform and improve decision making through access to more information) as knowledge sharing devices. These developed frameworks first, influence decision makers: the students and their decisions in their personal architectural design process and second, develop a framework on vegetated assemblies (building assemblies that incorporate plants such as green roofs and walls) as vegetated assemblies relate to color theory and its implications in design methodology.

Specifically, this decision support framework assists students in their design process in studio and studio-like educational environments. The purpose of this decision support framework is to influence the students in using vegetated assemblies in their future design inquiry. After implementation, the purpose was to determine the worth of the framework as a mechanism for knowledge sharing. Both purposes were reviewed in developing the framework using immersive case studies, classes both in traditional studios and studio-like courses, website development and member feedback.

These objects are what designers can give to others by taking into account and carefully crafting the stimuli in a space. We as designers need to continue to think, to contemplate, to understand. We must think about the phenomenon and its worth. According to Rudolf Steiner, in Goethe's (1749-1832) scientific writings he believed that thinking should direct observation (Steiner, Goethe, & Barnes, 2000). If thinking about our observation is necessary to a more complete understanding of a given situation, then our interaction with a phenomenon is influenced by the knowledge that we both have and do not have. The purpose of studying the phenomena of color theory in vegetated assemblies is to then be able to implement such knowledge later in design. The core of the study is how vegetated wall assemblies, through their plant colors and materials, are influenced by color theory and how that influences their aesthetic design. From this core, a framework is developed.

This Decision Support System or Framework is not a series of mandates, but a suggested guide through a designer's process. The framework would impact the more prescriptive design method and philosophy that the student has begun to develop during

their studies and experience. The decision support framework would not make the decisions for them as that would negatively impact the ideation process.

Architectural design is inherently a decision-making process of which ideation and representation are at its foundation. Designers typically move from ideation to representation and then to iteration as a cyclical process and ideation and representation are at its foundation. Moving from the more abstract step of ideation, representation allows the architect to move from an idea to issues of quality of space, materials, construction, and, in this case color theory. The framework can serve as an outlet, an extension of the representational process, allowing for a more complete design, not simply for the ideal conditions. The framework would allow designers to better understand their implications and help clients to visualize a potential design to support for construction. This research has at its foundation this evolution of this process.

Figure 4: The main diagram about ideation, representation and iteration. This basic process is what makes the iterative design process a powerful method for generative work from the vegetated assembly framework.

Therefore the purpose of the study is to combine the desire for creating a framework to assist students with a personal exploration into the vegetated assemblies and representational techniques that are combined with it through phenomenology. Generative work and frameworks without context do not lend themselves to a cohesive design process or representation. Each different question is specific and in the case of this series of work, to create this dissertation, more than one theory is used. Perhaps this

generative framework could move into the spaces between different theoretical positions, making a pluralistic view of design thought? This pluralism can bring multiple views together, and begin to interact with the boundaries of different positions. Conversely, this introduces the potential for mixing and matching philosophies to meet the needs of particular situations which then could contradict themselves. But how can we have a pluralistic view on philosophy, and then counter it immediately? The purpose is to understand that if a thought process is pluralistic, it needs to be sufficiently grounded and each position is respected, not mixed-and-matched without discipline.

This dissertation will reside in the larger concept of phenomenology, and how we as individuals interact with and engage the phenomena of the world and its objects in space. This further specializes to Kenneth Frampton's position of Critical Regionalism and of an anti-centrist view to cultivating a localized culture or response to a place and its influences. As the world continues to trend towards complete globalization, the ability to assimilate and then re-interpret our surroundings as designer will be critical in forming responsive architecture in the face of a universal technology (Frampton, 1985). This assimilation and re-interpretation is vital to making the pluralistic view of my architecture.
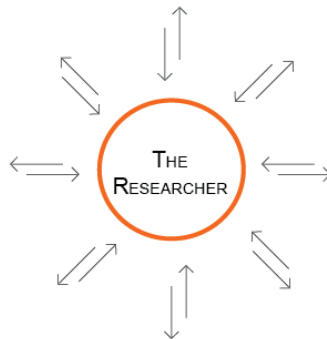
Figure 5: The researcher serves as a node for many topics and methods of thought. In this way a pluralistic approach to the dissertation becomes its foundation. It is these phenomena that influence the researcher, and his experiences, knowledge, and understanding.

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There are multiple views that make up the pluralistic approach to the dissertation. The first is contextualism: that everything has a context in which the action, intervention or expression exists or occurs. Tim Black in the Internet Encyclopedia of Philosophy, describes contextualism in epistemology. This has two major areas, one of the object or person and their knowledge or context, and that of the attributor (or researcher) depending on the relation of the statement (T. Black, 2015). For example, depending on my own knowledge and experience, the context that I create for a site, or historical context can influence the designed response. So, if I and others all have an individual understanding that is regarded as our own truth, this can lead to relativism. Relativism defeats the purpose of understanding context as everything is now understood as relative and nothing can be said for certain. That is why for this dissertation, contextualism will be what the researcher can observe and infer or interpret from the observations and reflection on the personal knowledge of the researcher. This way contextualism provides a basis for understanding interpretivism on the part of researcher and the potential knowledge of the students who will engage the decision support framework for vegetated assemblies and its capability as a knowledge sharing device.

Next is naturalism, that certain things are governed in accordance to natural laws and mechanisms without the supernatural (Papineau, 2009). This is problematic, as having no link to the supernatural ultimately limits the context of an architectural intervention. What is meant by introducing naturalism is explaining how the plant biology and characteristics will be understood and characterized in their natural context. This concept of a natural setting will be important in observing users of the framework in

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a 'natural' studio setting. Naturalism has a wide variety of meanings, thus the use of typical or natural settings for researching is also critical, both for the students and plants characterized in the framework. Simply, the philosophy of naturalism organizes the world of the plants and their inclusion and choice in the framework and the setting in which the students work, but not the greater understanding and usage of color theory in the design framework. This is discussed later in regards to native and invasive plants. By engaging naturalism in this manner, only certain parts of the methodology will reflect this philosophy, as methodological naturalism. This concept is in reference to the systematic method or scientific method or science, rather than a purely philosophic or religious one. In this way, philosophy and science together synthesize information from the phenomena of the natural world.

In summary, these philosophies including phenomenology, through critical regionalism, contextualism and naturalism, are not melded together to make a new philosophy, but are used in different realms of the dissertation. There are different sections to the dissertation that respond more favorably to using different methods of thought. Moving from the most specific to over-arching, naturalism is used to organize and evaluate the biological principles of the flora selected for use in the process of the framework. Contextualism provides a basis for understanding interpretivism on the part of researcher and the potential knowledge of the students who will engage the framework. This coupled with writing from the students will help to mitigate relativism complicating the issue. Through context, critical regionalism engages the designer to take and inject some form of designed response whether from the site, or larger cultural

context. Finally, phenomenology is used to understand the method of engaging the world in relation to the senses.

The questions posed in our time are often at the boundaries of constructed disciplines, requiring multiple viewpoints, and engages other disciplines critically. To tackle a fraction of open-ended or "wicked problems", the decision support framework as a knowledge sharing device will use vegetated assemblies to engage color theory and apply its synthesis as decision support in the developed framework. This synthesis of ideas and understanding makes up one facet of the designed response, the other is responding to the site conditions, and its context. This framework serves as an extension of the designer's contextual understanding as a support system; just as reading a history book could give context to a country or place. This decision support framework should assist designers in understanding the phenomena or color and vegetated assemblies as it exists. The concept being that, without experience or context, design is somehow lacking. This will become important during the study as we need to observe our surroundings and objects based on our previous experiences to understand the world around us. This process of accumulating knowledge is fundamental to our understanding of the world.

This then necessitates defining a personal position of philosophy and how these philosophies will be used in the purpose of the study itself and its relation to design technique and representation. The framework is not restrictive, as there is not one correct or normal way of designing. However, the framework can provide a new normative basis of what ought to be, but does not have to be in a design process. In designing, especially with color theory and vegetation, there are not incorrect answers, but adequately supported ones. For example, a plant may be a better choice on a wall or assembly, but

what does that mean? Is it better since the colors are more vibrant, because it was not

invasive? This is why the framework will not prohibit the use of plants, or styles of

representation, but show possibilities, of which certain ones will respond more favorably

to the context of the site.

This shows that all of these different methods of thinking and engaging the world

do have a relevance to our cognitive and physical world. What we think as designers and

our designed responses can become physical reality through built form. As shown in

Figures 6 and 7 (on the following page), this process of including how we choose to

engage the world has an influence on our design process. Memories of vegetated

assemblies on travel then begin to inform later design work.
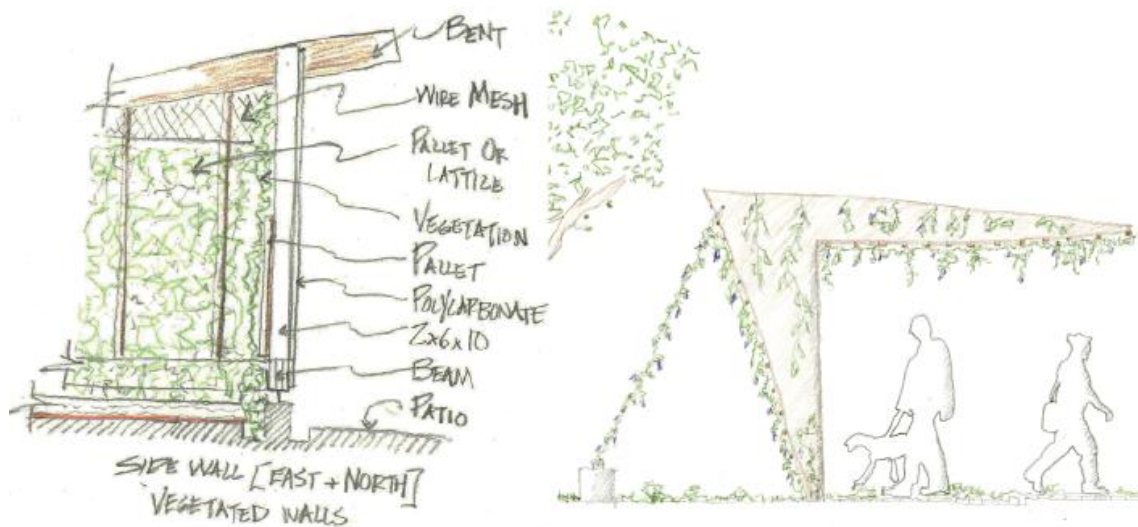
Figure 6: Two examples of design using vegetated assemblies and how these assemblies are constructed or interact with people.

Figure 7: Image taken of a vegetated assembly in Bellinzona, Switzerland while on travel on the path to Castelgrande.

This process of thought and engagement with design is how all of these different topics (naturalism, contextualism, critical regionalism, phenomenology, and normative) are brought together that creates the basis for a methodology of answering the question: What place does color theory have in a normative framework for the design of vegetated assemblies? Figure 8 below begins to look at the place of where vegetated assemblies and color theory ought to be in a decision support framework in the design process.
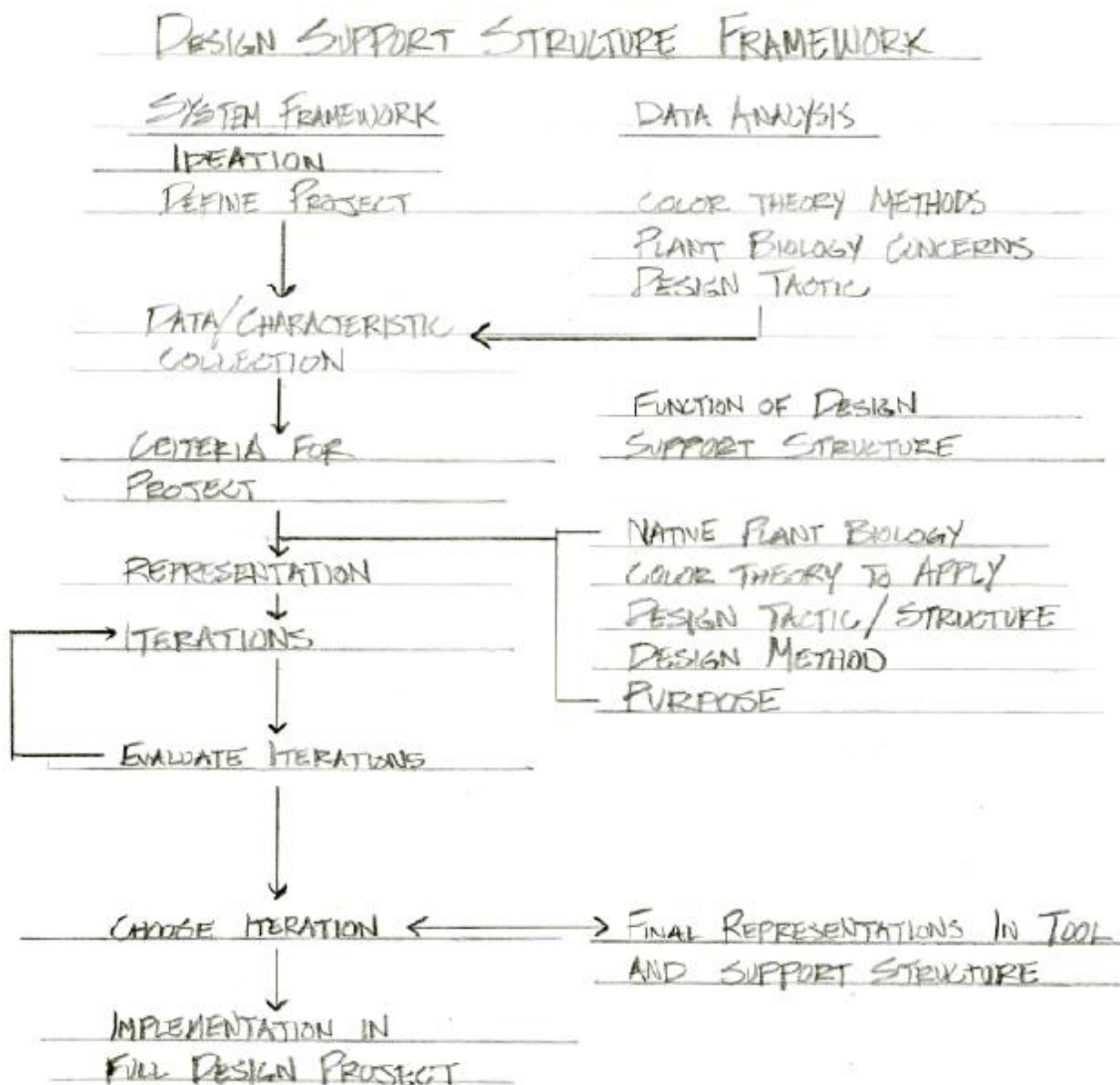
Figure 8: initial sketch of the decision support framework.

Research Questions

The purpose of the dissertation then becomes the central research question: How ought a decision support framework to serve as a knowledge sharing device? What is the subsequent representation and graphical method of this decision support framework? Finally, what is the influence or effectiveness of the decision support framework on students and their design process if improvement is measured as access to more information to make a more informed decision? These two main questions become:

Questions of the Normative Design Process:

How ought the decision support framework be as a knowledge sharing device?

What is the method of graphically representing the framework to others?

What philosophical or metaphysical lens ought the framework have?

How ought the framework relate to a general normative design process?

How ought the framework filter and serve as a node for information?

What educational environment should the framework be used in?

Questions of the Framework's Decision Support Ability:

What improvement is there in the ability to make decisions by students?

What are the metrics to measure the improved decision making capacity?

What topics should be included in the decision support framework?

What is the formative role of vegetation outside of energy conservation?

How do we meld the science of plant biology with environmental design?

How can plant biology and color theory respond to the building envelope?

Other more specific questions that stem from these larger ones have been introduced in Chapter 1.2, regarding ideas, frameworks, and the inclusion of nature in design. However the inquiry does not stop there. How do we as designers begin to use, through the normative design process and frameworks, the aesthetic that is created when plants over time interact with each other spatially and chromatically in vegetated walls? Further: how can this be used in a representational framework to synthesize vegetation/plant growth, color theory, and design-decision making?

In order to provide a knowledge sharing device in the form of a decision support framework for vegetated assemblies in relation to color theory, the research will attempt to discover the characteristics of vegetated elements in architectural design in reference to color theory and plant biology. When selecting plants for vegetated walls what are questions to consider? We need to consider what kinds of plants are adaptable to vegetated assemblies. We need to consider if there are compatibility issues between types of plants selected in the assembly. We also need to consider what the possible implementation issues are for plants that are adaptable in vegetated walls, such as watering, pollination, or root depth. Other plant characteristics that need to be considered when implementing vegetated facades include: a plant's origin, range applicable hardiness zone, climbing mechanism, resiliency to climatic conditions, weight, profile, and texture.

These questions will be applied to vegetated facades to determine a regionally inspired expression of a Southwestern Virginia climate based on useful flora. The characteristics of plant biology coupled with color theory influence the designed space. In

order to know how these characteristics are influencing color theory in vegetated assemblies, the plant biology of the flora needs to be observed or obtained.

If vegetated assemblies are to be designed with these questions and color theory in mind, color theory is not simply the color wheel or feelings associated with colors. Color theory is heavily influenced by the infinite nature of color. Color within light resides in a spectrum of wavelengths, with each color blending into the next. In the spectrum, light displays itself and the face of nature, informing us of the characteristics of surrounding objects. The resultant color is at all times specific and characteristic of the object, yielding significance. By understanding the relationship aesthetics has with these theories, it will allow for a better integration of aesthetic design with vegetated building assemblies through synthesizing vegetation/plant growth, color theory, and design decision-making.

The framework that will be the result of looking at all of these factors then becomes a source for information to further the dissertation as well. The concept of representation also relies heavily on techniques that are employed by the designer, not only the theories or data characteristics that are accumulated. This then makes how students use the framework and in what manner the framework is presented to them is as important as the information that is contained within the framework itself.

These questions led to the fusion of studio with research, and how students can become an important part of the research process. The feedback they provide will serve to guide the course of the framework and its analysis.

Procedures / Methods

There were five main aspects to the research process: logical argumentation, photographic analysis, prototyping the framework development, immersive case studies, and a member checking or questionnaire. Logical argumentation was comprised of the literature review as a basis for plant selection, structure of the framework to be used, and what the framework will provide in terms of decision support through the design process. The photographic analysis of selected plant color characteristics were then integrated into the framework.

The stages of development served as a process for prototyping the framework based on color theory and other design factors. Immersive case studies then served as testing for the framework and to test its usability toward improving the support of design decision-making. This immersive stage used me and 2-3 other "designers" or colleagues to develop the framework. Then various projects of the immersive case studies of using the framework provided a body of work that can be associated with the framework process and refined its abilities.

A final member checking or questionnaire stage was completed to gain an understanding for the positive impact on decision support on design decision-making. These responses from the questionnaire were reviewed using descriptive statistics and the interpretation of completed student work. Questionnaires occurred in traditional studios alongside the testing of the framework by teaching a studio module with a vegetated assembly theme. A secondary thesis project was developed as a basis for exploring an architectural idea, light, in relation to vegetated assemblies through the immersive case studies. All of these methods served to confirm the observations from the studio and

confirm the potential of decision support frameworks to further develop decision-making in students.

The investigation through the literature review of vegetated building assemblies in reference to color theory and plant biology was conducted with a review of both historical and current literature. Key questions have been listed out previously in the research questions prior. After the literature review, a series of design and photographic studies was done in the immersive case studies with their construction at full scale. These immersive case studies provided a method for understanding how representation and then implementation can be used to create and evaluate vegetated facades. The selection of the plants was based on appearance, plant biology characteristics and color theory.

Depending on the student, this developed decision support framework was used with techniques such as: Photoshop, which is a flat rasterize program; and Grasshopper, a Rhinoceros plug-in, Google SketchUp, DIVA for daylight analysis, or AutoCAD software. During the development of the framework, it became apparent that a paper framework was not the only way to represent information, nor should it be. Later in the dissertation we will explore the differences between the book and the digital website in relation to the framework's representation.

After working on the development of the processes in the representation framework, three methods were used to triangulate its effectiveness and usefulness. The first was to be interpretive on my part as the researcher. The second was on the part of the immersive case study, using a follow-up documentation of the work directly with the framework. The third was the member-checking or questionnaire stage. This stage of using a questionnaire about using the framework was given to 8-12 experts to use the

decision support framework for a number of different design cases. They sorted through the steps necessary to design the vegetated systems according to color theory. Afterwards questions and information gathered at the meeting was used to inform another iteration of the framework for studio system.

This questionnaire was developed for students in the 2nd year of their architectural studies first to see base knowledge, assessed the desire for such a support framework, and then to review their thoughts after performing a small design exercise using the framework. This was done over two years with two different studios. Project work from the studios and the questionnaire exercise were collected to later review for themes and possible improvements. All of this work was then compared to a large lecture class exercise and a smaller discussion-based course run through the University Honors program.

The primary research instrument of the dissertation was interpretation. Interpretation had a major role in the observations of the students using and interacting with the framework. The researcher was the most vital link to synthesizing information out of conceiving and then implementing the framework initially and interpreting the intra-personal interaction a student had with the framework and their personal design process and architecture. Before starting into all the specifics, it is important to understand that by choosing to interpret, I have chosen to reject the notion that all social or design interactions are derivative of logical processes, thus treating interpretivism as anti-positivism.

This did not mean that I, as the researcher, cannot find information or use a logical process to interpret sensory experience, as that would undermine the use of

phenomenology in the dissertation. What this meant was that not everything can be known or understood logically. Phenomenology, in order to understand and interact with objects, and subsequently the world required not only self-reflective thought, but also the context of sensory experience when interpreting the framework, or a subsequent model, drawing, or construction. I have viewed interpretivism as an extension of phenomenology, generating a renewed experience by systematically reflecting on a series of personal and student works through the future framework. I became a node for not only gathering, but disseminating knowledge during this process. By having students use the framework as a method when I, personally, am not available helped them to understand and engage vegetated assemblies.

My hope as the researcher was to not only balance my interpretations of the students, but also allow the students to speak for themselves in describing their interactions and understanding of the framework. Everyone engages phenomena differently, and this required a balanced approach, or the engagement was only my own. I was an observer, and personally do not explain all the facets of the framework for everyone at every step of the process. This is why a completely logical and derived set of conclusions from or for the decision support framework was not possible as I cannot know everything of everyone's design process.

What do we get out of all this? We find that phenomenology was used to guide interpretivism, to systematically reflect on observations, interviews, and produced representations to inductively analyze the information gathered. As the researcher and primary instrument, the ability to inductively analyze the interviews was critical. This

required identifying key themes, developing and utilizing a coding and memoing scheme, and then synthesizing the information into a usable narrative for others.

This process was heavily detailed in Architectural Research Methods by Groat and Wang (2002). Many of the topics, charts and tables were adapted from this source as an introduction to the processes that defined the research plan, which reviewed types of data, how these were collected, and how they were analyzed. There were a litany of different general characteristics to qualitative research that weaved together a process for understanding knowledge and reality, including: natural settings, interpretation and meaning, respondents' understand of circumstances, multiple tactics, holistic approaches, prolonged contact, an open-ended mindset, the researcher as the primary instrument, analysis through words, and a personal informal writing stance.

From this continued interaction of the researcher with not only my, but the participants' natural settings comprising 'studio', interpretations were made. These interpretations were based on the experienced views of the students and the researcher. Using interpretivism in this study not only required observing a studio using the framework, but then understanding the context that the studio was in, who the participants were and could be, and what the interaction of these two could mean for the researcher (in reference to my own understanding of architecture and my students and their representation).

In Architectural Research Methods (Groat & Wang, 2002), there were case studies that begin to show how an interpretivist approach can be used in qualitative research, one as research design and the other as studio design. In this case study, a quote was used from Clare Cooper Marcus from House as a Mirror of Self, stating that "a

deeper level of person/environment interaction can be approached only by a means of thought process that attempts to eliminate observer and object." (Marcus, 1995). In my understanding of this, the observer was the researcher, and the object was the participant or phenomena. If we only deal in binaries, we cannot truly engage the phenomena and gain experience. Phenomenology cannot be used if the observer does not engage in the experience themselves. This was the core of my methodology, that I too, experienced the framework and teaching students.

Validating Findings and Further Study

Validating the work in the dissertation uses the triangulation method. By using immersive case studies, the questionnaire studio, and observation and feedback from students, different perspectives can confirm information found in each individual validation method. All of these parts are used under interpretivism. The information given to me as the researcher is each individual's, I have to give it context and verify it again against other observations and framework intentions. This is why, as the researcher, I need a thorough understanding of the framework itself, of teaching and observational methods.

Each iteration of the framework would go through a questionnaire phase in studio, with feedback and resulting work to see the usefulness of the framework for students. There is also the potential to verify work through publication which has also been tested in relation to the project and has been successful, hopefully with more to come.

By using some of the characteristics outlined by the photographic thesis study and representation, and the refinement of the framework, the decisions made in the Solar

Garage would validate some of the tenets of color theory as applied to vegetated walls and provide a base for further study. The student work and personal thesis also show possible designs and the potential of the characteristics amassed in the study to be used in architecture. This could become a language of vegetated assemblies for the built environment in the future, prompting a much larger study.

The study could be expanded by enlarging the geographic areas from where plants are chosen. Then, after a necessary number of examples and desirable design characteristics are compiled, a decision support structure (DSS) could be developed to aid in the aesthetic qualities from which an architect or designer could choose. The system would provide a base of knowledge that could be drawn from, streamlining the process and incorporating color theory more actively into vegetated assemblies earlier in the design phases.

Following is a diagram (figure 9) of both the current methodology showing where the validation of the study combines with logical argumentation and the other studies, surrounded by the dotted box. Above the methodology are examples of possible validation methods and below are methods of data and other feedback collection and verification. This overall methodology of the dissertation, expanded to show different validation methods in data collection and analysis and the triangulation of this data through immersive case studies, the questionnaire studio, and observation and feedback from members such as the students who participated in the studios.
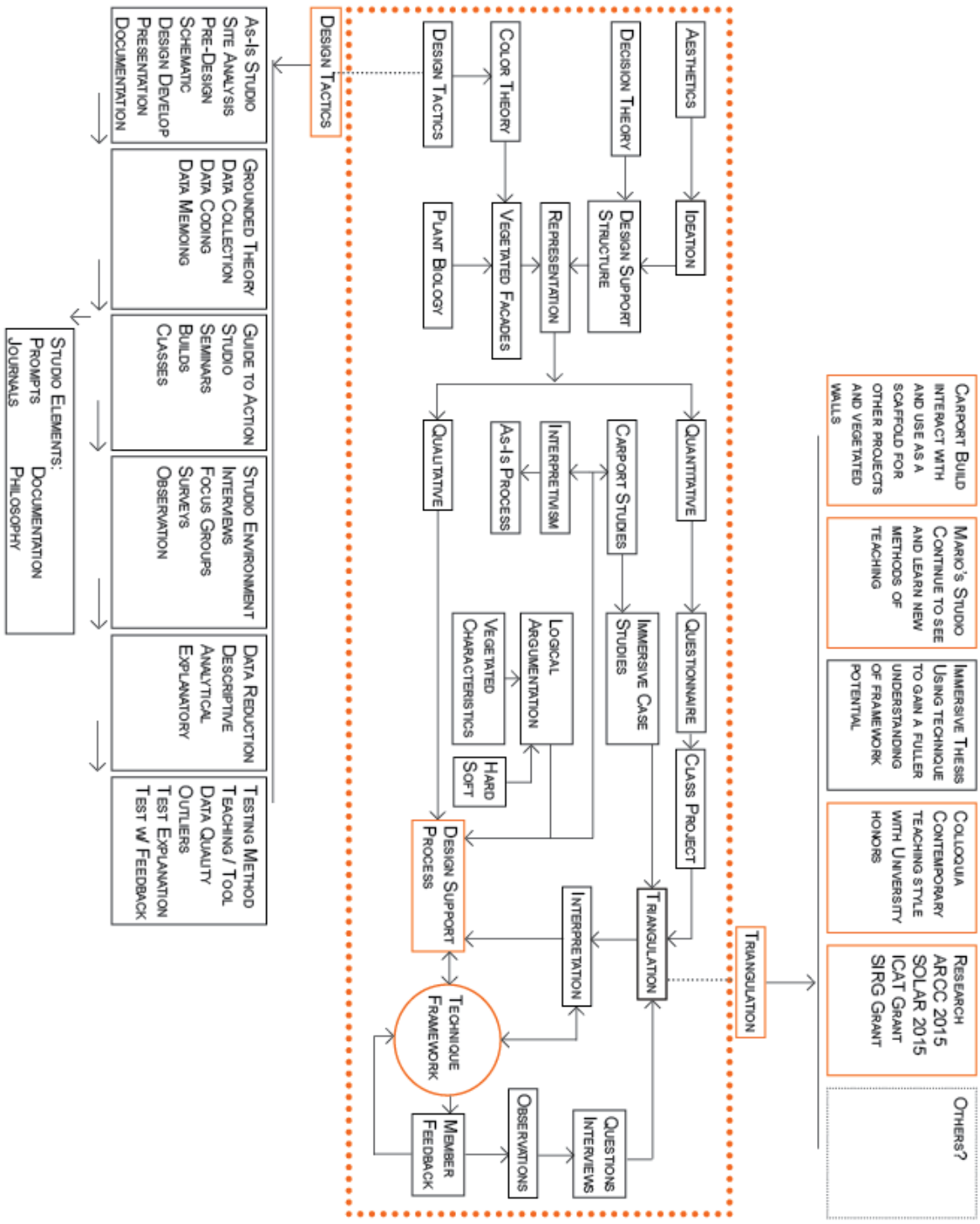
Figure 9: The greater validation method with examples of work done in each aspect in relation to the larger methodology of the dissertation within the dotted box.

Anticipated Ethical Issues

Ethical Issues could arise if the study reveals either through the design process, or through the monitoring of the electric car structure, that certain types of plants or products do not perform as specified. Moreover, if certain species of plants, proprietary or not, perform better than others, the study cannot inadvertently place product placements or unfair advertising for or against them.

The characteristics amassed in the Solar Garage project and field studies must rely on facts with critical thinking applied. The success or choice of certain plant species could be detrimental as some companies could have a vested interest in the use of vegetated building assemblies as an aesthetic in addition to the primary environmental benefits. Therefore, as a researcher it will be prudent to remain a third party while observing the characteristics and plant biology in vegetated assemblies.

In the classroom, there are other issues to consider. Though not high, there are some risks associated with surveying and recording information about student work and abilities. Therefore the Institutional Review Board process for verifying survey methods is important. For example the method for such a survey is determined ahead of time:

> The study procedure will involve the completion of a web-based survey with consent information provided at the beginning of the survey. Consent will be implied by the completion of the survey and the submittal of the CD-ROM. A blank CD-ROM will be supplied by the researcher and then returned to the researcher once the students add images they are willing to share. The CD-ROM will only contain images of the completed projects from the final presentations of

the project to the class (models or scans of drawings) no personal information will

be included. [...]

Furthermore, a detailing of risks is critical to understand:

This study involves no more than minimal risks to study participants. These may

potentially include the typical emotional, social and dignity risks to students

describing participation in a studio project. Given the small group size it may be

possible for students to deduce that their work or effort is being described by

another student in the resulting paper. The goal of this is two-fold: one to gain

feedback for the framework, but also to expose the student work to others:

The direct anticipated benefit to the surveyed students will be to give visibility to their

efforts on a design project about vegetated walls through the publication of a scholarly

paper. The indirect anticipated benefits to society are the demonstration of a process of

design before the design of the prototype framework and then be better able to design the

future usable framework both as a hard-copy appendix system and a digital application.

Definition of Terms

The study has four main concepts: aesthetics, decision theory, color theory, and

plant biology. The critical experience of phenomena is in reference to an object by its

content or meaning in reference to our own notions and thinking. Aesthetics means: of or

relating to beauty. However there are many different kinds of interpretations of this

beauty. Immanuel Kant believed aesthetics to be a subjective experience of beauty,

universal in function only when disinterested (Kant & Walker, 2008). To Friedrich

Schiller, aesthetic appreciation of beauty is the most perfect reconciliation of the sensual and rational parts of human nature (Schiller & Snell, 2004). As expected, methods of thinking or expression that are subjective in nature have many different definitions or processes when attempting to understand the subject matter.

Decision theory or decision-making theory is centered on the making of decisions. Decision theory resides in the theoretical unknown or making a decision in response to a problem without a clear, single answer (Hansson, 2005). This definition of decision theory is more general, in design; another type of theory is present: design support structures (DSS). These structures are less about making the final decision for the designer and more for supplying the designer with information with which to make an informed decision (Cross, 2007, 2011). Therefore the experience of the designer works with the DSS to design more effectively.

Color theory, according to Goethe, is a guide to the nature of colors and how these colors are perceived by humans (Steiner et al., 2000). He understood color as how the phenomena of color are perceived and was less concerned with the analytic properties. This is only one view of color theory and this concept is expounded upon in the literature review.

Plant biology, also called botany or plant science, is the scientific study of plants, including their physiology, structure, genetics, ecology, distribution, classification, and economic importance. In relation to plant biology, according to Edward O. Wilson, Biophilia is an appreciation of life and the living world (Kellert & Wilson, 1993). This unspoken but deeply connected bond with nature people have is how plant biology and the expression of vegetation on the envelope of a building, will be combined with color

theory when using vegetated building assemblies to develop a new stance on their synthesis.

Finally, the building envelope is the physical separator between the interior and exterior of a building, and serves to keep occupants comfortable again undesirable exterior conditions. Depending on the climate, building envelopes can have a wide variety of implementations. The building envelope is where vegetated assemblies are usually located; on the exterior of a structure. Some vegetated assemblies, when cared for correctly, can be on the interior of the structure.

These topics combine to make the representation of the vegetated assemblies, but the interface of the framework is found with the student and his or her technique. This implementation of technique is critical to the implementation of the framework. Technique is a means of expression in representation. The framework will be the most useful in schematic design, towards the beginning of the design process, where changes to the design are the least costly and most effective. There are standard sets of drawings used in conveying ideas in the form of graphical representation. With the introduction of greater computing power and the personal computer this means that not only analog or hand-drawn techniques are present, but also digital or computer-assisted techniques. These two categories are what will generate the criteria for techniques and their focus.

Limitations

As the study is specific to the biology of plants usable for vegetated assemblies, baseline data collected from field guides of local plants will be both quantitative and qualitative. However, much of the information collected during the study will be

observed from photographic studies or mock-ups, rather than solely empirical testing from a hypothesis. It will be important to use causality appropriately and not to overreach inductions from specific observations.

Based on the main tenets of color theory and plant biology, the research is limited by the study location and the types of plants useful to a Southwestern Virginia climate: USDA Plant Zone 6 and hardier. Furthermore, the colors can be variable based on the geographic location and climate of the plants selected. Color can also change over time in plants, thus making analysis variable over time, but cyclical over the course of the year based on the seasons. As the local plant species are based on a regional macroclimate, it would not be appropriate to extrapolate all findings to all species of plants or locations. Different species of plants or plant physiology would induce different color or spatial characteristics.

Another limitation to consider is perception. We as humans perceive light and color similarly, but our reaction to these color and stimuli can vary. While perception is important, it does not invalidate the purpose of the study, as phenomenology acknowledges the inherent personal interaction that an individual can have with objects or architecture. This limitation is acknowledged in the use of interpretivism, which becomes a central theme through the methodology of the dissertation and how interpretivism is implemented in not only the research of my own individual work with the immersive thesis, but also in interpreting the work of the students that use the framework.

Each of these techniques requires a significant amount of time to master and then become an expert in. With essentially an amateur's eyes, how can technique be reviewed

for purposes of inclusion in the framework? Individuals can only know so much of the personal design process, as latent talent or specific implementation will augment technical skill. Therefore, everything cannot be known about the design process as far as individual technique is concerned. The beginning of understanding in order to make something known lies in the accumulation of knowledge, at least in the technical skill aspect.

This concept of being able to learn technical skill, but not individual mastery or finesse without considerable experience, is what generates the individual thesis portion of this dissertation. This series of immersive case studies, tentatively titled "An Experience in Architecture: The Weight of Crafted Technique" will take the parallel Solar Garage project and begin to use it as an impetus for designing the projects through the lens of full-scale design. The use of the Solar Garage as a common thread allows the techniques to be learned, at least to some basic level, as a technical skill. This can make the researcher a node for others to begin to understand a technique, but mastery will need to come from a different resource. Personally, this will also allow me to discover my strengths and weaknesses and determine a series of techniques that I wish to master myself throughout and long after the dissertation process. Now, I understand that this is an incredible undertaking. Representation and the nuances of a single technique can take a lifetime to perfect. This is why I only hope to experience the technique and understand it to introduce it to others.

As a consequence of the framework and this immersive thesis informing each other, the techniques used in the framework will at least reflect the ones used in order to make documentation of the design work. I can interpret technique and methods from that

which I have experienced, and therefore know. Without some kind of context or reference for a technique, I do not believe I can adequately interpret something from its image. However, I have selected images from students who have used the framework in the studios I have assisted with and my own studies to provide examples for others to start their own. Below in figure 10 is this process in relation to the process of the dissertation.

AESTHETICS → IDEATION QUANTITATIVE

DECISION THEORY → DESIGN SUPPORT STRUCTURE CARPORT STUDIES →

REPRESENTATION → INTERPRETIVISM

COLOR THEORY → VEGETATED FACADES AS-IS PROCESS

DESIGN TACTICS PLANT BIOLOGY QUALITATIVE

IMMERSIVE CASE STUDIES
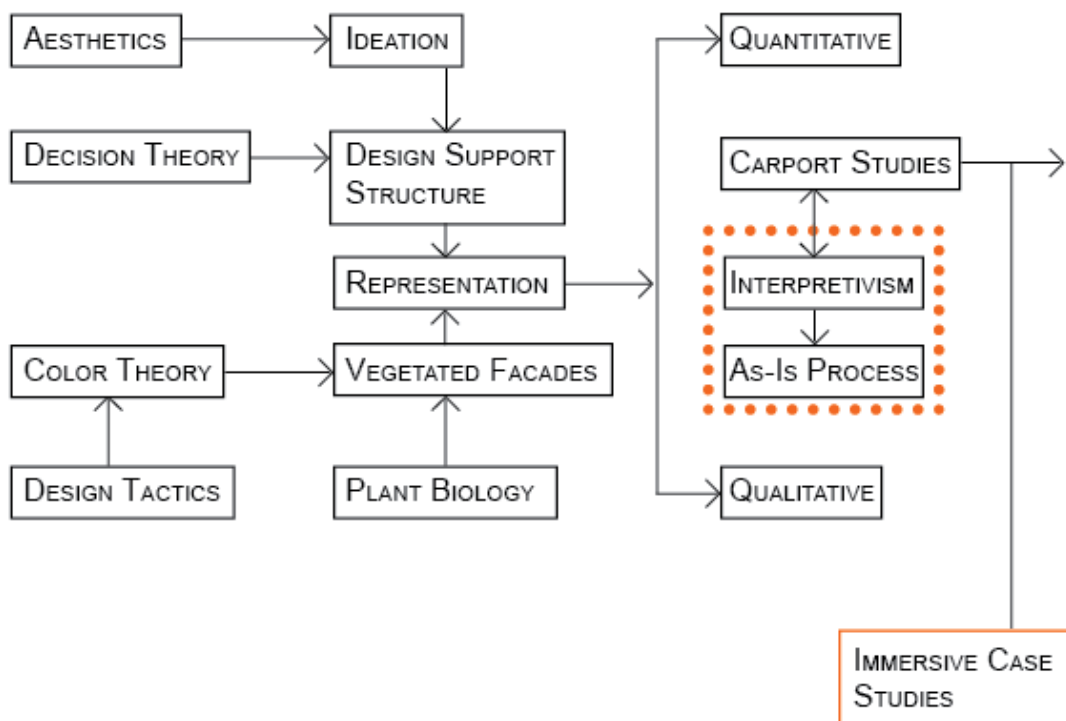
Figure 10: Taking the philosophy of the dissertation and beginning to insert the immersive case studies and technique exploration into the dissertation methodology and processes. This is fused with the topics discovered through the initial design of the framework and overarching research questions.

With this in mind, there is always an element to design, especially in architecture that is simply unknown. This, to borrow from Kahn, is the "immeasurable". It is the world of ideas, and ideation that is different with every designer. It is the reason, along with the concept of "wicked problems" from Cross, that when you ask for the design of

architecture the designed responses are all different. There is not a correct architecture, but rather 'your architecture' that is manifested though the design process.

The process itself can be given steps, categories and frameworks; however the method of a designer and what truly occurs in the mind of the designer cannot be known. We can approach it with journaling and other writings that the designer can give to us, but still it can never be an exact understanding. The framework becomes the basis for design, that what can be known are the topic and the material, but not internal cognitive process of the individual. Not everything can be explained by reason, logic, and knowledge. That is the realm of the immeasurable.

The immeasurable and mastery are necessary obstacles and limits to the dissertation and resulting framework. The immeasurable allows the analysis to be limited to the collected data, that some forms of extrapolating theories from the data are either not feasible or responsible. As the researcher, I can only interpret from what I know from my previous experiences and what other designers tell me about their work. Anything past what can be found in the data or are comparisons of data amongst designer's submissions from the studios, or pertain to my implementation of the framework can verge on conjecture.

This improper extrapolation is also present in technique, as I cannot say that a particular technique is 'correct' for representing vegetated assemblies, but is how the designer chooses to represent the design. This is why the framework is limited to providing options and student examples as support for the designer rather than a decision making process. If the framework made the decision, there would be no reason for the designer as experience would be taken out of the equation. This spark of an idea is what

makes design so powerful, as designers make and observe the phenomena of the built world.

It is the accumulation of knowledge over time that yields experience, in this case mastery of a technique. I personally cannot have the experiences of another. That exact interpretation of knowledge and experience is not known. I can be told or shown the knowledge, experience, or technique, and two things can occur. Either I copy exactly what I see, without producing only a copy, or I can internalize the technique and then make anew with my own experience. The synthesis inherently makes the technique I now have different. Over time this constant tooling of a technique develops mastery. Without acknowledging this lack of mastery, a researcher can be a reckless amateur who can actually hinder the learning process of others. The important concept is to have the researcher serve as a revolving node of exchanging knowledge, rather than an absolute terminus.

Finally, the techniques that are used by the students are those they are most often familiar with. Some of these limitations include my own personal skillset and the current understanding of various techniques by the students. This is not a negative in that the dissertation will suffer from; rather the dissertation will reflect the knowledge of the students more closely and give more accurate feedback in refining the vegetated assembly framework. This also extends to the researcher, myself. I am more comfortable with design and the process of making at full-scale and the techniques and methods often include physical to-scale modeling or construction of projects at full scale. The following image (figure 11) is an example of making such a project out at the Research and Demonstration Facility nearby Virginia Tech in Blacksburg, Virginia.

Figure 11: A full-scale example of using the framework, the Solar Lounge. This project was the second test of the framework with a client and a built project.

Significance

The significance of the dissertation lies in a number of difference capacities. The application of color in the design of vegetated assemblies provides a unique opportunity to merge nature with architecture directly. This study suggests that a decision support framework will allow for more informed design processes and more refined, personal representational techniques of vegetated facades. Architecture exists as an expression of man's engagement with the surrounding environment, as an interface between the individual and nature.

Architecture should be responsive to the conditions on the site and design should allow for the designed response to the site. A designer cannot take the phenomena of nature on only faith or fact, relying solely on the literature. The designer must synthesize experience with the problem at hand. A systematic approach allows for a more complete understanding of a given intervention; therefore the immersive case studies were conducted to understand developing and using the framework. This included gaining a background in the topic, merging it with color theory, then selecting plants with using newfound experience from the development of the framework, constructing the design at full scale and then interpreting the results.

When vegetated assemblies are used as architectural systems, it is important to consider over time, the interaction of plants with each other spatially and chromatically and how we as designers begin to use that aesthetic. For vegetated assemblies, this manifests as the characteristics of plant biology coupled with color theory influence the designed space. This study looks for a regional expression in an Appalachian Mountain

climate based on useful and commercially grown flora. However we can find inspiration

from all over the world and apply it, such as the image in figure 12.
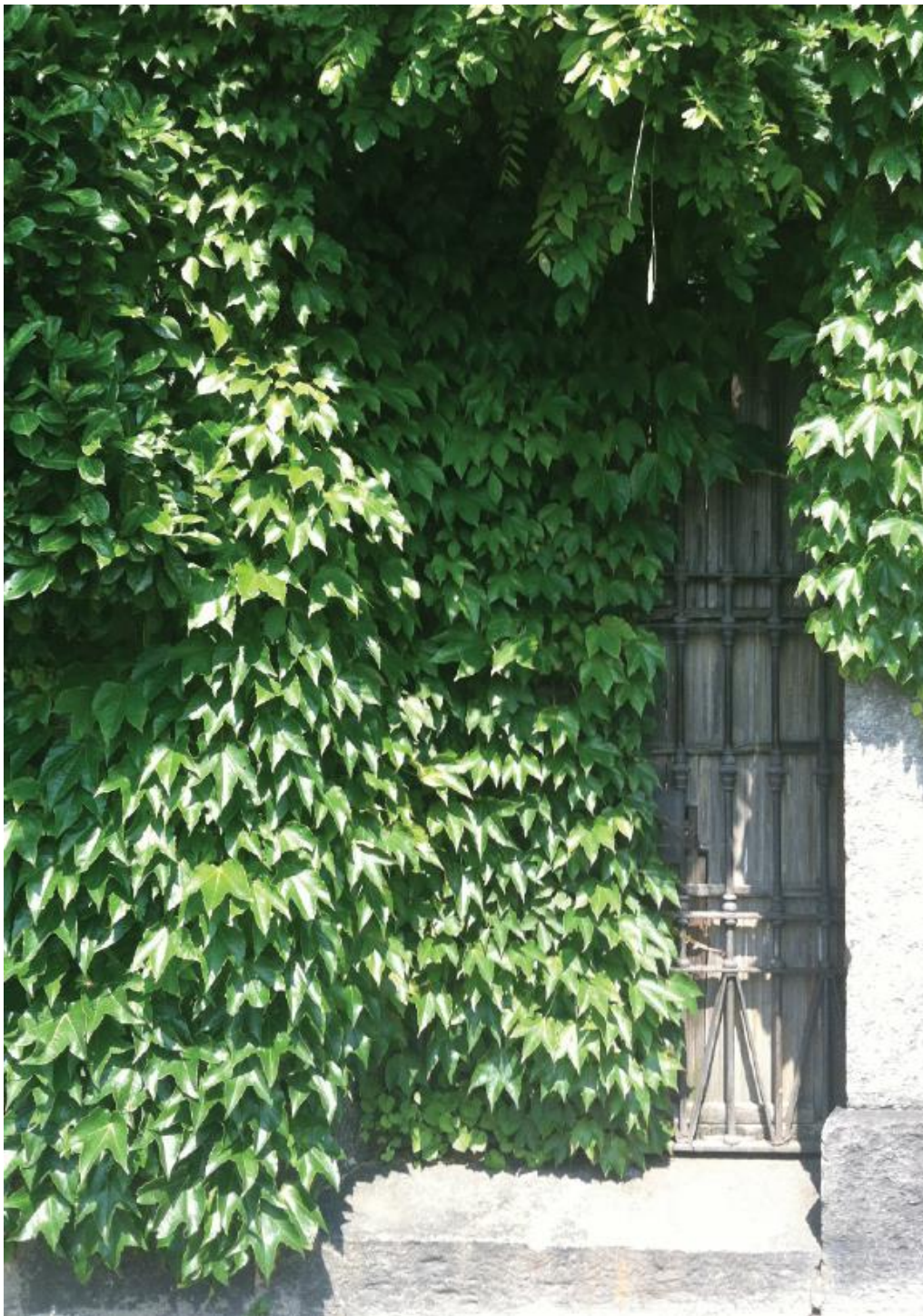
Figure 12: This doorway in Bellinzona, Switzerland introduced and showed concepts of composition such as hue, saturation and value (shadow) in plants.

The active and passive (reflective) modification of light yields colors. The question of color theory in relation to plant biology in vegetated assemblies is not proven or disproven, but observed to gain information on potential characteristics. Therefore, the study considers and examines these as architectural elements of the visible world in order to purposefully design aesthetically pleasing objects. This is what designers can give to the users by taking into account and carefully crafting the stimuli in a space.

Light is the progenitor for colors. Using light and the color theory that arises from its interactions with the environment, the design of vegetated assemblies can be considered for both aesthetics and performance. Color is on a spectrum and is highly influenced by other colors in proximity. Color is always determined by its context and source light. Due to the relative nature of color, the language around color is also personalized, in that the perception of color is dependent on the individual experience. While color is at times variable, the base tenets of color theory provide a common base from which color can be evaluated. Color is not a binary situation and by definition color is placed on a spectrum and should be evaluated on a continuum of contexts.

From these base tenets, color theory can be applied to the physical world. In this study, the Solar Garage project and field studies can reaffirm the colors and pairings found in color theory and begin to understand their application in architecture. The built environment creates an atmosphere for the user to experience the space. For example the inclusion of plants in a public fountain shows how plants can be used as a component of enlivening a place as in the following image, figure 13.

Figure 13: The fountain in Lugano with vines growing on a rock-like surface. This fountain was in the center of a plaza space directly across the road from the lake.

Thus, while individual colors can be dependent on the perception of the user, the individual experience of the user is based in the applied tenets of color theory. This self-reflective experience through the use of immersive case studies or travel allows the designer to both influence the space through design in color theory and later be influenced by the constructed space along with other users.

Nature and its application can provide the inspiration for man-made interventions in the form of vegetated assemblies. As explained previously, the value of bringing vegetated walls and façades into harsh urban settings produces positive effects, both intrinsic and performance based. They decrease air pollution, thermal loads, stormwater runoff, and increase the user's quality of life. This increase in the quality of life can be found in the Biophilia theory proposed by Edward O. Wilson, in which humans feel an innate connection with nature. This connection back to nature provides context and an impetus for the use of color theory, taking a somewhat abstract theory and grounding it in the natural environment.

However it is important to perform an analysis of observations made after the amassing of characteristics and desirable qualities. This amassing is not to form a catalog prescribing architecture. It is to show qualities that are found in architecture, color theory and nature and then allow the designer to apply concepts, not prescribed solutions. Architecture is not a problem to be solved, but a process of inquiry over much iteration. These iterations allow for the process of exploration that architects need to refine their architecture. This iterative process proceeds from ideation to representation to iteration, with many revisions and circular evaluation along the way. As such, a combination of

both theory and practice solidifies assertions made from the study in the form of a built construct.

These characteristics of color theory and plant biology have implications for the design process. If these considerations are implemented earlier in the design, vegetated assemblies can be a critical facet of the design. The varying climates due to geographic regions and different building standards could change the effectiveness or necessity of some design decisions for better or worse. As mentioned before, a design should be reflective of the surrounding environment and site conditions. If the site and climate are ignored, then the final intervention has not reached its full potential. While color theory as applied to vegetated assemblies is important, these assemblies must gain further acceptance and then be validated by construction and repeated methods in order for designers to gain practical experience, and not simply theoretical knowledge. From this initial understanding of the vegetated assemblies, designers will then be able to experiment and improve the quality of systems.

However, the actual aesthetic of the vegetated assemblies and the reaction to the building conditions and climate is not completely predictable, nor should it be. This allows the process of ideation, representation and iteration to inform the inquiry into "wicked problems" in architecture. A decision support structure (DSS) such as the accumulation of analyzed design explorations and field study conditions can show designers a beginning to start from, but not an answer. Architecture and design is not a problem to be solved, but a process to be explored.

Chapter 2: Literature

2.1 Grounding the Pluralistic Study to Understand Frameworks in Multiple Contexts

Overview:

A framework is an object, technique, and process that assists us in getting started in thinking about something. This systematic review of relevant types of metaphysical thought is meant to organize the different potential ways of engaging thought specifically about a decision support vegetated assembly framework. The framework serves to be a guidepost to myself and others as we meld and combine our own experiences and ideas for new potential. Where do we ground our philosophy and the ideas we have in our research? That is where the philosophy of science and discipline-specific philosophers and philosophies guide the conversation. There will be three parts in this process with the first focusing on larger questions of the philosophy of science, the second moving more into the discipline and phenomena of architecture, and the third specializing in topics of the building sciences. This allows the researcher to determine how to interpret the framework and what the researcher's desire is for its essence.

Part 1: Dwelling in Studio as the Beginning to a Circle of Thought

The discussion of this first section will begin and end with thoughts inspired by Heidegger: Building Dwelling Thinking and The Origin of a Work of Art. First, consider these two questions: Are we looking at a thing to see its architecture or for a set of rigid architectural rules?; and What is the architecture or essence of a framework?

If we think about the first question we see other considerations embedded within. How do we approach architecture, and how and why do we design? We are not looking at something for it to give us direct answers; rather, we are looking at what it means to think about architecture and its process. There are no completely inflexible rules, only guidelines for the individual designer, imposed from within when designing. These guidelines are meant to be explored and bent, looking for the edge of what will work. If I were to ask everyone to conform to my standards and my method, everyone's work would not be their own, their being or essence rejected and substituting myself. To engage the world without thought is neither how we discover architecture, nor our place in the world.

Heidegger asserts that to dwell is to cherish and to protect while remaining in a place all through the activity of construction and cultivation. This is how we might begin to look at studio: not that one dwells at studio in the traditional sense, but that we begin to see traces of dwelling in a studio as a locale and as a space one can go to and occupy with the purpose of construction through making and cultivation of the mind. If we ask how to do these things or why, we can look at the framework as a thing that expresses the process of thought visually and for the essence of combining ideas and teaching this to others using studio.

By using the studio environment we can begin to provide ownership of what we build. Heidegger states that, "[…] we do not dwell because we have built, but we build and have built because we dwell, that is, because we are dwellers." (2008, p. 350). We often do not do something for the sake of doing so, rather it is inherent to our essence or mindset, in this case as designers, and how we dwell within our view of the world.

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Taking a step away from the direct quotation, in studio we do not make for the sake of making, instead we make in order to understand. The framework is a part of this making to understand. The framework is the unfolding the ideas of others along their continuum of design, bridging gaps of knowledge. The framework does not work because it exists, but because a designer thinks and reflects on it. Without the designer to make decisions, the framework is a mere paperweight.

Building, and by extension, designing, holds the ideals, the hopes, and the desires of the designers to dwell. Building is often a physical locale created by man, and frameworks give a locale for the thoughts of man to dwell, to remain in place, and to construct and cultivate new ideas. Heidegger suggests that building and thinking belong to dwelling (2008, p. 362). From this I believe that learning to dwell is both in a physical locale (studio) but also in thought (the framework).

The framework is based in philosophy, such as Heidegger's, but it needs to be grounded in a manner that reflects its intent, which is also to teach and help others. Teaching demonstrates and engages others in ideas and what such ideas can bring to a profession. These ideas are often founded in prior interests and create a body of knowledge or experiences for the individual to draw from. Jerome Bruner, in On Knowing: Essays for the Left hand states that "hunches and intuitions generate a grammar of their own—searching out connections, suggesting similarities, weaving ideas loosely in a trial web" (1979, p. 4). If we are using what we have already experienced as a reference for design and learning, then our methodology is the source and foundation of the fruitful results we later experience.

This methodology is and should not be done alone, however as "the effectiveness of the group members consisted in their sense of freedom to explore possibilities, in their devotion to elegant solutions, and in the interplay among them that, in effect, made each man stronger in the group then individually" (Bruner, 1979, p. 11). Through working together instead of alone regardless of the subject strengthens the group's potential: an idea that might have seemed dangerous or insurmountable becomes approachable. However, it is solely working together for a goal that brings meaning and dignity to work.

There is something that happens in the mind. This occurrence, according to Henri Poincare as described by Jerome Bruner, draws meaning and relationships between things known but not associated. Bruner takes this a step further, suggesting that "Experience in literal terms is a categorizing, a placing in a syntax of concepts. Metaphoric combination leaps beyond systematic placement, explores connections that before were unsuspected." (1979, p. 20). This connection was recently described as the adjacent possible (Johnson, 2010) and experience creates a higher probability for success based on a feeling of intuition between topics, ideas, or physical associations.

With experience, things neither go as badly as feared nor remarkably better. If we consider Heidegger, things are their essence. I have taken this to mean that there is no duality of good and bad as labels, but the designed response and levels of appropriateness that reside in a continuum. Our understanding and experience of phenomena create our design identity. Our identity serves as an extension of these phenomena and our interaction with them. Our selective remembrance combined with the adjacent possible structures results in possibilities and potential in design. So, if our experience and our

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understanding of it are important to our ability as designers, then self-reflection and self-consciousness is critical to the expression of this development. Coming back to Bruner, art can be used as a mode of knowing, and connectedness as a reflection and understanding of the voids between impulsiveness and rationality, merging the unlikely (Bruner, 1979).

Regardless, "Discovery, like surprise, favors the well-prepared mind" (Bruner, 1979, p. 82). This requires a blend of external and internal motivation for students. Bruner describes four topics: increase in intellectual potency, shift from extrinsic to intrinsic rewards, learning of heuristics of discovery, and the aid to conserving memory that help make a well-prepared mind (Bruner, 1979). In summary: looking at what you have done and being self-reflective and internalizing it in your own process and representing it to yourself guides development. Using Bruner's (1979, p. 101) description of representation and discovery:

> Manipulation and representation, then, in continuing cycles are necessary
> conditions for discovery. They are the antithesis of passive, listener-like learning.
> Yet representation is not frenzied activity. Though active, it is still ratiocination, a
> going back over experience, a listening to oneself. (1979, p. 101)

If we are preparing students for their future both professionally and societally, then knowledge is to give structure and meaning to experiences. So as Bruner and Dewey rightfully ask: What is nontrivial, what is worth knowing? Therefore what is the nature of the method in which we teach our students? (Bruner, 1979) By teaching to the test or telling them what is important, we are producing extrinsically motivated students. This

removes discovering it for themselves and the pride in new knowledge from experience, especially if the situation is formalized or formulaic.

However, there is the need to have control: an uncontrolled, chaotic environment is unhelpful to students. Therefore, "how to obtain necessary control while preserving the necessary variability that permits change, innovation, zest, and a lively sense that the invention of new alternatives is more important than the suppression of ones that may prove ugly" (Bruner, 1979, p. 148). This is especially important in studio where exploration and making is critical to the learning and design process, especially in an architectural studio.

If we think of studio as a place to dwell and gain experience in an effort to obtain knowledge about our profession, in this case architecture, then the way in which we engage the discipline and the environment we do it in should be as carefully crafted in the same manner as our designed work.

The Philosophy behind Developing a Framework for Studio

Moving from the place in which we design, the framework will be explained from the view of general topics in the philosophy of science. Afterward, this discussion will begin to narrow down to more specific considerations of designing the process of creating and maintaining a decision support framework. Using current texts about the philosophy of science, such as Philosophy of Science: A Contemporary Introduction (Rosenberg, 2012) and Philosophy of Science: A Very Short Introduction (Okasha, 2002) we can begin to see how methods and ideas apply philosophy to influence our work and results.

Starting with Rosenberg's work, there is a litany of things that will serve as the basis for understanding the philosophical placement of the framework. He begins with the idea that the sciences are borne out of considerations of several aspects of philosophy, including logic, ethics, epistemology, and metaphysics (Rosenberg, 2012). Logic looks to the reasoning and its verification. Ethics asks to review our philosophy in terms of conduct. Epistemology is the range and amount of understanding, specifically knowledge. Metaphysics concerns the philosophy of being and our place in the world. Another way of looking at it, as explained by Okasha (2002) is: "[the] principle task of philosophy of science is to analyze the methods of inquiry used in various sciences" (2002, p. 12). We are seeking to uncover assumptions on why we do what we do, the way we do it and how we should do it.

Rosenberg summarizes the philosophy of a number of critical philosophers, including Descartes, Locke, and Kant (2012). Specifically, Kant thought of analytic truths (knowing the words to establish meaning with no experience required) and synthetic truths (knowledge borne out of some level of experience). He viewed truth and knowledge as 'a priori'– what we know with no experience, and 'a posteriori'– what we know with experience (Rosenberg, 2012). These three men are not exhaustive of the philosophers who contributed to the next two concepts: empiricism and rationalism. Their thoughts contain empiricism, which states that information is justified by experience, and rationalism which states that information is innate knowledge of world and its nature (Rosenberg, 2012). Between these two concepts, the frameworks will not only be engaged empirically (experience informing its design), but also tested empirically and

reviewed by others. The framework simply cannot exist without experience from innate understanding.

Rosenberg asserts that philosophy and science cannot escape each other, and must function as a pair, functioning as thought and love for wisdom with experience and measurement (2012). Sciences are often borne from philosophy to explain applications of the physical realm. Philosophy then, is how we organize our thoughts in a series of frameworks. Each has an equally important, but functionally different contribution to conceiving and empirically testing the framework. Because science and philosophy are a pair, science should have questions it cannot answer yet, but can pure philosophy answer it either? That is a question for another time. These unanswerable questions often come from the application of philosophy in areas of expertise. In the sciences there are methods that work well, but if these are directly translated to design, the methods break down. This introduces the idea of normative theory: what we ought to do, as well as introducing inductive arguments, ones that move from finite data to develop general theories. Purely empirical or evidence-based methods often have prescriptive methods that may not work well in design.

This creates the context for the proposed dissertation and its result: the framework serves as an initial start for reviewing an idea or for a process. Further, designers are encouraged to change the framework should a personal need arise or as experience suggests it. The framework has a base in design methods, but the additions we make in terms of topics to review can be intensely personal or on the basis of a longer line of inquiry. The framework serves as an initial guide in applying normative theory as "what we ought to do," as design is not deterministic. This process of mapping out of what we

ought to do can be seen in figure 14. Figure 14 is a first attempt at mapping and

graphically representing the framework and its processes. This first framework used only

the literature review to arrive at a conclusion. After an initial test of the framework it was

determined by the researcher that we as designers cannot use the past to completely and

accurately predict the future of design. Our lines of inquiry can suggest areas of study,

but not definite results.
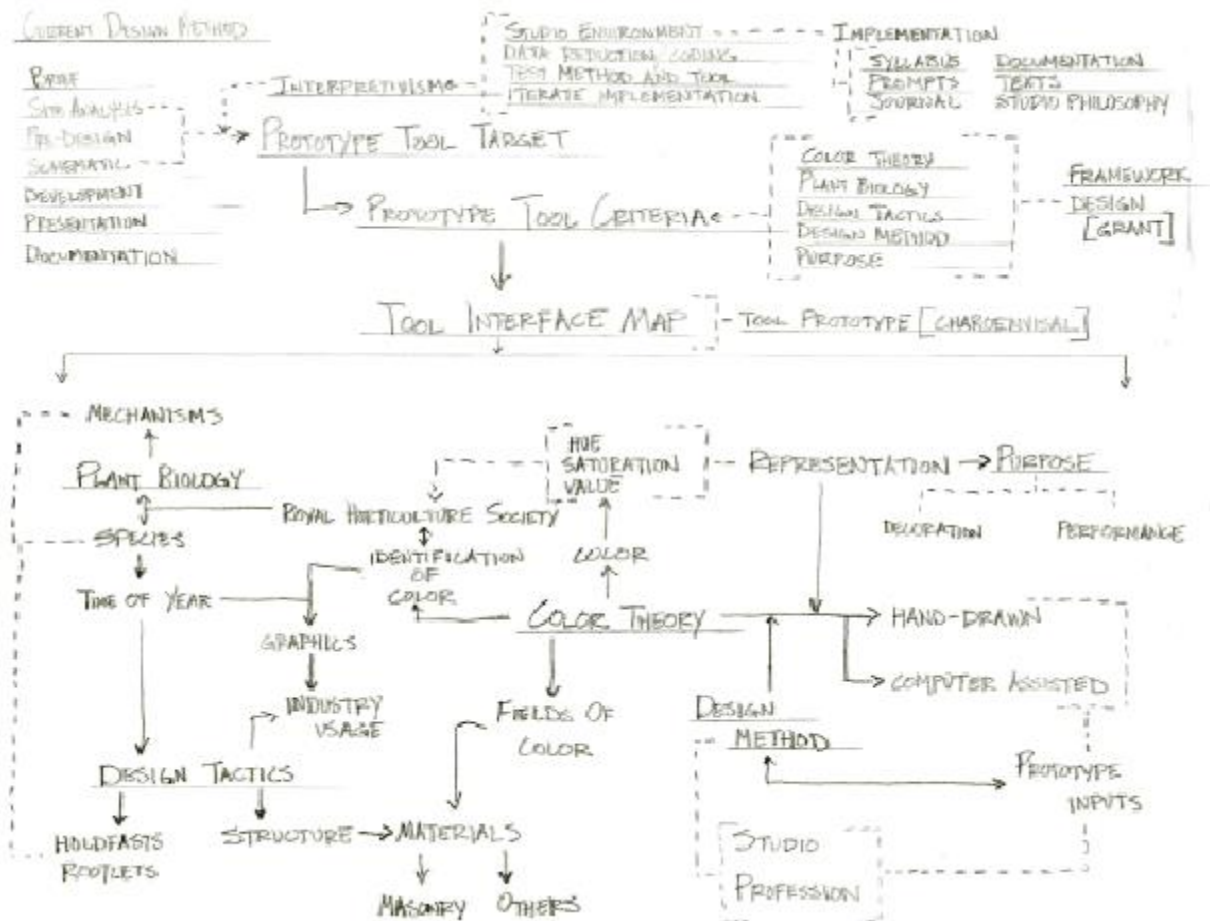
Figure 144: An example of thought mapping using all of the literature. This was the first round of the framework without any organization.

This results in the semantics of 'a' vegetated framework rather than 'the' vegetated

framework or 'a' frame of mind rather than 'the' frame of mind. We are not all the same;

our experiences influence methods, processes, and future thoughts, rather than

determining them, as further outside influences can change them. So, is the mind a

physical thing? If so, it could be deterministic, however, if it is not physical, it could be

indeterministic and of our own choosing. If organized by natural law, perhaps science

and evidence does not have all the answers. This does not ridicule science, but rather

shows limits to every area, and that different methods are appropriate at different times.

This concept of appropriate methods extends to graphic representation and the art of

diagramming the framework which started with figure 15. Figure 15 shows the more

organized diagrammatic approach to the development of the framework as compared to

figure 14.
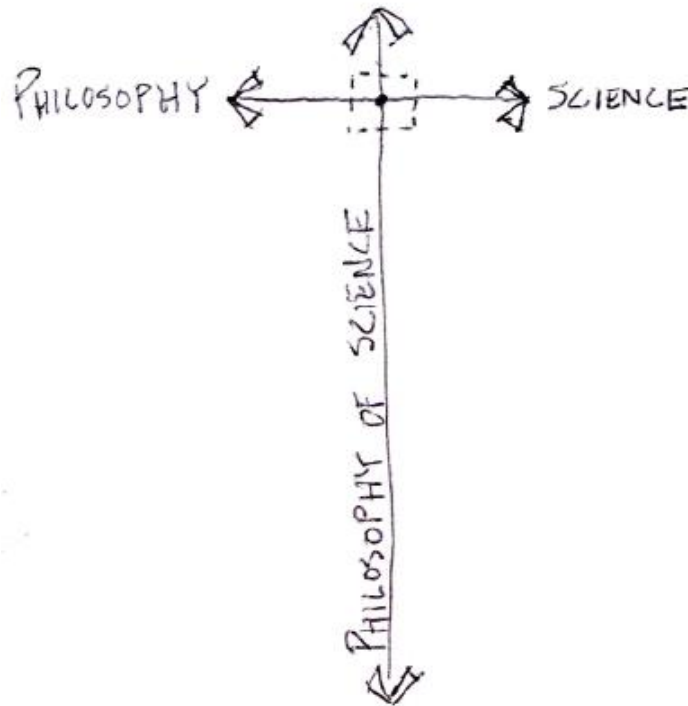
Figure 15: The intersection of science and philosophy as a beginning of the framework as it might relate to the spectrum of the philosophy of science. This process of diagramming served to organize future iterations of the decision support framework.

Measuring and Methodological Rules as Desired Limitations

What we physically are can be measured, but how and why we think cannot be

fully measured. The framework does not measure the success of combining ideas, rather

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it serves as a scaffold to help explain and visually present my processes to others. The framework is not trying to prove any truth, but rather assist the designer in their line of inquiry. This line of inquiry is not based on mathematics. As described in Rosenberg, we, like Gödel, can choose or rectify inconsistencies, or at least identify them, while rigid formulas may not (Rosenberg, 2012). From this analysis, not all can be known or understood, but our thoughts are aided.

Thus, the framework has rule-based limits. These translate to the amount information present on each page and the depth of explanation in a topic or number of topics. It simply is unrealistic to measure all processes that are made in the mind at once, let alone for all of personal experience. This makes the framework inherently incomplete, a fragment to the full mind. That, along with leaving the final decision to those using the framework, is what makes the framework a decision support tool and not a decision-making tool.

However, we cannot and do not explain away the mind for the physical phenomena. The mind is still attached to the brain, and the framework to the mind. It is a support for our own processes. If we detach the mind from ourselves, what makes us unique and not simply determined thoughts of a physical world? Personally, my mind is influenced by my surroundings and phenomena that I interact with. The framework is a constructed phenomenon with constructed rules that influences and attempts to organize the physical topics and world. It aids in organizing my thoughts that are separate, but linked to a product of my interactions. This brings us back to and summarizes the normative process of how things are and ought to be in the framework, but not how things have to be as each mind is different.

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From this understanding of the intention of the mind and framework, this work is not positivist. There are no checklists, no set of guarantees for success. However there are what Rosenberg describes as boundary conditions or initial conditions which are relevant factors to how or what something is (Rosenberg, 2012). We can have the boundary conditions for the visual framework (depth of detail, visual ordering, appendix method, etc.), but these conditions are not always rigidly adhered to in the mind. This means that the framework should not limit the ability of the designer to synthesize information and to move past or beyond the framework in the future.

What is interesting is that, while the pure methods of logical positivism (philosophy of science engaged in an empirical manner and tested and supported (Okasha, 2002)) are not the way this study will be grounded, the life of a prominent logical positivist shows one of the main concepts that the framework hopes to facilitate.

Thomas Kuhn was one of the most influential writers on the philosophy of science. His thoughts suggested that the means of creating the hypothesis are immaterial, but that how it was tested was critical. He developed a concept of changing ideas and beliefs through the use of paradigms via exemplars that define the paradigm. A paradigm was when scientists not only agree on scientific propositions, but how to pursue them. They accepted the paradigm and willingly test within it, then when anomalies developed and built up it led to a crisis and then a paradigm shift, given enough advocates. He believed that new and old paradigms were incompatible, but partial translation was possible and somewhat comparable (Kuhn & Hacking, 2012; Okasha, 2002). This word, paradigm, has been overused in the sustainability and green have, and has lost some of its meaning, but what does this mindset of philosophical continuum mean for design?

In the introduction essay by Ian Hacking (to the 2012 edition of The Structure of Scientific Revolutions by Thomas Kuhn) Hacking brings forward a quote from Kuhn: "The most striking feature of the normal research problems we have encountered is how little they aim to produce major novelties, conceptual or phenomenal" (Kuhn & Hacking, 2012, p. 35). Is the work I do a 'revolution,' as Kuhn describes progress through revolution?

Innovation within Normal Science with Decision Support Frameworks

The decision support framework is most likely not a revolution, nor will it likely lead to a revolution, but it can serve as a method for visually seeing the mind as a source of ideas rather than a physical deterministic process. In time the brain may be mapped, but for now the brain is not all-knowing, and not all can be observed, as the mind continues to evolve with us. We constantly re-adapt the mind as we move through life and accumulate experiences and begin to combine ideas. This is what the framework is designed to do, present, and facilitate. We can begin to map our own minds. This is why it is less about the ideas that Kuhn created but his own process to discovering these ideas. This reflection and synthesis become what is most important to the process of the framework.

> The essay that follows is the first full published report on a project originally conceived almost fifteen years ago. At the time I was a graduate student in theoretical physics already within sight of the end of my dissertation. A fortunate involvement with an experimental college course treating physical science for the non-scientist provided my first exposure to the history of science. To my

complete surprise, that exposure to out-of-date scientific theory and practice

radically undermined some of my basic conceptions about the nature of science

and the reasons for its special success. Preface, xxxix T.S.K.

Kuhn talks about the experience as a junior fellow of the society of fellows of Harvard

University which provided the environment to make the transition to a new line of

inquiry and how it progressed. He then moved to the Center for Advanced Studies in the

Behavioral Sciences and benefitted from the support and patience from the editors from

the Encyclopedia of Unified Science to publish his work (Kuhn & Hacking, 2012). While

my intervention into design and research is much more modest than Kuhn's, the same

ingredients provide the opportunity for change, no matter how small, in the body of

knowledge and the lines of inquiry that we may follow.

Kuhn mentions the environment and mentoring that he had in developing his

thoughts. Another example of this is found in Architecture and the Sciences (Picon &

Ponte, 2003), written by Martin Berssani (p.118-139). How you think of things combined

with why you might think of them, combines with the influence of our surroundings and

experiences. Berssani describes Viollet-le-duc's optics and compulsion to draw and

augment and analyze. What he drew were not simply recreations, and he began to

understand spatial characteristics and context over time. While he learned much through

his studies, we can also learn from the traditions of those around us and our mentors.

Berssani tells the story of Viollet-le-duc and his uncle, Delecluze, who was inspired by

the study of anatomy at the School of David. It was not necessarily the topic, but also the

methodological exploration of nature in their studies, that was transferred between

Delecluze and his nephew. A disciplined approach and a daily ritual to exploring

conferred understanding. We understand drawing as a physical and intellectual process. Representation is not always reality, but is a filter to see the processing of reality into your own designs. This once again confirms that our mind, our mentors, and our environment greatly influence our ability to generate ideas, combine them and synthesize new methods of thinking and representation.

Grounding the Influence of Decision Making in Frameworks

This concept of influence brings us back to one of the more general tenets of the philosophy of science: causation. Causation is used to control and predict phenomena: for example that an 'x' causes 'y' in some relatable manner (Rosenberg, 2012). This is not the framework in any sense. The framework does not cause ideas, the mind does, along with an individuals' choice of topics and use of the scaffold the framework provides. The framework itself does not understand it needs your personal understanding of design. This information and understanding brought together with experience is how the framework is used, not by a series of predetermined laws about how frameworks exist. The framework can provide a method for ordering, but not a holdfast law.

The question is now where to place emphasis in the design process and in your resulting process from the framework, and how you decide what the resulting iterations are and then final design chosen are. Designers need context and understanding. We must also ask if the designer's thoughts, the framework, the environment, the topics, or other objects are to be emphasized the same manner every single time. I think it depends based on the designer's context in design. This makes the framework malleable, but so is the designer by topics, ideas, environment, or thought itself. All of the factors are interrelated and intertwined in the later process of design and phenomena.

Developing the framework is a more inductive process, and the framework will assist in the design process. It may not be effective at assisting someone who is not interested or has already gained a body of experience from the framework. Thus we assume it to be inductive when assessing its effects. We cannot empirically test that the framework will not assist someone, nor be needed with a level of certainty. This brings us back to how not everything about the framework can be known, as it is dependent largely on the design process, which also cannot be fully known, as some processes are unique to the mind of the individual engaging in the design process. This process can be diagrammed out as shown in figures 14 and 15, and continues to be elaborated on bringing in how the influence of the framework might be measured using sets of rules or checklists. Through diagramming and representing the process of considering how the framework would be viewed, a phenomenological approach seemed more appropriate than a positivist or post-positivist one as shown in figure 16.
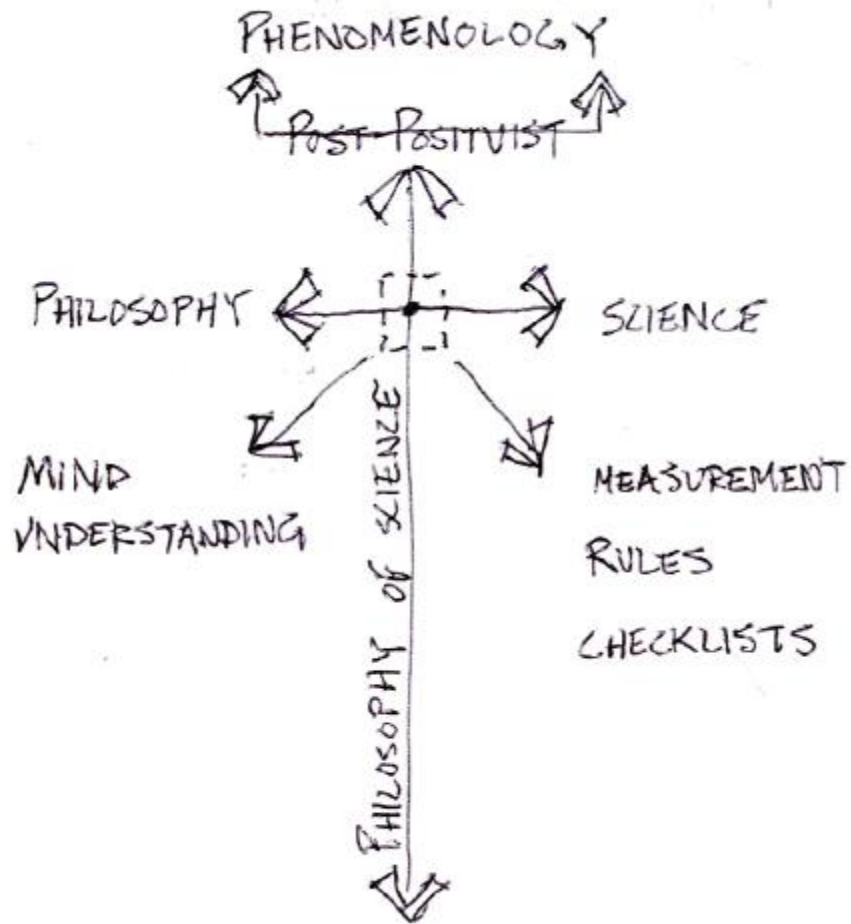
Figure 16: Where does the framework lie? Is it post-positivist? No. the framework is phenomenological in nature.

The framework is not an if-then statement that can be measured. We can write "If a person uses the framework, then it should help them." However, this is not measurable, as "help" does not have a measureable descriptor. The amount of help may vary by each person. Also, as we described before, the use of the framework does not directly cause useful or good design. To make such an assertion would be irresponsible. Furthermore, making a blanket statement as "the framework will help everyone" is not responsible as every individual is a potential falsifier and not everyone uses nor needs frameworks to

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design. So the potential falsifiers are necessary to finding an improved decision support framework, or determining the scope of its necessary influence. This shifts to that a framework and its results are not a contingent truth based on the way things are, and are better explained by normative theory of how things or processes ought to be: "Frameworks could or ought to be used in the design process." It is not grounded as a natural law as gravity, or a necessary truth such as 3 being an odd number. This makes the framework something that ought to be (normative) rather than what things are (positivist or descriptive).

Now does the framework have a platonic realism or an existence that is outside of its particular series of instances? In this case is it able to be cast aside from color theory and vegetated assemblies? Are there aspects of a framework that are universal, which all things that are frameworks have? Perhaps there are features of a framework that are universal, but when a framework describes a method of thought, can a method of thought be universal? These are questions for another time, but are interesting to consider. What we need to focus on, as the central metric of this dissertation, is:

> Does the framework improve one's decision-making, where improvement may be measurable through having more direct access to information that improves one's knowledge of the situation being decided on?

From this question the dissertation is not looking for a causal role, only a method to inform design with the framework. The problem lies in trying to leave everything explained, when this is not possible. There are things that we simply do not know. This leads us to question whether the framework is an observable or unobservable phenomenon. Okasha begins to explain the mindset behind the observable and

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unobservable parts of the world which are found in realism as the description of the world versus anti-realism, where only the un observable is described (2002). How does realism interact with the mind, and is the mind or a thought process completely observable? I believe that the mind is observable, but that not all of it can be empirically explained, at least as of yet. Further, the unobservable might be false due to inductive thought, but much of science relies on this method to explain the unobservable. Okasha explains that theories are mostly true until proven false, and that past theories are now proven false but can be and were empirically successful in the past (2002). I sit in realism, in which the observable can be explained, but induction begins to explain the unobservable.

My first dilemma is: are ideas currently completely observable? The second is: what happens when the method to make such things completely observable exists in the future? We have an upper limit to knowledge which is based on time and the ability to observe. From this, knowledge is not just in the directly observed, but in the experience and collective knowledge from the process of deduction and induction in the present and potential future. The concern is in the methods to obtain measurable data. We can observe people and their design process, but at what point does our observation change the results? Also, at some point each person has an individual design process in their mind that may not be directly observable. Currently the physical mind might be measured by MRI or other devices, but does the act of measuring inherently change the paths and methods of thought? Thought or the non-physical mind can be observed through reflection and survey, but these methods must be applied after the process is used or

completed to not influence the results. If people know the question, they can begin to tailor an answer to meet it.

We also have to consider our assumptions of the mind, the framework, and how both work. For example, does the framework attempt to control thought or does it provide an opportunity for people to grow their thoughts? Is the mind unknowable as it is unobservable? Is it a function of being as a phenomenon? Rosenberg describes how as we attempt to understand smaller unobservable things, they are not analogs of larger entities, they are their own things (2012). We fall short in knowing because we cannot measure, and because measuring is done by seeing how things manifest in experiments. This raises two questions:

- How do we get the idea of how something manifests?

- How do we know to re-interpret something or that it has been grounded correctly?

Our premises of understanding our own minds are incomplete, as the premises do not contain the conclusion forcing us to be inductive without confirming or guaranteeing truth. This is why the framework is so important to pursue. We can begin to represent something that we cannot see: ideas. With enough information we can prevent underdetermination: more than one conclusion can be determined from a set of data, as more data might yield a conclusion or confirm a hypothesis. As Rosenberg describes, "theory choice is a continual process of iterative application of this same toolbox of considerations in order to assess the implications of empirical observation in making theory choices" (2012, p. 214).

Since we cannot observe ideas in our mind, we bring them to the page and represent them to others. Therefore we observe the person as the origin of an idea and the

origin of combining ideas, with the framework as a support system to represent these ideas to others. This idea of origin brings us back to Heidegger. Our art is conveyed through representation, using the framework as a guide. And "What something is, as it is, we call its essence" (Heidegger & Krell, 2008, p. 142). So, can ideas be the origin of physical works and their creators?

If we are going to attempt to understand something that is unobservable, perhaps beginning to understand its essence through other observable characteristics is a beginning. Heidegger considers the problem we ran into about ideas and the essence of things. Heidegger states: "The artist is the origin of the work. The work is the origin of the artist. Neither is without the other. Nevertheless, neither is the sole support of the other" (2008, p. 143). Heidegger asserts that all works have a "thingly character," that in some way they exist, but that "something other is brought together with the thing that is made" (2008, p. 146). The designer creates the framework, but the framework informs the designer's decisions. Also, the nature of place creates certain physiologies and characteristics and their distribution, but this physiology informs us of place.

What is the Essence of the Framework?

In the end the framework is an object but also a technique, and a process, that must not be seen as paramount to the individual. We can take the ideas from the framework in one view; however the designer-framework pair suggests that stripping the framework away leaves the designer. This means that after stripping the framework away the essence of the designer is the ability to design. This seems obvious. Take the framework away, and the designer can still perform work without that specific

equipment. However, this is critical to the view of the dissertation, as the framework is a stepping-stone for designers and not a crutch they must use. For this reason, students are the focus of the work, and to assist them in becoming more experienced.

We can sit and define the framework in its totality; however, the process that underlies the framework cannot be fully seen or known. That is in the mind of the designer. This creates a situation where the mind is the essence of the designer, who uses technique and craft as reliable methods to represent the physical. This means, that the essence or origin of the framework is the process the designer's mind uses to explore. Its essence is the cognitive mind.

So the purpose of the work here is: to see if the framework is in fact a reliable method for assisting designers in designing and representing vegetated assemblies; and, again does the framework improve one's decision-making, where improvement may be measurable through having more direct access to information that improves one's knowledge of the situation being decided on?

Part 2: Discipline and Phenomena of Architecture

Narrowing the focus of the pursuit of what a framework is or ought to be, the discipline of design and architecture begins to organize methods or processes of thought. The Philosophy of Science, when applied to architecture is now structured as "design thinking or knowing". From these discussions of thinking and the normative processes and methods a designer can use, we reveal that sensory phenomena become experiences that are the core of our design lives and are internalized as a series of memories as reflections of experience.

This section will look at phenomenology and how using the senses and past experiences and memories can help to inform architecture. We know it does, but is there more to a framework and the mentality behind it? At some level simply following a framework is useful, but understanding how to interact or engage the framework and modify it to specific needs shows a vast amount of potential. The framework can become a visual representation of a cognitive process, and if it is modified, a personal thought process as well. I, personally, am engaging the framework as an inquiry between myself and the world, while the framework itself is presenting constituent parts of the design process and vegetated assemblies and their elements of design to me as a support mechanism.

The question we hope to answer is if nature and its atmosphere is what can influence the design of inspiring and moving spaces which frame our lives.

Thinking of a Vegetated Architecture: Design Thinking

There is order to how designers come up with ideas and then how they begin to refine them. Often this has an intended direction with a purpose in mind and while perhaps nonsensical to others, there is a process in the mind of the designer. There is a topic or a desire attached to a set of organizing ideas in their designs and they strive to implement those specific ideas or methods rather than choose other perhaps easier-to-implement ideas.

Peter Rowe determines that there are two factors that influence design the most: "First there was sustained influence of initial ideas in the form of organizing principles, rules, and references. Second, there was the influence exerted by the particular structure

of the problem-solving process itself," (Rowe, 1987, p. 37). I believe that what influences

and guides these factors in our work lies within our personal level of understanding the

discipline and our personal experiences and memories.

Our design problems are often ill-defined, but need to be present to provide

context or limitations our design decisions. Rowe defines them as well-defined, ill-

defined and wicked problems (Rowe, 1987, pp. 40-41). When comparing these three

types designers find that for well-defined problems, the beginning is known, as is the end,

and a typical process is known; for ill-defined problems, the beginning, end or perhaps

even the process entirely is not clearly known; and finally in wicked problems, the

beginning, end and process are simply not known and need reformulation over the

process of working on them (Churchman, 1967; Cross, 2011; Newell, Shaw, & Simon,

1967; Rittel, 1972; Rowe, 1987). If the problem itself cannot define a beginning, then the

impetus come from a potential solution or idea. For wicked problems there must be ideas

to solve such problems, otherwise they would be deemed unsolvable.

The framework proposed serves as a partial guide for these "wicked problems"

(for vegetated assemblies) that are amorphous and change with new information,

conditions, situations, or interests. Rowe brings forth many different types of these

models including: the Asimov model, the Iconic Model, decision tress, and others as

staged process models were used in design schools such as the Ulm school. The process

at the Ulm school was adapted by Bruce Archer, as an operational model with feedback

loops (Rowe, 1987).

These feedback loops are also known as iterative design and that we are

processing information and making decisions. Perhaps then, frameworks can serve as

creative models. The difference between these processes and the specific framework proposed and discussed is that the Design Framework has a decision-support structure not a decision-making structure. The purpose is to support the designer in making decisions for themselves, not make the decision for them.

When designers make decisions, there needs to be some sort of process. This process does not need to be precise or measurable, but known at some level. Elizabeth Grant summarizes the work of Jim Suhr (Suhr, 1999), explaining how Choosing By Advantages allows users to choose options, via the importance of their advantages (the differences between options), rather than by weighting and rating the individual factors that make up each option. This allows for a more complete evaluation of each option, rather than relying on an evaluation of abstract factors (Grant, 2007). This follows a more design-oriented method, as ranking individual factors, stripped of a greater context can make for inadequate decisions when compared to an evaluation of the larger design concept. He or she then uses this approach, in this case, for designing vegetated assemblies as entire systems rather than as a means of satisfying a single attribute. This process of Choosing By Advantages may not help a designer choose a design that is optimal in one area or attribute, but instead one that can serve as a most advantageous solution to many conditions. While Choosing By Advantages is a very specific approach and tied to my specific research and context, it touches on the larger concept of a design process, which Rowe summarizes saying:

> In summary, the design process may be seen to be marked by a sequence of episodes or situations that are, in turn, coincident with periods of heuristic reasoning through which problems are defined and solutions sought. During each

episode a particular heuristic device or set of devices can be said to be in

operation and in general control of the reorganization of a problem space. Further,

the orientation of this operation is neither entirely objective nor entirely

subjective. It is both. Between episodes, control is relinquished, so to speak, from

one set of organizing rules to another. (1987, p. 77)

This summary is interesting for a variety of reasons. Though Rowe mentions that a

phenomenological stance is spiritually sometimes more appropriate design activity, Rowe

suggests the designer is working from a "general adherence to the information-processing

paradigm of problem-solving theory will be maintained because of its breadth and

precision" (Rowe, 1987, p. 91). It is here that I will make my distinction from Rowe in

my guiding principles.

I will be using phenomenology to guide my work. I do not feel that control is

relinquished, at least in decision-making or what rules to use and when to use them. No

rules are absolute and neither are the thought processes that govern their use in a personal

design process, therefore the ability to support or define portions of these "wicked

problems" using experience and memory for others is the critical task. The framework as

shown in figure 17, has an order and supports decisions that the designer has control over

and work together to solve "wicked-problems".
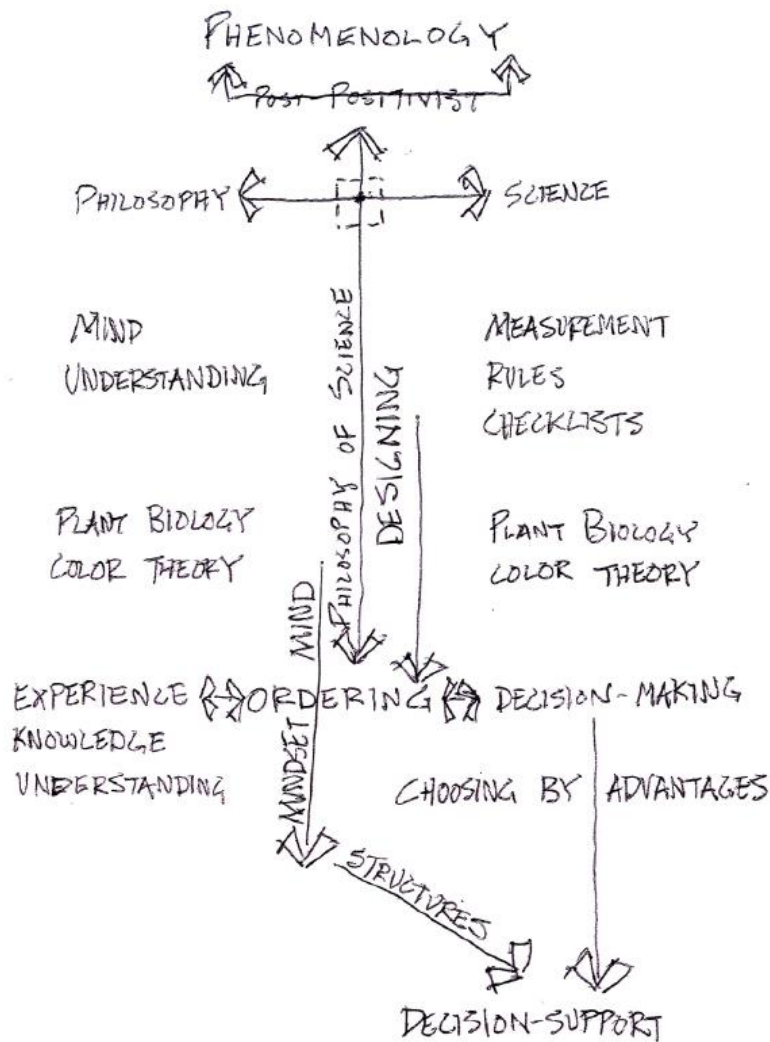
Figure 17: What topics are included in the formulation of the framework? How do we make decisions and how might they be supported?

If we consider the current state of the framework, control is different from order, which is not entirely the same as systems or being systematic. Control is being able to choose and decide about the task at hand, in this case being able to decide with information gathered from using the framework. This process of using the framework is being systematic or purposeful in your approach, being methodical; that using the framework is founded in the designer being able to make the decisions according to the

rules they make for the design. This purposeful and systematic approach is ordered, that "Order must be understood as indispensable to the functioning of any organized system, whether its function be physical or mental," (Arnheim, 1977, p. 162).

While the framework is an ordered, systematic and purposeful method to assisting in the design process, some other types of order can yield a pattern at any level, that is to say it presents an organized composition. For example, plants follow a natural order along what makes them survivable in necessary conditions. Arnheim continues saying that symmetry and self-contained and parts of a whole have an intended order and practical execution, and disorder is conflicting partial orders (Arnheim, 1977, pp. 165-169). Our example is that order is when a plant grows in its uninterrupted manner. Disorder is normally when we saw a plant is disturbed, as if an animal is eating it, a parasite is attacking it, the plant is sick or other negative conditions. But both comprise the whole. There is order in its growth, such as spirals or helices, cylindrals stem or tapering shapes as both mathematic, biological, and spatial phenomena, and then there is order to the way we characterize or name such plants with similar characteristics and their phyllotaxis (Thompson, 1992).

Arnheim talks in relation to Adolf Loos, that architecture was a "man-made object placed in a natural setting" (1977, p. 213). Should architecture be an extension of nature? I believe so, but the question is in what manner? I have taken this to mean using plants and vegetation and infusing them into a building and its performance, rather than adding them in as an additive design feature.

Plants can serve as a method for a connection to nature, using the Biophilic mindset. They are not simply ornament that can be exchanged for something else. Plants

have a function to perform, and aid in the aesthetic of the composition, provide a quality of space, but to also shade and permit sun, to have color splashed along a surface, to change and flower, and to provide a habitat for insects and bugs that then bring birds which add even more life, color and song.

Arnheim raises a good point: "Since all human thoughts must be worked out in the medium of perceptual space, architecture, wittingly or not, presents embodiments of thought when it invents and builds shapes" (1977, p. 274). If architecture is an embodiment of thought, then the method of thinking and teaching that we choose is significant to the outcome of our design process.

Nigel Cross states that we are currently in a model of teaching as designers who happen to teach versus teachers of design. He describes and summarizes the work of the educationist Peters, looking at factors that influence education such as: manner, matter, self-awareness, and education (intrinsic vs extrinsic) and states that simply training as the purpose of education is not desirable (Cross, 2007, pp. 20-21). He continues describing that designers seek design solutions, and use problem solving through synthesis.

But what is most interesting for the framework is this by Cross: Designers tackle "ill-defined" problems. Their mode of problem solving is "solution-focused". Their mode of thinking is "constructive". They use "codes" that translate abstract requirements into concrete objects. They use these codes to both "read and write in object languages". Their importance in education lies in that design develops innate abilities in solving real-world, ill-defined problems. Design sustains cognitive development in the concrete/iconic modes of cognition. Design offers opportunities for development of a wide range of abilities in nonverbal thought and communication (Cross, 2007).

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And these problems can be externally or internally derived. Often they are external with an intrinsic motivator attached. For example in the framework the project might have a set of requirements, but then the designers brings that rule or idea to the design and makes it their own, seeking a solution that will be the most appropriate in their eyes. The increased ability to define and overcome such problems and achieve pleasing results is then design ability.

Cross states that "designing is a form of a skilled behavior. Developing a skill usually relies on controlled practice and the development of technique [….] underneath skilled performance lies the mastery of technique and procedure," (Cross, 2007, p. 47). Design is persuasive, moving, and as inspiring it is exciting; fun even to the point of being engrossing.

Cross describes a series of experiments with designers showing how past experience assisted them in design even if the idea or task itself was new or they were redesigning from a fundamentally new perspective (Cross, 2007). Using the framework in the past, I have seen students do this by taking extra time to start and by combining their ideas. From this they are able to ask what the fundamental purpose of the thing should be, rather than simply accepting it as the only thing it could be. This is different from observing something as it is. From there they are able to find a rule or a principle that will guide the project.

Cross identifies these rules and principles as: taking a broad systems approach to the problem, rather than accepting the narrow problem criteria; framing the problem in a personal manner, and designing from these principles (Cross, 2007, p. 97). He also identifies topics of understanding design cognition: problem formulation, goal analysis,

solution focusing, coevolution of problem and solution, problem framing, solution generation, fixation and fixation to concepts, generation of alternatives, creativity, sketching, process strategy, structured process, opportunism, modal shifts, and experience (novices and experts) (Cross, 2007, pp. 99-116).

The framework is also a sketch of a cognitive process allowing the more abstract process of the mind to be made concrete and reflected on. It also allows the designer's intuition to be utilized by providing the process for a designer to sketch immediately. The framework is like a pond that can help to source ideas. The creative leap comes from finding information, discovering what is important, applying it to the solution and then understanding what has occurred. The leap is simply the particular result of a regimented and consistent stepped process of design. That does not mean that a large leap cannot occur, just that it is always derived from somewhere and contains persistent thought, even if only in the background.

Phenomena and Their Interpretation and Understanding

So where and how do we find or create our pool of intuition or experience? I believe it lies in our memories and in our interpretation of the world around us from our previous experiences.

In *The Eyes of the Skin: Architecture and the Senses* by Pallasmaa, we begin to see how the senses give reference to our world and where we are located in it, both physically and mentally. This can be vision but also relation, mediation and meaning. Pallasmaa describes how we work to project ourselves into a space completely, to understand it. With internal and external stimuli we understand space through our senses

(Pallasmaa, 2012, pp. 10-13). He describes touch in its intimacy and nearness (using texture, weight, density, temperature). He compares touch to how sight isolates, hearing incorporates, sight is directional, sound is omnidirectional, and that smell is persistent recalling memories (Pallasmaa, 2012, pp. 50-62).

How do we begin to use nature to find our sense of belonging; that what we have around us is a sense of completion and not a series of partially derived structures focusing on the visual in architecture? We can use nature to engage all of the senses and by doing so create memories which will later define us. From these memories, our writing and method of architectural interaction is an indicator for our sense of being and place. Many of these arguments place nature and technology at odds. With the widespread use of personal computers and smart devices, are we missing out on something?

Can we have an interaction with nature and the computer and can this be balanced? The computer is a tool, but it does change the way things are done. Should we be fearful of technology? Is there an interesting level of personal interaction with a framework and the hand and mind? The phenomena of writing a framework and the dedication that go into its creation use all of the senses. It is important to be able to have a foundation to do and see how you can help to remember to include all of the senses. Instead Pallasmaa sees technology as a polarizing force: "the growing experiences of alienation, detachment, and solitude in the technological world" (Pallasmaa, 2012, p. 22). This is interesting because technology, while being associated with these, is seen as a negative. However, this concept of being apart in airports and hospitals gives rise to a sense of isolation together. That is we have people all around us, activity and movement, but in our minds we are alone.

And this is terrifying.

There are many different types of personalities, and these can thrive on other presences or thrive on the absence of others. This can literally be nature as I enjoy its presence and it calms me, even when alone. This is critical because we make the assumption that others wish to be with us. The difference is in the fact, I feel, in the broken or fractured nature of these spaces. The fractured nature is not being able to make a connection with so many others around. That there is potential for a gathering, but everyone moves along through space without interaction. On an innate level some yearn for this interaction, others are thankful to be spared this interaction. It, as many other things, lies on a spectrum of desire within us.

This spectrum of desire is what is so important, especially in design. We have so many different options at our disposal, so many varieties of potential. That enjoyment and desire may come from our surroundings and our interaction with them. This is not our interaction with other people all the time, but what our body tells us through our senses.

According to Rudolf Steiner, in Goethe's (1749-1832) scientific writings he believed that thinking should direct observation (Steiner, Goethe, & Barnes, 2000). If thinking about our observation is necessary to a more complete understanding of a given situation, then our interaction with a phenomenon is influenced by the knowledge that we both have and do not have. The purpose of studying the phenomena of color theory in vegetated assemblies is to then be able to implement such knowledge later in design. The core of the study is how vegetated wall assemblies, through their plant colors and

materials, are influenced by color theory and how that influences their aesthetic design. The way that we choose to discover and explore is our being, perhaps our essence.

My Interpreting the World through Senses

So often we measure our thoughts by what we are good at, or what we think we should do or ought to do, but what about our desire to enjoy something? I will be blunt; I enjoy nature and its infinite opportunities. It is simple, yet complex. It can embrace you in a moment and then also cast you aside in another. Enjoying a topic and experience is what makes thinking and making more exciting; is doing tasks with a topic you enjoy.

I felt that this method of thinking and learning needs to be shared with others. Not that they would do exactly as I have done, but they can find the similarities to themselves and then modify and adapt, as nature does, to their needs and desires. The topics I often choose to explore come from a series of topics in the natural sciences and biology. They are something I found enjoyable, but never wanted to make a profession of. This tendency finds it roots in my own background starting with the Natural History Museum summer camps, moving to Cub Scouts, then Boy Scouts, and working as a counselor at Nature Camp. I still do and enjoy hiking, examining plants, and interacting with natural settings.

Much of what we do focuses on the eye and this is not right or wrong, much of the world simply: is. The world exists and that we have the ability to interact with it. We continue to view the dominance of a sense as wrong; however sight is often the first way we interact with something. We need to find our own balance of our senses. We do not need these senses to be equal, but in equilibrium with each other.

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I feel that this equilibrium depends on the conditions, not only of the nature around us, but also of ourselves. If I take my glasses off I am a blind man, with colors all blurred, shapes distorted, blending into a single mass of existence. But I can still hear you, seek you out with my hands, and understand that there is excitement in the other room and smell of food lingers. It is the equilibrium, and balance fused with intent that makes interacting with phenomena so interesting and enjoyable. But this can be over time, that all senses can activated or not. Tranquility and silence and solitude are needed to balance chaos and ruckus and presence.

Our senses allow us to characterize our experiences as an action, not a simple fact, and these facts around us are interpreted to our liking and to the level we desire to do so. We interpret them. We in a sense become our work as we interact with it. To this end we need to show not only who we are and interact, but that the level of discipline and integrity of our work is critical. If a task is done haphazardly without intent, this is a lack of rigor and integrity of the designer.

Translating Senses and Experience to Architecture

Peter Zumthor, a Swiss architect, describes how "people interact with objects […]. The real has its own magic. Of course, I know the magic that lies in thought. The passion of a beautiful thought. But what I'm talking about here is something I often find more incredible: the magic of things, the magic of the real world" (Zumthor, 2006, p. 19). He considers skills and tools as necessary parts to understand this; however I would add processes as all three are highly personal to everyone.

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Zumthor writes about a number of concepts: the body of architecture (the thing itself), the material compatibility, the sound of a space, the temperature of a space, the surrounding objects, the composure and seduction of space and time, the tension between interior and exterior, the levels of intimacy, and the light on things. These topics combine with architecture as surroundings: things that move you in the moment with quality that may not be talked about in the farther future; coherence: we can have an intent for the building, but that these objects also find a sense of their own on their own; and beautiful form: the object comes together and moves him (Zumthor, 2006).

I have the desire to teach. I cannot say for certain if Zumthor ever directly meant for his work to teach, but instead moves people or more likely himself. And I believe that this is critical. If it moves you, then perhaps you can show it to others, rather than simply tell them they should be moved. In response, the dissertation will be in two forms, the first is the typical written dissertation and the second is as an interactive living document in the form of a website. This will allow different representations of the same information to be conducted. The larger, full dissertation will have all of the information and necessary analysis outside of the object or process being presented: the framework. The website will be a version that is accessible to everyone who has the internet.

Essence of a Framework: Do frameworks have a soul?

If these memories and experience the Zumthor writes about are our own, then we must begin to understand not only our methods of perception, but at least acknowledge cultural perception. Pallasmaa states, "natural material expresses its age and history as well as the tale of its birth and human use" and that "the builders of traditional societies

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shaped their buildings with their bodies in the same way a bird molds its nest by its body"(Holl, Pallasmaa, & Pérez Gómez, 2006, pp. 29,34).

Furthering this argument, Holl reminds us that we observe partial perceptions of a phenomenon; that we begin to try to understand what we have encountered, considering "space, light, color, geometry, detail and material as an experiential continuum" (Holl et al., 2006, p. 45). A fascinating example of this is projected color. A physical example of this is the St. Ignatius Chapel by Holl. The type of color he is trying to experience, or have others experience, is found in the washes that occurred when color is picked up and transferred through light in the hidden colored walls in the sanctuary. The memory of a color is projected into the space, which was intangible from unseen surfaces.

Architecture is a personal memory, we ground our work in our own memories or experiences. My personal separation of these two is that memory brings a story back to your life, it moves you, and it begins to help define your interests and work. I feel that experience sometimes can be a little clinical. I am guilty of using these two words interchangeably, but will try to keep them in mind.

But how are things and even thoughts brought together? Zumthor believes that thought and use combine – the impractical is not useful. He describes that the construction of architecture and how it joins is important (Zumthor, 2010). There is the need for a very methodical and understood process of designing in the mind. This is something that the framework tries to do. While you can make and use the framework quickly, there is something to seeing your mind and process out in the physical on the piece of paper. That you not only understand the thing before you, but also some part of the mind and memory that the physical derives its power from. This is a reciprocal

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process. The mind receives from the world and at some level the mind gives back. In architecture this is the object we design, we build, we make.

Zumthor asks us to be looking at an object for what it is. I also believe that a thing is what it is, if you will, but we need to consider the associated phenomena it creates. This brings us back to what I was trying to talk about with Heidegger. The framework is an object, but also a technique and a process. The question is what kind of phenomena does this object create? There is nothing spectacular about the form or the object that the framework is, but we need to be able to look long enough at it and ourselves to understand what it means in its entirety. The object is interesting because the framework starts out as ideas and writing and when composed on a page, becomes an object that shows a mental process in the physical. The framework is a process to show a process. If we can begin to understand ourselves, we may begin to understand the world and the phenomena that surround us.

The decision support framework is like a working drawing. Zumthor describes, "they do not try to convince and impress like project drawings" (Zumthor, 2010, p. 18). Things simply are. This is what the framework is to some extent. The framework does not try to impress you with its outward appearance, but it reveals something about the mind of the designer, and my mind, as I understand design. These types of decision support frameworks are a combination of passion and insight that inspires them and they need some level of rational and ordered thought process. The original inspiration is sometimes hidden behind what is later brought to be. It is the desire to do so and the normative concept of ought to be that makes this work interesting. The discrete space on the page that the framework takes up is confined compared to the space it could then

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inform, which is even smaller as compared to the vast reaches of space that surround our existence. But the mind is where the process begins, continues, reflected-upon, and informed and renewed though the life of design.

The framework does not carry any unnecessary things. It has what it needs because of what we believe it ought to have. The framework reflects who we are as designers, our thoughts, and our impressions, our desires to include and decide to design certain phenomena. These parts and pieces come together perhaps without our knowing of what to achieve, and then a new phenomenon is derived from the process.

The framework itself is the thing in which our ideas reside. I have taken my mind and brought it forth into what I feel is a thing worthy of some merit. The framework allows me to use the memories that I fondly remember, and translate them to others. The framework can guide and help others even if I am not there as a knowledge sharing device. I may not give someone my exact memory, but if the framework is used to design spaces, perhaps new memories can be given to others which can inspire them.

And do frameworks have a soul because of this? Not a soul as though it has been given life, but something else beyond the words and form on the paper? Perhaps, but I do not know what this would mean. Maybe it has a presence that is important to the person who thought of it; that our personal understanding of what we have created and will discover from our memories is inherently important to us; and that because it is an extension of ourselves it can have a soul, or presence.

I do not know the answer to these questions of frameworks the same way I will never know what architecture completely is. But I do know the experience that making them has given me; the memories of working with students to more completely

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understand them and their use, and the potential that lies in the process of learning and reflecting. That they help others along the path to their own architecture is most important, even if I never find my own.

Rasmussen reminds us that in architecture we make things look a certain way and have things as they are. For example color as a plane – mosaics, skylines of cities, tiled exteriors, reflected color off of water, color by location. Or that architecture can and does borrow from art: cubism and earlier modern architecture with Corbusier, or the attitude in reflected light in materials from Mies (Rasmussen, 1962, pp. 83-103). Color and light often work in tandem and reveal qualities to us such as texture in sight though shadow and light. He uses more light, less light, trying to experience "an excellent light" (Rasmussen, 1962, pp. 171-173,190).

I think back to my own apartment and its light through the window (which would become one of the case studies: Turtletown). How would this be different with plants? What is a personal excellent light? Is what I have experienced here an excellent light? Does it have excellent color? We always have color as no architecture is without color. Architecture has color whether it is applied or inherent to its materials. Color can be inspired from the world around us and our memory. I think and look to nature to help define what we then are accustomed to and would be comfortable with. Color is such a wonderful thing.

Part 3: Topics of the Building Sciences- The Designed Response

Our work is dependent on the memories and the life that we have led. I will use examples from other architects, however it is important to understand where I come from

and how I reflect on the work both of my own and others that is present and for the intent that I have.

There are many different topics that can contribute to the development of a process of thinking. There are philosophical grounds that guide our processes in general and then thought that is applied to our discipline. These examples now become the centerpiece for understanding the development of the designed response and the decision support framework as a typology. From all of this framing we begin to see that the frameworks are concentrated applications of a set of theories and positions on observations of phenomena. These positions can be summarized graphically and serve to organize a systematic approach to ideas and design, as shown in figure 18, to develop the designed response in the form of architecture.
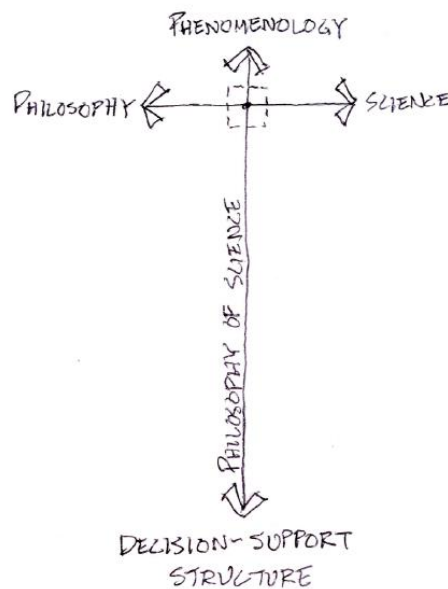
Figure 18: From all of the discussion on phenomenology and decision support structures, a point of intersection creates a place for the development of a line of inquiry and thought into developing a designed response.

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Developing a Designed Response beyond Simple Form

We need to begin somewhere when thinking of a designed response and Norberg-Schulz gives us that impetus for thought: "I am referring to that enduring relationship that exists between man and the environment, a relationship that must be constantly reinterpreted" (Norberg-Schulz, 2000, p. 8). This work tries to find that re-connection with nature both as an experience, but in the past as a memory, and in the future as a design consideration and intent.

Norberg-Schulz summarizes the work of how Husserl "had demonstrated that perception is function proper to corporeality, and the senses" and that phenomenology is "science of the possible experience of the world" (Norberg-Schulz, 2000, pp. 10, 21). I believe that phenomenology also is how we present the space and how the place presents itself to us and the interpretation of the two. Norberg-Schulz sums it up nicely as the science of being; that phenomenology gives us access to the original, which is also the presupposition of any symbolism (Norberg-Schulz, 2000). He defines phenomenology as assisting "us in the development of a cognitive method of being in the world of the individual, and as a consequence both art and architecture can be considered manifestations of applied phenomenology." "Or that […] rather than a theory, is a path that has as its purpose the providing of access to the structures and the meanings of the world of life" (Norberg-Schulz, 2000, pp. 15, 21).

Life is structured and forms a continuum punctuated by experiences of mundane or great significance. These experiences stick with us and inform future decisions. He and Zumthor speak of atmosphere, and Norberg-Schulz gives two examples of which I have had the opportunity to visit: La Rambla in Barcelona and Place Georges Pompidou in

Paris. I can say that these places have a distinct atmosphere and sense of place. As he later describes when we feel or are at home it "validates our individual identities, the place offers security and safety" (Norberg-Schulz, 2000, p. 39). There a sliding scale to these words; you can be at home in a place without it literally being your home such as in nature, but this is maintained by a sense of familiarity from recognizable characteristics.

He continues on the topics of memory, orientation, and identification to use what you have before to understand what is around you, and then begin to interpret that which is now there. This develops into the concept of the Genius loci and the identity of a place by its space, form, and figure working together. This is also suggested in Heidegger's earth-sky relationship. Here it is as a foundation both in place and time "an architecture based upon the comprehension of the environment" (Norberg-Schulz, 2000, p. 75). Interestingly and pertinent to the framework was that he used gardens to show this point.

Critical Regionalism is the understanding of the difference between the universalization of modern civilization and the need to retain some sort of regional or location specific design. This does not mean superficially engaging culture or the local vernacular, but that a design is of a place (Frampton, 1983, 1985). Frampton quotes Barragan on his memories of a pueblo from his childhood. In summary of all of the characteristics the pueblo had, "it gave this village an ambience of a fairy tale. No, there are no photographs. I have only its memory" (Frampton, 1985, p. 474). The point is that there is a time and place for a type of architecture or design to occur. These conditions allow for the development of a critical regionalism.

Frampton then speaks of the work of Tadao Ando and how Ando describes the connection to nature that was lost due to the rapid modernization of Japan after WW2.

However Ando strives to make his modern architecture pay homage to its place, having design for the senses such as light and wind. Ando states "Light changes expressions with time. I believe that the architectural materials do not end with wood and concrete but have tangible forms but go beyond to include light and wind which appeal to our senses" (Ando, 1982; Frampton, 1983).

Indeed, architecture goes beyond tangible forms, melding with our memories and thought. Architecture is then an embodiment of the thoughts of characteristics and desires of the designer. I hope and believe that the framework can work as a catalyst for this potential.

Peak Ecological Concern

To summarize the discussion so far, if design (architecture) is to be an embodiment of thought and memory, it should be carefully crafted so that future memories and people are influenced in a positive manner. This lies in the concept of being stewards of the places and things that we love. If nature and plants are foci of the argument, there is no wonder that ecological concerns would begin to enter the discussion.

This has been considered in the dissertation as being part of the site as a context for development, but also the building of the environment. It is the reciprocal nature of the building being a reflection of the environment and the environment of the building to be designed. If we are to be stewards of what we love, then I should be a steward for the natural settings I so enjoy. However is the current situation of my partial stewardship sufficient? I have devised a framework to help the process of designing, but not a final

solution to the larger societal issues. "The scientific community is usually paid to study problems, not solutions; indeed finding a solution to the problem under study usually brings an end to funding for research. […] Moreover, we scientists are trained in analysis rather than synthesis" (McDonough & Braungart, 2002, p. 12). While no complete solution to all issues presented in ecological design exists, the framework is the synthesis of analysis and may help others to understand this process of bringing together information for a situation, that as Cross described can be summarized as problem-solving or solution-seeking.

We do have a method of mass construction that has negative impacts to the environment and warps our interpretation of what nature is and how we should interact with, and enliven how it is in our lives. Nature and architecture should combine to make the framework around our essence, our lives. Our ill-defined problem lies in the fact that in current design and construction:

> "trees are felled, natural flora and fauna destroyed or frightened away, and the generic mini McMansion or modular home rises with little regard for the natural environment around it—ways the sun might come in to heat the house in winter, which trees might protect it from wind, heat, and cold, and how soil and water health can be preserved now and in the future" (McDonough & Braungart, 2002, p. 33).

However, is it necessary to use scare tactics and superlative language to get people's attention? Depending on the way we engage with others as designers and try to communicate with them we instead turn them away from the ability to understand something. I can see how environmental concerns were fought against, not because they

did not have merit or the potential for it, but in our method of how we ask others to participate. You are bad. You are being harmful. Why are you not scared of the future you are creating?

It is a series of blame and accusation that simply does not solve the underlying problem. We need to do something, how can we help? How can we be stewards? Why should we? The first step is working together. It is how we can demonstrate to others rather than demanding right from wrong. There is a continuum and there having always been different methods and styles of environmental concern, foundations made, progress rendered. However, there is always another topic or discussion on the horizon that looms and scares us: our lack of knowledge of the future. So instead of telling others they are bad, how can design be more ecologically minded?

There is a framework that can help with that.

Now I am not saying that this dissertation will help save the world, but its process can help to remind us of what we find important. If we use it alongside others, we can begin to identify concerns we have and how they differ from those next to us. Perhaps then with identification, can next be design and from the process of design a discussion on what could be shifts to what ought to be done.

This brings us to teaching. We have the opportunity to help future professionals bring these concerns back into their designs and integrate them. If these students are comfortable with thinking in an ecologically sound manner, they might be inclined to do so in the future. The framework is something that they can take with them and change to their future needs. For some the physical framework might be useful. It is something that they can touch, see, understand, and have as an object of reference. Others keep the

tactics in mind, others use the computer to search for it again, and some few simply ignore it. The point was, is, and will be showing others where they can start from and then grow beyond.

Biophilia and this connection to nature, being once again part of our ecosystems can lead to informed decisions (Kellert & Wilson, 1993; McDonough & Braungart, 2002). McDonough jokes that we cannot leave the planet (at least at this time), so what are our methods for co-existing with our current environment and leading to a balanced lifestyle? We are not looking to govern down, but enrich our surroundings. Signal your intention, restore, be ready to innovate further, understand and prepare for the learning curve, and exert intergenerational responsibility (McDonough & Braungart, 2002, pp. 181-186).

We must respect what others hold dear: their ideas. If we engage our students in the process of ecological design, and show them how it can be integrated into their current design process without a perceived detriment to what they love and hold dear we have a chance. Then we have the opportunity to see how nature fuses into a multitude of unique designed responses. These responses will then reflect not only the environment, but the person who designed it.

Ecological Design and the Designed Response

The need to have technological solutions to ecological issues has continued to present itself. In the past to the modernist times power requirements and standards were lower, combined with less need and pollutant output. In recent times this requirement for solutions hit the hardest in the energy crisis of 1973 leading to the desire for low-energy

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strategies and natural ventilation strategies (Daniels, 1997). Add in a booming

population, and a simultaneous need for less energy use and more ability created a

menacing cocktail.

As countries in Asia and Africa continue to modernize and mimic our methods of

living, the need for resources, power, food, technology will increase as well. This is not a

call for a doomsday scenario; it is a call for governing our current rate of consumption,

using what we have already created, building low energy and embodied energy methods,

and developing strategies for updating existing building stock. Multiple authors echo this

trend of ecology and ethics (Daniels, 1997; McDonough & Braungart, 2002).

"Energy can be gained from: the sun, water, soil, air, fauna (conditional) and flora

(conditional). The first four items in this list play a major role. The use of plants inside

and around buildings is of particular psychological significance," (Daniels, 1997, p. 42).

Responding to the climate and local meteorological conditions are vital to the

development of the designed response. Designing to the location, climate and local site

not only is important for energy savings, but can also reflect the traditions of the area and

the experience of the individual in these ecological or phenomenological spaces (Ando,

1982; K. C. Bloomer & Moore, 1977; Daniels, 1997; Frampton, 1983; McDonough &

Braungart, 2002; Pallasmaa, 2012; Rasmussen, 1962; Zumthor, 2006, 2010). These

concerns are two sides of the same coin. Some designers view these concerns as numeric

and quantitative, others in the phenomena, the qualitative. Both are important as numbers

do not always reflect the feeling of a space, and the phenomena do not reveal discernable

metrics. Thus if possible, it is desirable to reflect both sides in designs. Personally I feel

this is achieved by experiencing the phenomena of the space and its memory and

intention to be informed by quantifiable characteristics of the site to define a designed response.

But what are the topical considerations that we can use to design a response? Are we looking to the building to have solutions to work in an environment, or using the environment to design an appropriate response? I feel that while there is a reciprocal nature between the building and the environment, it is the environment that will reveal a building type that is appropriate for the place.

Some main topic considerations come from Daniels in *The Technology of Ecological Building: Basic Principles and Measures, Examples and Ideas*: Exterior Space as Air, soil, water surfaces; Technical installations as heat energy, cooling energy, electrical energy, water; and the building fabric as façade and roof, construction, atria (Daniels, 1997, p. 47). One interesting project is the DAK building and its atria for plants. The architects consulted the Hamburg botanical gardens for help. The gardeners suggested plants that: "are used to deep shadow from tall trees, which have a wide temperature range and high tolerance to cold." (Daniels, 1997, p. 182) Essentially they needed plants that were highly resilient for a subtropical rainforest for Germany. This shows the different between indoor and outdoor conditions and will mainly focus on outdoor planting conditions that reflect the local conditions. However with enough time perhaps the framework could be expanded to include thoughts on internal designs and atria in the future.

The mindset that the designer has is what is key to a designed response. If we are looking at a place and responding appropriately to that place, then it is a designed response. If we are accumulating characteristics that will allow us to design in an

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irresponsible manner then we are not holding our desire to be good stewards. This is the difference between doing less harm, and enlivening the places in which we live.

The Individual and the Designed Response

"Individuality means mobility, space, resource consumption – and this is where we encounter limitations. Never-ending luxury, consumption and pleasure no longer deliver the satisfaction they once promised," (Daniels, 1998, p. 15). We are becoming global, but how do we retain individual character? Is there a total loss of individuality? This is the concern that founded critical regionalism.

Daniels lists off concerns of an information age: databanks, and the internet, building for climate zones, environment and town structures, and extreme conditions. He investigates solar energy, water energy, rainfall and surface water, planted areas, energy potential in soil, daylight, and combines it with the need for integrated buildings with topics such as living and working areas, understanding the thermal, hygienic, visual, and acoustic comfort and electromagnetic comfort.

Color makes an appearance in these considerations: "we experience colour as a fundamental quality of our visual perception: surface colours – mainly perceived as an inherent quality of the object – are the visible 'skin' of the environment" (Daniels, 1998, p. 100). He cites three main methods of using color as indicative, symbolic and aesthetic functions. Daniels makes a list of topics that should be addressed in color, considering people and their environment: cultural factors, milieu factors, individual disposition and preferences, function and the meaning of the room, color-form relation, color-material

relation, factors given by and in the surrounding environment (landscape, urban surroundings, historic, and stylistic)(Daniels, 1998).

If we take all of these considerations into account, is our architecture merely in the environment or with the environment? Summarizing Daniels' inquiry, there is the need for a contextual building, one that can be found in green spaces, with wind, with the sun, near water, building with mass, or without. We need to find and use renewable raw materials such as wood and paper. We ought to be designing new building envelopes considering insulation, shading, daylight and glare, natural ventilation, considering ecological planning, its motives and planning and lifecycle, and after a period of use, expansion and renovation of structures.

While these are all valuable considerations and help to ground our designed response, do they alone bring delight? We can go on and list a never-ending number of considerations, but we need to tie them together with more than a plethora of numbers. Remember it is the combination of the quantitative and qualitative that defines architecture.

But can we take delight in the method of construction that continues to ignore place and the designed response? "In regards to inefficient construction: It has not responded to the various ways that people use, remember, and care about the environment and how they associate their thermal sense with their own senses" (Heschong, 1979, p. cover). Lisa Heschong argues that thermal qualities: warm, cool, humid, airy, radiant, cozy – are an important part of our experience of a space (Heschong, 1979, p. vii). As architects our questions should be: How is it perceived? What role does it play in people's lives? What is wonderful about it? How is it part of a greater whole

(Heschong, 1979)? Our environment thermally reflects us and we it: clothes, acclimation, and the evolution of the characteristics of animals and plants.

Heschong describes the ability of visualizing and adapting your microclimate in three directions, inside, outside, above, however I would add below as well. Microclimates do not end at the surface of the earth as underground characteristics can greatly influence a design and the thermal delight in a place.

There is a character of trial and error of personal learning with plants and thermal qualities such as stinging nettle, weeds, flowers, grape vines, blackberries, and others. Finding a plant that was edible and not sour was a delight for us. Plants have sensitivity thermally and visually, we use our senses of interacting with a plant at certain distances, from far to near to touch. As Heschong finds delight in warmth, I find delight in plants. I continually am adjusting and engaging with planted space and its meaning and phenomena. There is something about a natural space and its foliage, breezes, and visual arrangement that serve as a refuge from daily life. There is a process of being in these spaces and all the comfort physically and mentally they provide. Plants and nature provide refreshment with thermal qualities, light, and shade, warm and cold.

I have affection for plants and personal affinity for some. Plants can serve as a daily ritual in the form of gardening or simply being and moving through them. We make a connection to the plants and it is deeply personal. Our experiences leave in us profound memories that we then cherish as a sense of place. Something is communicated through our senses to our mind through the unmatched state in plants and nature we encounter. Founded in natural law and our senses, we can move beyond the physical to give us the

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metaphysical and cognitive experience. This can generate a personal ethos of existing in nature, the natural, the environment, and the plants.

Personally, I think thermal delight was seeking refuge in a cave from the elements and fire was an accompaniment in time. I remember back to being cold, sitting around at scout camp being brand new to the process. Then suddenly light. We as small children had been told that fire was fit in the fireplace, or was a danger to us. Now there it was, not just a novelty, but a necessity for comfort and food. What a feeling it must have been for our ancestors, even after one day outside in the elements, the warmth of fire gave not only thermal, but mental comfort. Humanity had tamed such a violent force to be our savior. Fire became delightful, wonderful, and a place for life.

From the Heat of the Flame to Designing with the Light of the Sun

Designers have had differing positions on the sun, the great fireball in the sky, as well. Corbusier thought of the sun as a clockwork mechanism bringing light in the winter (as it was a friend), not in the summer (as it became a foe) and relied on the cyclical movement of our star. Wright focused on fire and the hearth as the heart of the home, and the emotive qualities it possesses (Fernández-Galiano, 2000). We can use both of these positions to develop the designed response.

Further describing the difference between solar thermal technologies to passive strategies without technical infrastructure: "If heiliotechnology was a mechanistic thermodynamic architecture, bioclimaticism is organicist. The transit from machine to organism is like the transit from active to passive solar energy: the use of climate as an energy resource through the positioning and morphology of the building is a key concept

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of bioclimatic architecture," (Fernández-Galiano, 2000, p. 120). Do we think of design as a technological solution in spite of nature, or are we part of the place, part of the organ, part of the being that is nature that provided us with our beginning. The very nature that can harm us, also provides the methods for securing our future.

Do we find delight in our designs and the methods we use, as in the natural or thermal environment? Or are we simply solving a problem posed to us, trying to place the same box in a different place, without regard for the consequences? Passive design does not mean being passive in our mind and process. We must "maintain and, where it has been disturbed, restore biodiversity; minimize the consumption of resources, especially non-renewable resources; minimize pollution of soil, air, and water; maximize the health, safety and comfort of building users; increase awareness of environmental issues" (Hyde, 2000, p. 6).

Becoming even more specific, bioclimatic design moves from the architecture to synthesize with the environment and climate responsive design takes characteristics of the microclimate and uses strategies to reach the architecture. The largest difference is in the site study of climate responsive design as compared to climate data in bioclimatic design. The first looks at the place, the other general trends of a larger area. The Universal sought in modernism is not really desirable, nor possible, as a designed response to the place (Hyde, 2000). We continue to look for the intangible qualities of a place – its experience, connection to the climate, and the surrounding landscape. Designers use the bioclimatic or psychrometric chart to move the comfort zone to increase the comfort of a designed space as it depends on the place, its conditions, daily

and seasonal cycles of the place, plan orientation, landscape, verandas and courtyards (Hyde, 2000).

Summarized and adapted from a number of tables made by Richard Hyde (Table 1, following), we find specific considerations for environmental design concerns (Hyde, 2000, pp. 29-32, 57, 69) and can combine it with the work of Norbert Lechner for the particular climatic area of Blacksburg, Virginia: climate region 10, represented by Knoxville, TN (2009, p.114). Hyde speaks to a more tropical climate design, however many of the points selected can be generalized to most environmentally responsive design. The concepts Lechner proposes are specific to climate region 10, which contains Blacksburg, Virginia. All of these considerations can overwhelm a person, and make it difficult to design, or even understand the task at hand. While useful here to see all of the information at once, will not be the format for the framework as it contains too much information and earlier reviews from students suggested it was overwhelming to newer designers as this table does not even get into more specific strategies nor the decisions to be made.

Table 1: Summarizing the work of Hyde and Lechner into a single table. This method was not recommended as a graphic representation of the decision support framework, nor does it provide adequate information for decision support.

Author and Topic	Design Suggestion or Guidelines
Climate Concerns (Hyde)	adverse climate elements: rain, snow, cold winter, winds, summer heat, and high humidity
Climate Methods (Hyde)	1: Minimize heat loss in winter 2: Allow solar access in winter 3: Minimize insolation in summer 4: Utilize ventilation in summer
Responsive strategies (Hyde)	1: Good insulation with roof insulation or vented roof 2: Large windows facing the winter sun with solar access 3: Overhangs/eaves for excluding summer sun 4: Large openings with cross ventilation in summer 5: Building planning to optimize orientation 6: Maximize the passive thermal zone 7: Increase ceiling height 8: Passive cooling, natural cooling and thermal performance 9: Energy Supply: on site generation, integrated PVs, renewables, gas fuel cells, thermal energy storage, ice storage, user control
Summary of Climate Zone 10 (Lechner)	1: Keep the heat in and the cold out in winter 2: Use natural ventilation for summer cooling 3: Admit winter sun 4: Protect from the summer sun 5: Protect from the cold winter winds 6: Avoid extra humidity in the summer

Why do we even care?

We care because we have a need for a home; to have a place that we recognize and can return to at times. Without carefully considering the nature of a place, we might not recognize what is left when we are done designing a building. If we can be stewards of the things we love, we can begin to form a foundation for our memories and thoughts. And through all of this we begin to understand how our memories influence who we are and what we do. This framework (figure 19) is my designed response to the question of what I wish to cherish and protect: my students and their future. For this reason, our designed response is of a place, crafted to allow dwelling to contain our very essence and

memories, and that we may enliven the nature of a place as it forms a scaffold for our

lives and future. And I find delight in this act.
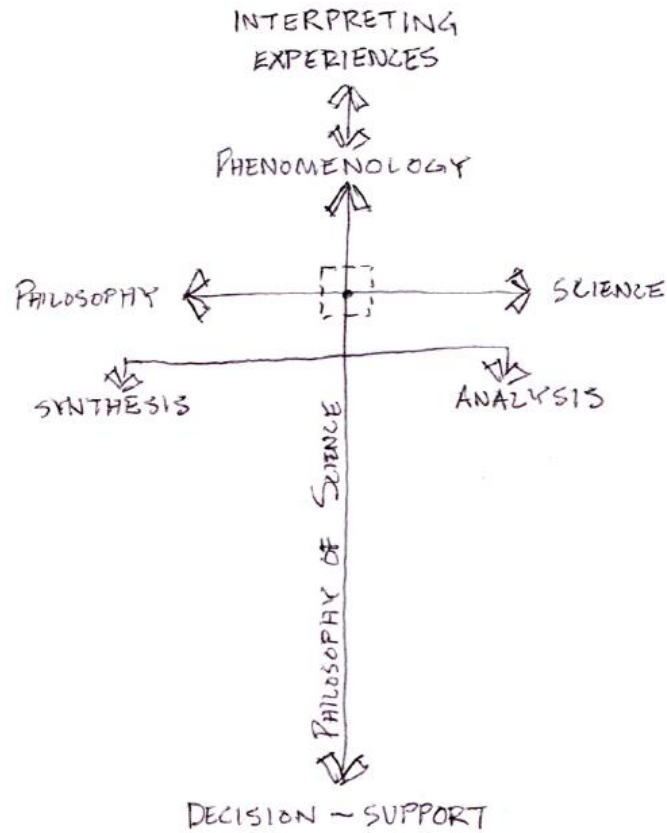
Figure 19: Overall organization of the grounding of the framework within the literature as a product of the intersection of science (quantitative), philosophy (qualitative) to be viewed through the lens of phenomenology as a way to engage the world, organized by decision support structures for others.

2.2 Learning a Passion: Vegetated Architecture

Overview:

I find delight in the act of teaching. After working through the underpinnings of the dissertation I have come to a certain conclusion: that we can find delight and engagement in the things we love. But what is it that I enjoy? I have a number of hobbies, but are these hobbies the things you would want to do even on the worst of days? The topics you consider must be a passion, a desire to continue long after the lights are turned out and last person goes home. The passions we choose begin to define who we are, and in return we are given the opportunity incorporate them into our essence.

After thinking about these desires and how they ground portions of my life, I realized that nature and plants have defined much of my design work and life experiences. If I am to believe my own rhetoric, then I must begin to ask if this is a fleeting interest, or the beginning of a life-long line of inquiry into what vegetated architecture means, or ought to mean. This work hopes to bring the question of vegetated architecture, mostly as vegetated assemblies, and begin to find design characteristics and questions that can inform the development of the design framework. This process revealed a sense of what can be or ought to be, not only what has already been accomplished by society. I choose to believe that this is done through a solid foundation in the discipline of architecture, and combining precedents with passion-inspired topics with this core.

I have found that what we experience and we hold desperately to are often critical or defining memories. These memories begin to inform our design and axioms of interacting with a discipline. The smell of a wood stove, the holes of dirt in the yard with

matchbox cars, the gardens that brought life and order to the relatively chaotic natural spaces, still resonate within the walls I have yet to build.

Part 1: The Merging of Literature and Street Smarts of Vegetated Assemblies

This will serve as a combination literature review and written history of some of my experiences in finding and understanding vegetated assemblies. It is not all about the books and the authors and the studies that begin to define our discipline, it has to have heart. Now plants do not have a heart, but they engender some kind of connection. Was this connection because my parents took me to scouts and that was outside; was it going to the park down the street and playing under the solid canopy of umbrella pines which began to define my world; was it watching Fern Gulley more times than my parents ever thought possible, playing with it running in the background; was it enjoying earth science in middle school?

Who knows, and it may not have been one moment that defined that shift. I learned what Biophilia was as a concept in my spring 4th year studio. Did this mean I could not have that connection without knowing previously about it? No. I have all of the memories and could then begin to attribute a possible theory as to why I enjoyed them, and could begin to ground my investigation into why I might enjoy certain kinds of spaces in the future. This glimpse of my interest into ecological theory and other types of restoration was not new; this history of enjoying nature has had great meaning for the direction of my architecture.

Examples of Vegetated Roofs and Walls through Time

There are a vast number of projects that influence our work both as contemporary and historical precedents. In the process of designing a contemporary building envelope, specifically a vegetated facade, it is vital to understand the historical background of such designs. Without understanding the impact designed vegetated spaces had on history and its people, contemporary projects would be without context. These vegetated spaces exist all over the world, each with a different method of implementation and aesthetic. These precedents inform the designer of each aesthetic, but also about what types of local flora can be used when applied to vegetated assemblies. Not all of these vegetated assembles are large and grand, some are humble as the saucer-size moss insert in a doorway I found in Basel, Switzerland (figure 20).

Figure 150: Not every vegetated assembly fills an entire wall. Some are humble such as this doorway insert of moss in Basel, Switzerland.

Every climate creates a context for the plants and systems used in a design, and this palette of plants is critical in the design of a vegetated wall and its implications on the designed response. While this study will refine its focus to a Southwestern Virginia climate, an initial global perspective is important to the overall understanding of vegetated systems. There is something about seeing a vegetated wall. Whether it is a juxtaposition of vegetation where a wall should be, an innate connection with nature, or the wall's inherent aesthetic qualities, experiencing its unique nature is exhilarating.

This history of vegetated assemblies begins with the ziggurats of ancient Mesopotamia. These temples were built in stages with each flattened terrace including plants to allow for rest on a person's journey upward. These gardens exemplified the power of a ruler as Osmundson (1999) explains, "It [the ziggurat] was completely remodeled by the last neo-Babylonian king, Nabonidus, […] in an effort to surpass the splendor of Etemenanki in Babylon," The Hanging Gardens of Babylon are another example of the grand nature vegetated gardens held. What is critical to note is that the gardens were supposedly built by the ruler, Nebuchadnezzar II, for his wife who desired and missed the landscape of her homeland. (Osmundson, 1999). While the tangible evidence of these ziggurats and hanging gardens no longer remain, the inspired grandeur of raised gardens above expansive plains in a desert must have been extraordinary. The natural beauty of the landscape was an aesthetic quality that people admired and desired. These massive undertakings had to be considered in both as an aesthetic and engineered marvel.

Vegetated assemblies continued to be constructed in the Middle Ages and Renaissance. Mont-Saint-Michel in France, Palazzo Piccolomini and the Tower of the

Guinigis in Italy, and Tenochtitlàn all continue the tradition of vegetated roof gardens. In the Industrial Age such gardens were built in Germany, Russia, and the Nordic Countries. At the turn of the century summer entertainment gardens were built on the rooftops of theaters in the United States such as Madison Square Garden. Frank Lloyd Wright and Le Corbusier also designed vegetated assemblies in spite of radically different architectural philosophies. (Osmundson, 1999).

The tradition of vegetated roofs continues into the present with projects such as the M2 Metro Station in Lausanne, Switzerland, the Consorcio – Santiago Building in Santiago, Chile, and Acros Fukuoka in Fukuoka, Japan, to only name a few (van Uffelen, 2011). These vegetated assemblies continue into the present and continue to be built in a variety of locations, at all scales, with many different aesthetic qualities.

These were commonly roof gardens, a horizontal application of vegetation and construction. The roof garden produces a sense of place and nature in places that were not commonly vegetated. The peculiarity and uniqueness of the raised roof gardens were found in the grandeur and infrequency of their recorded implementation. As the history of the vegetated assembly is covered, there is a dramatic shift in its complexity. Such assemblies were typically found in high-class institutions as they were costly, not reliable and prone to leaking, requiring extensive maintenance (Dunnett & Kingsbury, 2004; Osmundson, 1999). Many of the previous examples were for the entertainment of the privileged classes, however, the Nordic vegetated assemblies (sod roofs) investigated by Dunnett & Kingsbury were used for their measurable characteristics: the abundance of sod, effective insulation, and water retention. Once again we find that these vegetated assemblies are implemented for both the aesthetic and performance qualities, however

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from this history, we find that vegetated assemblies are much more common in Europe, and much of this research is not available in or has only recently been translated to English.

In contemporary design, the implementation of vegetated assemblies became more common and the types of the assemblies now vary widely. These vegetated assemblies were not only chosen for scientific characteristics or a point in a system for accrediting sustainability such as LEED. These vegetated assemblies were also chosen for their aesthetic qualities and the spaces that were produced for the users. What must be understood though is that in contemporary times design must merge these two important concepts of performance and aesthetics, and produce qualities that perform in the site and bring out the quality of aesthetics desired in its existence. These vegetated assemblies should be integrated into the design rather than only systems added to the face of a wall or roof. This residence in Zurich, Germany has extensive roof gardens that can be read in the language of the home (figure 21).

Figure 21: A residence in Zurich, Germany with extensive roof gardens that can be read in the language of the home.

Experiencing the vegetated landscape

It would really not be as interesting, I feel, to have a collection of historical precedents without a context of why I find them interesting, how I discovered them, or what it really all means to me. Being clinically distanced from design is not helpful. I, we, engage design on a fundamental level that uses the senses, and then bring those experiences into our minds as memories to be called upon later. While the ziggurats of ancient times are an important foundation, what are the vegetated assemblies of today that I can see, touch, smell, the ones I can interact with other than through a book?

I have had the opportunity to live in and travel to Europe a number of times in my life. I was quite young when I first lived there and did not really comprehend the wonderful opportunity I was given. Then later I was able to travel with a friend throughout most of the European Union countries through a program called the Sophomore Scholarship, and then finally I had the opportunity to go back with a future professoriate group specifically to Switzerland. While I have not reflected at length about the whole series of experiences, now seems a particularly good time.

Camp Colon walking trail

My father at the time was in the military and he was stationed in Rota, Spain. While we lived there for four years (1999-2003), there is one particular memory that starts this story of my interest in building in the natural environment. In Boy Scouts there is one particular rank, Eagle Scout that requires each boy to lead and undergo a service project to the local community. There are a wide variety of projects that can be done, from fundraisers for charities, to book drives, to full scale construction projects. My project was one of these full scale projects. The troop (the whole lot of us) would

commonly camp at an on-base training area called Camp Colon named after Christopher Columbus (Cristobal Colon). This area was also commonly used for people to run as a part of physical training. I planned for the creation of a running and walking trail for the area and completed the first 500 yards of the project. Originally it was going to be a couple of miles long, but with material reallocation for the Second Gulf War I was fortunate to have any supplies from the public works department. The trail was simple: rebar would hold railroad ties in place as the edging for a gravel trail.

This was my first attempt to create a way to share nature with others. As part of the project I gained permission from the Spanish Military to make a jogging/hiking/walking trail to use during their leisure time. The trail was created not only for individuals associated with the military as it was on the Rota Spain Naval Base where I lived at the time, but also civilians. Before the reconstruction, the main feature of the raked trail was the worn-out culvert over a drainage ditch. My plan was to line the sides of the trail with timber and the fill in the middle with crushed rock.

The supplies for the project were graciously provided by the Public Works Department. The plan originally called for two miles of trail; however when the time came to create the trail the supplies were needed to further actual military applications. Therefore, the actual distance covered by the trail was approximately 500 yards. The trail would not have been a success without the help of others. My troop and the Seabees that came to help will never know what a difference they made in my life. Sometimes an action as simple as this service project can impact the lives of many people.

These are the before-and-after-images (figure 22). To the left is the example part of the trail finished with the gravel and railroad ties in place. To the bottom left is the final trail and new culvert, replacing the existing plywood bridge with a larger diameter pipe. I am in the picture for scale. I now understand that this was a really ambitious project for a 13-year-old and I was incredibly lucky. Was it fate or simple blind luck that got the project done, I will never really know. Somehow an entire battalion of SeaBees, (Navy combat engineers) got wind of the project and the free food and descended on the worksite. I got to ride a bobcat front- loader (a particular kind of small construction dirt mover) and tell them where I wanted to have the trail. Sledgehammers drove the rebar and the bobcat dumped gravel into the trail. One SeaBee and I cut the first mile of trail through the sand in about an hour. They had the tools, skills, and know-how to get the job done right and fast. A project that would have taken us multiple weekends was finished in about 8 hours.

Figure 22: The Camp Colon walking trail. This showed me that construction was fun and exciting, and could be a lifetime of enjoyment. I honestly believe this is what started my interest in combining the built environment with the natural landscape.

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Enlivenment in Designing a Living Wall: Reconciliation Ecology

Enlivenment and humanity are not mutually exclusive. This method of interacting with and respecting the environment, beyond Reservation Ecology and Reservation Ecology, is termed Reconciliation Ecology. Reservation ecology serves to save untouched ecosystems. Restoration ecology attempts to revert partially used ecosystems to natural settings. Rosenzwieg believes that these first two have reached their full potential and humanity needs to utilize the dormant form of interacting with the environment: reconciliation ecology (Rosenzweig, 2003). Restoration is looking to resurrect the past, reservation looks to adjusting the present, and reconciliation ecology looks to the future for potential. Re-enlivenment and living walls are rooted in the contextual past, existing currently in the present and have potential in the future. Re-enlivenment is a continuum that includes facets of restoration, reservation and reconciliation ecology. If these walls can create a sense of place and stewardship, they can rebuild the connection humanity has with nature.

This shows that re-enlivenment is a contextual, human condition that can mold the future. It not only suggests the return of life to the built environment, but to provide for life and nature in the future. Re-enlivenment is an extension of humanity to interface with its own inward nature and the surrounding environment, connecting itself with a natural context. Living walls within a community can show a visual link humanity has with nature. This visibility is informative, interactive, inspirational, and can transform the understanding humanity has for nature. This change is not rapid, but slow and meandering. The same patience in waiting for plants to grow exposes the resilient qualities of nature and shows the impact re-enlivenment can have on humanity in the

future. Specifically, living walls can reduce the perceived loss of nature, especially in the dense built environment. The story of living walls in relation to enlivenment hinges on not only facilitating nature, but adapting it for future potential.

After rediscovering these memories, I now understand that the line of inquiry and the method I have been suggesting for finding and combining passions and design for scholarly inquiry has a basis. I had not explicitly told myself of these ideas but remarkably over the years these positions I have of architecture are consistent. From this I have the opportunity to combine the quantified aspects of plants and vegetated assemblies with this idea of reconciliation and atmosphere and memory.

Part 2: Forming a Framework: Plant Characteristics to Consider

The qualitative experience of a vegetated assembly should be balanced with its quantitative performance. The data analysis portion of the framework needs some sort of grounding and development of the process by which information can be gathered, reviewed, analyzed, and then used in a design. Even knowing where to begin is very difficult and if someone does not have a series of mentors, it very quickly can become overwhelming and disorienting. Thankfully, I have been given many different mentors who have helped me find a place to begin.

In a vegetated assembly the vegetation and plant selection is one of the most important things to consider both for aesthetic and performance reasons. According to Edmund and Lucie Snodgrass, authors of *Green Roof Plants*, the initial considerations for plants include: the design intent, client's needs, expected outcomes, budget and maintenance parameters, life expectancy of the green roof, access and safety issues,

location, micro and macro-environments, exposure, humidity or dryness, temperatures, medium weight, depth, composition and irrigation (Snodgrass & Snodgrass, 2006). While these considerations are specifically listed for green roofs, these considerations are also necessary for vertical green walls and green facades. Plants that are taken out of a completely natural environment and placed on the façade must be tougher and less nutrient dependent. The new planting medium that is created must have a specific organic content, pH and nutrient levels, weight, porosity, and water retention capability that suit the conditions above. Both roof and wall medium must be lighter, more porous, and less rich in organic matter (Snodgrass & Snodgrass, 2006).

The surrounding environment and geography certainly play a role in the development and success of a vegetated assembly. The heat and hardiness zones that the site is located in combined with the reasoning that site-specific temperatures are more localized than the temperatures on high-low temperature hardiness maps and do not account for micro-climates, is a driving factor for development (Snodgrass & Snodgrass, 2006; White, 2005). The climatic conditions including sunlight, wind, shade, and temperature fluctuations are critical to consider. Sun, heat, and wind are more damaging to an exposed plant on the envelope of a building and mounting plants will stress the plants. Therefore, plants selected are commonly heat, cold, sun, wind, drought, salt, insect, and disease tolerant, requiring minimal nutrients and maintenance (Snodgrass & Snodgrass, 2006).

If plants are selected that are not suitable for inclusion in a vegetated assembly, the necessary fertilizers or other additives can be harmful to the local environment. For example, if a plant is nutrient dependent, local riparian zone pollution can occur due to

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fertilizers that are washed out of the assembly and into stormwater (White, 2005).

Furthermore, depending on the location, irrigation systems or watering may be needed

(Kolb, 1995; Snodgrass & Snodgrass, 2006). The vegetated assemblies need to be

considered at multiple scales in order to be successfully implemented in design and

construction. There are many different types of environments in which plants thrive.

These environments can include: mountains, high-latitude, coasts, limestone vegetation,

Sclerophyllous woody vegetation, and semi-desert (Dunnett & Kingsbury, 2004).

Southwest Virginia is a mountain climate, though not as extreme as others. The

more extreme alpine plants can be found in meadows above the tree line with shallow

soils, scree slopes of greater of lesser stability, and rock faces. Depending on the

direction of the slope face, plants can also be subjected to harsh sunlight or very little

sunlight (Dunnett & Kingsbury, 2004). The Appalachian Mountains are a mountain

environment and this should be reflected when selecting plants for use in design

applications.

These vegetated assemblies are living systems and certain issues can arise from

plant selection, invasiveness and maintenance. Globalization and bioengineering also can

contribute to the changes set forth in incorrect plant selection. The use of native and local

species in this study is supported by the literature as a means to curb the influence of

invasive species. There are a variety of things to consider including: invasive root

systems, using a trial period to verify a new species, self-sowing or short lifecycle plants,

berries or wind-blown seeds, large quantities of seeding, climbing type, and climate

characteristics. Finally, maintenance such as feeding, plant protection, unclogging of

drainage, and weeding also influence the success of a vegetated assembly (Dunnett &

Kingsbury, 2004).

From these sources we can begin to find a series of characteristics that are

necessary to the development and maintenance of a successful vegetated assembly

system. These characteristics and associated design concerns can be found in Table 2.

Table 2: Summary List of Characteristics for selecting plants

	Project Level	Individual Plant Level
Initial Design Concerns	1: design intent 2: client's needs, 3: expected outcomes, 4: budget 5: maintenance parameters, 6: life expectancy 7: access and safety issues, 8: location	1: micro and macro-environments, 2: exposure- humidity or dryness, 3: temperatures, 4: medium weight, depth 5: composition 6: irrigation
Vegetated Assemblies	The new planting medium that is created must have a specific organic content, pH and nutrient levels, weight, porosity, and water retention capability.	Plants must be tougher and less nutrient dependent
Assembly medium	The medium must be lighter, more porous, and less rich in organic matter than typical soil.	Plants must be heat, cold, sun, wind, drought, salt, insect, and disease tolerant, requiring minimal nutrients and maintenance.

Determining Plants for Southwestern Virginia in the Literature

The previous table shows us the beginning for how to select plants; however it

does not explicitly state which area of the country we are trying to design for, neither in

political demarcation or geographic location. For this reason, this study is specifically for

the climate and vegetation of southwestern Virginia. Natural plant communities will be used as a guide for the vegetated assemblies to be designed later in the study. For this study the examples will show natural regions as models for types of green roofs and walls, and then the focus will shift to southwestern Virginia in USDA Plant Hardiness zones 6a and 6b. Figure 23 shows us the United States in relatively low detail of where the USDA hardiness zones are located. To narrow down the types of plants that could be used, the plant hardiness zone for Southwestern Virginia must be determined. Looking at the USDA map of hardiness zones, southwest Virginia is mainly a mix of zone 6 and zone 7. These zones are determined by the average annual minimum temperature for an area with zone 6 at 0 to -10°F and zone 7 from 10 to 0°F. This is shown in both Plant Hardiness Zone Maps produced by the PRISM Climate Group at OSU.

This begins to help us understand an important part of any kind of decision support structure: to what level of detail will the structure be designed? It simply is not possible, nor useful to include every bit of information that is found in the literature review into the resulting framework. Designers would be overwhelmed and in the end make poorer decisions based on an overabundance of information that would conflict rather than a lack of information leading to uninformed decisions. So for the sake of everyone involved the location is limited to Southwestern Virginia for the development of the framework and the Plant Hardiness map will show Virginia as shown in figure 24. This allows for the process of the framework to be developed without overwhelming initial participants and the researcher.
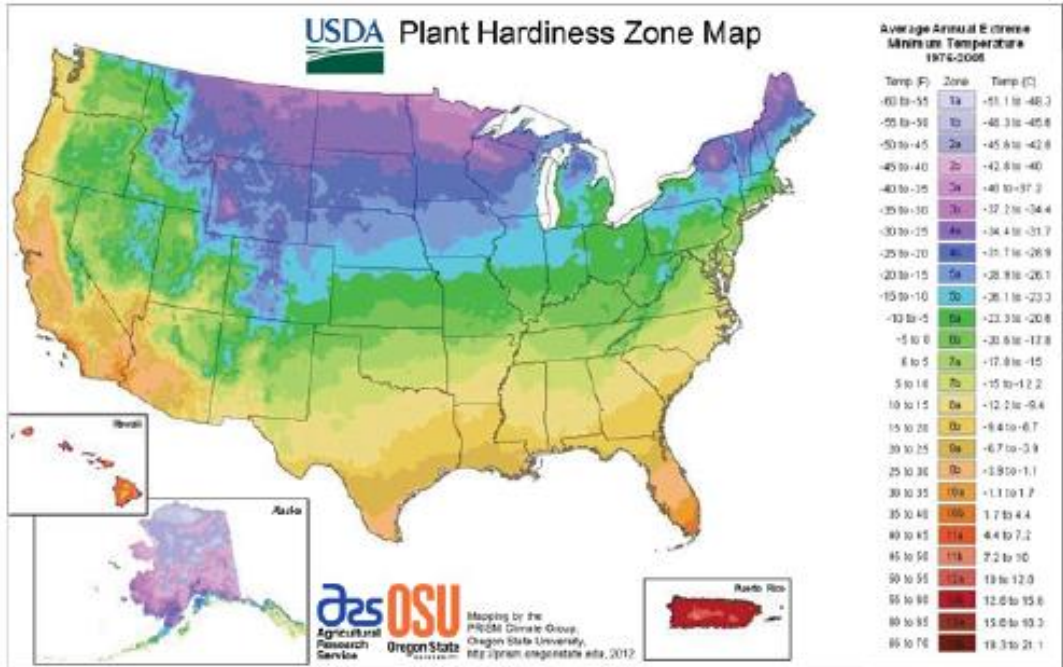
Figure 23: USDA US Hardiness Map Copyright © <2014>, PRISM Climate Group, Oregon State University, http://prism.oregonstate.edu Map created <13 Oct 2014>.
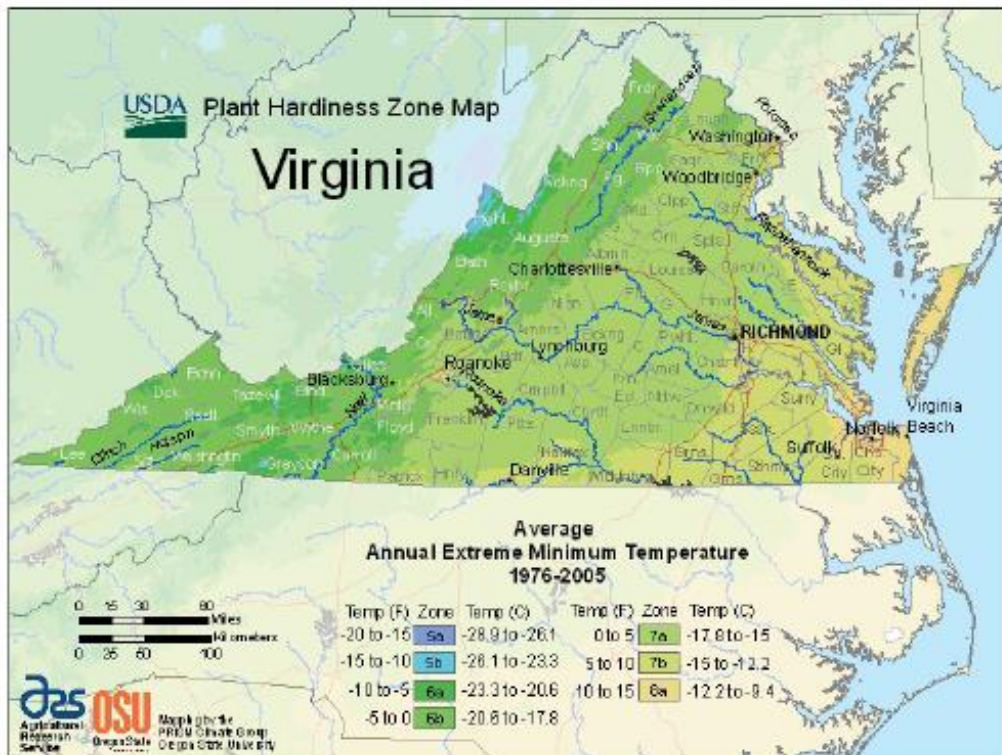
Figure 24: USDA Virginia Hardiness Map Copyright © <2014>, PRISM Climate Group, Oregon State University, http://prism.oregonstate.edu Map created <13 Oct 2014>.

In this round of plant selection the study will also look at plants that can survive harsher conditions, such as zones 2 through 5, and are perennials as well. Using a plant directory from Dunnett and Kingsbury, cross listing for plant origin or invasiveness (also in figure 25 and Table 3), starts with: Ampelopsis cordata native to southeastern US (zone 6-8), Aristolochia macrophylla native to the eastern US (zone 4-7), Celastrus scandens native to eastern North America (zone 2), Cocculus carolinus native to the southeastern US (zone 6-9), Parthenocissus quinquefolia native to eastern North America (zone 3), and Vitis aestivalis native to eastern North America (zone 3-9). This list of plants does not include some of the more commonly used plants in vegetated façades, such as Wisteria sinensis from eastern Asia (zone 4-9).

Table 3: List of possible plants form the literature.

Common Name	Heartleaf Peppervine	Pipevine	American Bittersweet	Carolina Coralbead	Virginia Creeper	Summer Grape
Scientific Name	Ampelopsis cordata	Aristolochia macrophylla	Celastrus scandens	Cocculus carolinus	Parthenocissus quinquefolia	Vitis aestivalis
Hardiness Zone	4	7	2	6	3	3
Range	S. Eastern US	Eastern US	Eastern N. America	S. Eastern US	Eastern N. America	Eastern N. America
Growth Rate	Moderate	Fast	Fast	Fast	Fast	Fast
Climbing Style	Vine-tendril	Vine-twining	Vine-twining	Vine-twining	Vine-tendril	Vine-twining

This is the process of selecting plants based on the geographic region of interest. However this disregards the types of plants that are commonly cultivated in the region and would most likely be available for purchase and then use in the resulting designs of the framework. Having a location not only shows what types of plants would potentially survive, but also what plants are grown in nearby nurseries. Figure 25, of the possible plant species follows, compared to Table 3 of the short list of possible plants generated by looking at the literature.

PLANTS ADAPTABLE TO VEGETATED WALL OR FACADE········· ·········IMPLEMENTATION ISSUES FOR SOUTHWESTERN VIRGINIA

ACTINIDIA ARGUTA
ACTINIDIA DELICIOSA
ACTINIDIA KOLOMIKTA
AKEBIA QUINATA
AMPELOPSIS BREVIPEDUNCULATA
AMPELOPSIS CORDATA
AMPELOPSIS MEGALOPHYLLA
ARAUJIA SERCIFERA
ARISTOLOCHIA MACROPHYLLA
BIGNONIA CAPREOLATA
BOUGAINVILLEA SPECTABILIS
CAMPSIS RADICANS
CELASTRUS SCANDENS
CLEMATIS
COBAEA SCANDENS
COCCULUS CAROLINUS
DECUMARIA BARBARA
EUONYMUS FORTUNEI
FALLOPIA BALDSCHUANICA
FICUS PUMILA
HEDERA HELIX
HOLBOELLIA CORIACEA
HUMULUS LUPULUS
HYDRANGEA PETIOLARIS
IPOMOEA HEDERACEA
JASMINUM OFFICIANALE
LONICERA JAPONICA
LONICERA PERICLYMENUM'
LONICERA TRAGOPHYLLA
MENISPERMUM CANADENSE
MUEHLENBECKIA COMPLEXA
PARTHENOCISSUS QUINQUEFOLIA
PARTHENOCISSUS TRICUSPIDATA
PASSIFLORA CAERULEA
PERIPLOCA GRAECA
PLUMBAGO AURICULATA
PYROSTEGIA VENUSTA
ROSA
SCHISANDRA CHINENSIS
SCHIZOPHRAGMA HYDRANGEOIDES
SOLANUM JASMINODIES
STAUNTONIA HEXAPHYLLA
THUNBERGIA GRANDIFLORA
TRACHELOSPERMUM JASMINOIDES
TROPAEOLEUM CILIATUM
VITIS AESTIVALIS
VITIS COIGNETIAE
VITIS VINIFERA
WISTERIA SINENSIS

ORIGIN OR RANGE
HARDINESS ZONE
CLIMBING MECHANISM
RESILIENCY
WEIGHT
PROFILE

COMBINE:
PLANTS + IMPLEMENTATION ISSUES

RESULTANT LIST:
COMPATIBLE PLANTS IN SOUTHWEST VIRGINIA

HEARTLEAF PEPPERVINE (AMPELOPSIS CORDATA)
PIPEVINE (ARISTOLOCHIA MACROPHYLLA)
AMERICAN BITTERSWEET (CELASTRUS SCANDENS)
CAROLINA CORALBEAD (COCCULUS CAROLINUS)
VIRGINIA CREEPER (PARTHENOCISSUS QUINQUEFOLIA)
SUMMER GRAPE (VITIS AESTIVALIS)

EVALUATE COMPATIBLE PLANTS:
COLOR THEORY + PERCEPTION

HEARTLEAF PEPPERVINE (AMPELOPSIS CORDATA)
AMERICAN BITTERSWEET (CELASTRUS SCANDENS)
SUMMER GRAPE (VITIS AESTIVALIS)

Figure 25: List of plants based on the literature.

These lists from figure 25 and Table 3 will then be compared to local growers' lists of commercially available plants to how theory and application interact. Looking at it from the grower's perspective, we find a modest list of vining plants that would be suitable for projects in the western Appalachian climate, with zone 6a and 6b. These plants are shown from the 2013 Guide to Virginia Growers, provided by the Virginia Nursery and

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Landscape Association (VNLA). It is important to not only include plants that will work in the tool from the literature, but those that will respond to the site and bring ecology back to the site, in an effort to re-enliven the building envelope and vegetated walls. If we review the list of plants from the working list and the list from the VNLA, we actually find no plants that match both lists (figures 25 and 26).

VINES

Bignonia capreolata (Cross vine)
Knotts Creek Nursery

Campsis (trumpet creeper)
Knotts Creek Nursery

Clematis (assorted varieties of clematis)
Bennett's Creek Nursery
Saunder's Landscapes
Knotts Creek Nursery

Gelsemium (Carolina Jasmine)
Knotts Creek Nursery

Hydrangea anomala subsp. periolaris (Climbing Hydrangea)
Inglesude Plantation Nurseries
Knotts Creek Nursery
Tankard Nurseries

Lonicera (Honeysuckle)
Knotts Creek Nursery

Partneocissus tricuspidata (Boston Ivy)
Knotts Creek Nursery

Passiflora incarnata (Passion Flower Vine)
Knotts Creek Nursery

Polygonum (Silver Lace Vine)
Knotts Creek Nursery

Trachelospermum jasminoides (Confederate or Star jasmine)
Knotts Creek Nursery

Vines (assorted)
Bennett's Creek Nursery

Figure 26: List of plants offered by growers in 2013. This list a very different from plants selected for use from the literature.

How did this happen? The reason for this is actually rather simple: the initial run of the framework was too demanding and too specific. The framework for selecting the initial sort list also asked that the plants be native to the region they would be designed

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for. Many native plants in the Blue Ridge region are not common cultivars and some do not actively grow outside of the mountain region. Common cultivars are common because they are either easy to grow, are popular, or are historically grown. This idea of native versus "non-native" is rather important in terms of designing, especially for a number of environmentally-based certification systems. So what does it mean to be native?

Defining Native and Non-Native

Types of plants can be great in theory, but what is actually grown and distributed by industry growers in Virginia, that can be used in zone 6a and 6b? To view possible plants, it is important to not only understand who is providing the information, but what the desired outcome becomes. Therefore the hardiness zone maps provided by the USDA and not strictly man-made delineations of states will guide what is considered native and non-native in the study. Referring back to table 3 for example, a pipevine might be found in a native nursery, but American bittersweet is most likely not, whereas Boston Ivy is preferred over Virginia Creeper, but both are viable and colorful over the seasons. What this shows us is that we can be limiting the usefulness of the preliminary prototype framework by not gaining information from the growing industry.

To take a look at the full United States map of hardiness zones again, we find the plants native to zone 6a and 6b are much father reaching than the outline of solely "Virginia". That leads to how to define what is native vs non-native – the study will be looking at plants for the prototype tool that can grow in the climate of a Appalachian mountain climate, specifically zone 6, as natives, while those that can grow in this

climate and are not from the regions in the US, but that can grow in zone 6 are considered non-natives.

A second way to determine native plants is the type and abundance of local insect larvae that will grow on the vines. The more larvae that grow, the more birds will be attracted, weaving a web of ecology for the entire system. This concept from the work of Douglas W. Tallamy from the University of Delaware, shows another method for determining what to plant in the US mid-Atlantic region (Tallamy, 2009, 2014). A portion of an excel sheet he provides includes woody, herbaceous, and vining plants, including Virginia creeper with 32 native larvae species. The inclusion of Virginia creeper in this list leads it to be the vining plant to be used at full scale in the project.

This brings us to two main questions about the plants that would be selected for a vegetated assembly if it is not already a complete proprietary system that uses specific cultures of plants. We need to define "native" versus "non-native", "alien", or "exotic" plants for the purpose of the study. What is your personal interpretation of these using multiple stakeholders (designers versus growers versus homeowners)?; and what are the qualities of non-native plants and what are the implications? There are many different methods to defining native plants. From research, there appears to be three main sets of stakeholders that define native plants including: government or law, scientific, and organizational. These definitions blend together and can appear similar; however the interpretation of these statutes, laws, or management guidelines can produce very different practices.

The first definition is from The Federal Native Plant Conservation Memorandum of Understanding (MOU) from 1994. This definition was used in order to carefully

manage the plant species that occur in the United States. The definition for a native plants

is one: "that occurs naturally in a particular region, state, ecosystem, and habitat without

direct or indirect human actions" ((FNPCC), 1994). This definition touches on many

important concepts related to differentiating natives from non-natives. Natives have

evolved with competing species, pests, diseases, and predators to achieve an ecological

balance, whereas non-natives have not and can often run rampant in new areas without

competition or limits (Harper-Lore, Wilson, & United States. Office of Natural

Environment. Water and Ecosystems Team., 2000). The definition provided by the MOU

also has language that is necessary to explain further as these concepts will guide

understanding of other similar definitions.

These topics include: naturally occurring, area of interest, native to nation, native

to state, native to region, native to ecosystem or habitat, and direct and indirect human

actions. Plants found in a place are considered to be native or naturally occurring, if they

occur historically there. The area of interest is where the plant is classified as native. A

plant can be classified as native to a nation if it occurred once in the nation. A plant can

be native to a state, but not all parts of a state and within that state there may be different

regions that a plant is native to. Then, within the state and region, there could be a

particular ecosystem that a plant is native to, and not native to other different ecosystems.

Finally, plants can be introduced to new areas either directly or indirectly. It is important

to understand that this occurs on a regular basis due to a more global economy, but that

introduced plants by humans do not become native over time (Harper-Lore et al., 2000).

There is not only one federal definition to a native plant. First is Executive Order

11987: "'Native species' means all species of plants and animals naturally occurring,

either presently or historically, in any ecosystem of the United States." (Executive Order 11987--Exotic organisms, 1977). This definition is very broad, as it must be for an entire nation. The explanation of the definition from The Federal Native Plant Conservation Memorandum of Understanding is more descriptive as it provides a more specific basis for defining native plants, where the executive order is legislation that the MOU might be founded upon. Second is a definition related to a specific organization, the National Park Service. "Native species are defined as all species that have occurred or now occur as a result of natural processes on lands designated as units of the national park system. Native species in a place are evolving in concert with each other." ((NPS), 2001).

This definition is limiting the discussion of native plant to a political boundary or jurisdiction as with the executive order to mean the United States, rather than also including possible geographic boundaries as in the MOU definition. The third definition is from a management perspective for a smaller biological region or ecosystem, the U.S. Fish and Wildlife Service: "Native. With respect to a particular ecosystem, a species that, other than as a result of an introduction, historically occurred or currently occurs in that ecosystem." ((USFWS), 2001). The final definition is from the Virginia Department of Conservation and Recreation: Native species are those that occur in the region in which they evolved ((VDCR), 2013). All of these definitions serve a purpose and reflect the group or institution that wrote them, giving each a specific context.

The scientific definition of a native species will allow for its comparison directly to an alien, or exotic species, and is not limited to plants. A native species is: "A species, sub-species, or lower taxon living within its natural range (past or present), including the area in which it can reach and occupy using its own legs, wings, wind/water-borne or

other dispersal systems, even if it is seldom found there." A non-native or alien or exotic species is: "a species, subspecies, or lower taxon introduced outside of its normal past or present distribution; includes any part, gametes, seeds, eggs, or propagules of such species that might survive and reproduce." (McNeeley, 2001). These two definitions from McNeeley show the attitude that exotic species are often seen as undesirable and that native species are more desirable. Executive order 11987 also addresses exotic species stating: "'Exotic species' means all species of plants and animals not naturally occurring, either presently or historically, in any ecosystem of the United States." (Executive Order 11987--Exotic organisms, 1977). The difference between these two shows in that the scientific definition has no reference to political boundaries, and focuses on the species itself.

This scientific focus on species as a reference is what will be used for defining native and non-native plants for the purpose of the study. This definition was chosen on the basis that is does not consider political boundaries, but instead references the native range of a particular species. The spread of nonnative species does not stop at a state or national border. Therefore the framework will consider not only native but also non-native plants. The reason for including nonnative plants in the list of potential plants for the framework comes from three main issues. First, native plants are often sold in a specific region, while non-native plants are more widespread. Further iterations of the framework would be for other regions, but at this time the framework will focus on plants native to the area and nonnative cultivars. Second, the economics involved in growing natives is more expensive than and not as established as currently grown cultivars, thus not as widely available. Finally, the industry has a wide variety of definitions for native

plants and the regulation that surrounds them, making it difficult to truly know what

constitutes a native plant (Norcini, 2007). Therefore the framework will be limited to

native plants and nonnative cultivars available in the area of southwestern Virginia.

This list of available vines from the Virginia Nursery & Landscape Association

(figure 26) for the framework includes the common cultivars available in the region from

growers. By using non-native plants in the framework, the framework now needs to

consider the invasive impact of these plants, depending on the plant's native region and

the location of the project. If a plant is non-native, the severity of the plant's invasive

nature will need to be explained and reported to the user as well. Many ornamental plants

are in fact nonnative and a massive industry has been built to import, propagate, sell and

plant these nonnative plants. Due to the debate between stakeholders that occurs when

trying to understand what constitutes a native plant, there is often conflict. Without a

clear sense of direction, this often leads to confusion in the main populace not involved

with horticulture research (Niemiera & Von Holle, 2009).

Plant invasion has happened since antiquity, and present anthropogenic factors

have increased the rate of invasion of plants into other areas (Drake, 2005), resulting in

their introduction to new areas and may go unseen until sought (Niemiera & Von Holle,

2009). This process of moving plants between or within countries results in the

introduction of a species (McNeeley, 2001). The time to naturalization of a species is

termed "lag time", and depending on the plant and conditions it may take anywhere from

a few years to a century to become naturalized (Kowarik, 1995; Riechard SH, 2001). "A

naturalized species is an alien species that reproduces consistently and sustains

populations over one life cycle […] and do not necessarily invade natural, semi-natural,

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or human-made ecosystems" (McNeeley, 2001). Another definition of naturalization comes from Radosevich et al. (2003) in Niemiera & Von Holle, (2009), when a naturalized species survives, becomes self-sustaining and is merged into the local ecosystem.

Within this concept of naturalization lies an important distinction. Richardson et al. (2000) describes three stages that a plant goes through: when it is first introduced (transported by humans across a major geographical barrier), then is naturalized (overcoming abiotic and biotic barriers to survival and regular reproduction) and then becomes invasive by moving to a site distant from the first induction. Other researchers describe that when a plant is invasive, there are three stages of invasion: widespread but rare (IVa), localized but dominant (IVb) and widespread and dominant (V) (Colautti & MacIsaac, 2004). These concepts are important for the framework, as a plant that is selected for a particular project can be nonnative, but if the plant is a known invasive, or has the high potential to become invasive, such plants will not be selected for use, and made known to the users of the framework.

If the framework is going to restrict the use of invasive plants, how do we know that such plants will harm the environment and to what predictable extent? In Niemiera & Von Holle, (2009), there is an argument made that current methods for cataloguing and providing databases for "invasive" plants are not consistent (Fox & Gordon, 2004), and that the level of invasiveness for species can range from innocuous to environmentally disruptive (Fox, Gordon, & al., 2003). In the end there is no real way to determine exactly what will happen, except that invasive plants should be monitored and controlled based on species and region conditions. This listing should: have a robust, scientific

basis, only list species already in the area, and be flexible enough to be useful to the purpose of the list (e.g.: regulation or advisory) (Niemiera & Von Holle, 2009). Since the framework is more of an advisory method, allowing designers to make a final choice on plant selection, the potentially invasive plants will be flagged, along with characteristics described in the context of the site and species.

Then, how do we predict that a plant will be invasive in order to flag a species in the framework? There are three main methods that will be used to determine if a plant is potentially invasive for the purposes of the framework. The first is to check the plant against the current Invasive Species Assessment Protocol for ecological impact, current distribution and abundance, trend in distribution and abundance, and management difficulty: http://www.natureserve.org/library/invasiveSpeciesAssessmentProtocol.pdf. The second is to check specifically for Virginia using a list from (Wilson & Tuberville, 2003) in appendix H of (http://www.dcr.virginia.gov/natural_heritage/documents/NHPc_Web.pdf). The third is to check the plant against the invasive list found here: http://www.se-eppc.org/weeds.cfm, taken from this larger list here: http://www.invasive.org/south/seweeds.cfm. At first this search will be done manually by the user in the framework, but in future iterations that would include a prototype tool, the list would be internal to the tool.

The implications of these different categories of native and more specifically non-native plants should be important not only to horticulturalists, but also designers. Designers should be aware of the impacts their designs make and how these can impact the local ecology and ecosystems. If designers choose plants that are known to be highly

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invasive and destructive to the site's local ecosystem, then we are not being adequate stewards of the place in which we design. The detriment is not only to the ecosystem itself, which we should strive to protect, but also has considerable costs in litigation, pest management, and loss of future contracts via tarnished reputation. If we choose to use nonnative plants, we must critically review these plants so that they are not environmentally destructive if implemented in design. It is important to remember that invasive plant species are not all equal, and perhaps not all invasives are undesirable, but that nonnative plants, especially cultivars for selection with the future framework, must be chosen responsibly.

Short List Characteristics

After creating a short list of applicable plants for the study, the plants must be reviewed in depth to understand how their characteristics and growing methods could cause them to interact with each other. This interaction can be both positive and negative. For example, the colors could not be compatible, or one plant could dominate the other over time, causing one plant to die out of the system. The characteristics listed here are a combination of physical observations and characteristics reviewed by the Natural Resources Conservation Service (NRCS), a part of the US Department of Agriculture.

The database that is maintained by the NRCS uses a set of characteristics that helps to design resource conservation plantings, and includes growth form and growth requirements for suitability for uses. Some of the characteristics used for reviewing the morphology and physiology of the plants include: the active growth period, dormancy period, fall conspicuous, flower color, flower conspicuous, foliage color, foliage porosity summer, foliage porosity winter, foliage texture, fruit/seed color, fruit/seed conspicuous,

growth form, growth rate, height, leaf retention, lifespan, shape and orientation, and

toxicity. The next set of characteristics from NRCS concerns growth requirements. These

include adaptability to soil types, drought tolerance, fertility requirements, frost free days,

hedge tolerance, maximum and minimum soil pH, planting density, precipitation, shade

tolerance, and minimum temperature. In order to be self-sustaining, a plant must have the

ability to grow and reproduce. These characteristics include the bloom period,

commercial availability, fruit/seed abundance, and periods, method of propagation,

seedling vigor and vegetative spread rate (USDA, 2014). The ability of the plant to be

used for commercial product will also be considered, but is not a part of the study or if

plants are useful in vegetated assemblies. Each plant will be considered for many of the

characteristics to determine if the plant will be useful in a vegetated assembly and if its

use will not negatively impact other plants. Table 4, serves as a combination of the

literature on vegetated assemblies from Table 3 and summarizes necessary characteristics

for self-sustaining plants and their identification.

Table 4: Combined lists of plant biology for use in the vegetated assembly framework.

	Project Level	Individual Plant Level
Initial Design Concerns	1: design intent 2: client's needs, 3: expected outcomes, 4: budget 5: maintenance parameters, 6: life expectancy 7: access and safety issues, 8: location	1: micro and macro-environments, 2: exposure- humidity or dryness, 3: temperatures, 4: medium weight, depth 5: composition 6: irrigation
Vegetated Assemblies	The new planting medium that is created must have a specific organic content, pH and nutrient levels, weight, porosity, and water retention capability.	Plants must be tougher and less nutrient dependent
Assembly medium	The medium must be lighter, more porous, and less rich in organic matter than typical soil.	Plants must be heat, cold, sun, wind, drought, salt, insect, and disease tolerant, requiring minimal nutrients and maintenance.
Plant Characteristics *Framework on plant biology or color theory*	1: texture, foliage size, color, shape 2: dormant season appearance 3: flower and fruit [conspicuous or inconspicuous, size, color; month(s) of appearance] 4: bloom period 5: commercial availability 6: fruit/seed abundance, and periods 7: method of propagation, seedling vigor and vegetative spread rate	1: the active growth period, 2: dormancy period, 3: flower color, 4: flower conspicuous, 5: foliage color, porosity in summer/ winter, texture 6: fruit/seed color, shape 7: growth form, rate, height 8: leaf retention, lifespan, shape and orientation, toxicity

The characteristics that will be used for reviewing the morphology and
physiology of the plants for the purpose of color theory in the study include: texture (fine,
medium, bold – may be one texture during growing season and another in winter), foliage
size, color, shape, and dormant season appearance, and flower and fruit [conspicuous or
inconspicuous, size, color; month(s) of appearance]. Most of these characteristics can be

found in the NRCS plants database. In regards to color documentation for color theory applications, the Royal Horticulture Chart will be used as the standard reference for plant color identification. This same color chart is used with food colorings, chemical engineering companies and fabric designers.

The characteristics of the plants will inform the design of vegetated walls and how the plants are introduced to surfaces and what materials are used. When reviewing local flora for use in the framework, we must understand that as designers we are attempting to reconcile two very different things. We are attempting to rationalize the natural beauty that nature provides through evolution, and model it in an imperfect binary computerized world, foreign to its existence. These plants and vegetated assemblies can be mimicked in computer simulations, but not replicated no matter how precise the model. No matter how much a designer can attempt to control for, nature will chart its own course and make every living thing unique by its own mechanisms.

Part 3: Types of Vegetated walls and Examples

We have defined what sorts of considerations we want to have for the framework, but there are still some limitations. First, I will need to heavily rely on horticulturalists and industry growers to truly design a space with vegetation that will meet the expectations of the potential clients. Second, what sorts of options are available for vegetated assembly design types? Third, I must base my design decision in what I have experienced in conjunction with lists of facts and figures about plants.

Ecotechnology and biotechnics are used in the design and construction of vegetated assemblies and living walls. Vegetated walls often are the literal application of

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plant organisms to the building wall structure. The first type of vegetated wall uses a growing medium at the base of the wall and climbers with self-clinging mechanisms to cover the surface of the wall. The other type of living wall directly covers the surface of walls with vegetation but is rooted in a separate artificial medium attached to the wall.

In the first type of vegetated walls there are many methods of wall plantings, for example: dry stone walls, stacked construction and modular walls, gabion walls, or mortared walls. Dry stacked walls are where plants have begun to grow in open spaces between the stones in pockets of soil. Modular walls are made of repeating and replaceable units that are assembled to form a wall surface and plants grow in a more regular fashion. Gabion walls are wire baskets filled with rocks. The wall is supported by the baskets, not the rocks and often there are too large of gaps and air spaces for plants to grow effectively without assistance. Commonly the spaces are filled with medium, typically on top for growth (Dunnett & Kingsbury, 2004). These walls are actually quite common and are often overlooked as areas for design potential. There is an abundance of biodiversity even within the smallest of spaces.

The second type of vegetated wall requires use of a medium on the outward facade of the wall. There are two types of such walls: hydroponic systems and living fences (Dunnett & Kingsbury, 2004). Hydroponic systems are blankets that require a considerable amount of watering due to relatively little medium, but are much lighter. The plants root into the felt/ synthetic cloth layer instead of dirt or engineered soils. The other style is living fences. These are self-contained living walls constructed with lightweight media and geotextiles within a framework of wood or metal (Dunnett &

Kingsbury, 2004). The living fence is the vertical application and treated almost as screens for plantings and as temporary structures.

These controlled and adapted vegetated walls have impacts on the built environment not only in terms of performance, but also in a difference of aesthetic. Typically, very few species of plants are directly planted onto walls due to their potentially destructive nature on poorly maintained walls, both superficially and structurally. For this reason plants are typically used on non-structural walls. These vegetated walls and façades change during the seasons. Traditional styles of climbers in Europe were self-clinging and applied directly on the façade. The tendrils of the climbers often attached to the weaker points of the façade, such as grout in brick walls and deteriorated it over time. In order to ensure the stability of the façades, the modern style of vegetated walls and façades uses separate structures such as cables or trellises, and a variety of plant species (Dunnett & Kingsbury, 2004). It is also noteworthy that living walls can be applied to interior spaces as well as exterior walls. If plants are commonly labeled as destructive to walls, it is often due to the fact that the walls were poorly maintained, or had compounding issues such as moisture or fungal growth. Thus, vegetated walls need to be maintained and designed for materials and their interactions.

Benefits of Vegetated Façades

These vegetated walls and façades change during the seasons. There is potential aesthetically for vegetated walls and façades as walls typically are more visible in the built environment than roofs. According to the work of Jeffery Price at the University of Maryland, the qualitative and quantitative effects of vegetated assemblies have produced

positive results, such as reducing solar gains and air pollution, mitigating stormwater runoff, and improving quality of life (Price, 2010).

A study by Manfred Köhler, showed the potential of vegetated roofs to maintain some types of human planted species, but also a much larger set of volunteer species that rooted into the systems. A set of 90, 1.2 meter square containers, utilized one soil mixture and maintained 7 of 22 planted species, but allowed 24 other natural species (Rosenzweig, 2003). If this sort of activity is happening on the vegetated roofs of buildings, could it not also be used in the walls as well? These walls serve as a scaffold for chosen plants to grow but also species from the built environment that come to thrive with our own. The mix of human and natural systems forms the success of reconciliation ecology and living walls.

According to the work of Jeffery Price at the University of Maryland, there are numerous benefits produced by living walls: they reduce solar gains and building temperatures; they absorb air pollution, mitigate storm water runoff, and improve quality of life (Price, 2010). In regards to the reduction of solar gains, climbers can reduce the temperature of the building envelope more effectively by shading large areas of the façade (Köhler, 1993). Laura Schumann, from the University of Maryland, developed a retrofit shading system called the 'Green Cloaks' in which un-conditioned structures were reduced (2007). The cooling of the façade is further supported by the work of Millward in 2014, stating that vegetation can reduce the solar gains of buildings, depending on the leaf area, plant size and proximity to the building, and plant location based on the solar path (Millward, Torchia, Laursen, & Rothman, 2014). Work by Steven Sandifer at UCLA found a series of positive results to lowering the temperature of the

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façade to almost that of the ambient temperature at 12-14 inches thick, eliminating the effect of color, that vines on western facades can reduce the problem of western heat gain, and spaces such as vine-covered pergolas can provide more comfortable exterior conditions (Sandifer & Givoni, 2001).

Vegetated facades also are a benefit in the winter by reducing heating demands from wind chill. The ability for vegetated walls and façades to shade the building envelope can reduce the urban heat island effect (Akbari, Pomerantz, & Taka, 2001). Vegetated walls can cool the building envelope by converting sensible heat to latent heat when released by evapotranspiration performed by the plants during photosynthesis. Price maintains that the benefits are not limited to heat flows between the building and the surrounding environment. These assemblies can trap dust and pollutants into plant material. For example heavy metals can be taken out of rain and stored in dead tissues. The ability to trap contaminants is greater with larger leaf areas (Köhler, 1993). This reduction is most evident near ground level, where particulates are deposited and retained in plant tissues (Thoennessen, 2002).

Vegetated facades can reduce damage from driving rain and hail and shade susceptible materials from ultra-violet light (Dunnett & Kingsbury, 2004). Furthermore, experiments and computer modeling have shown the capacity for vegetated roofs and walls to retain storm water (Grant, Black, & Jones, 2014; Roehr, Laurenz, & Kong, 2008; Schumann, 2007; VanWoert et al., 2005). These vegetated walls also slow runoff from urban environments (Tilley & Schumann, 2008). The vegetated materials can also begin to create new habitats for animals and insects. Climbers can be a benefit to wildlife, for example, birds and bats which prey on insects that live among the plants (Dunnett &

Kingsbury, 2004; Lundholm, 2006). While vegetated walls can bring wildlife back to

harsh urban conditions, they can also help the quality of life for residents. For example:

the view through a window of a natural scene positively influenced recovery from

surgery (Ulrich, 1984). Living walls bring nature back into the urban landscape

producing an aesthetically pleasing and visually interesting living membrane to the urban

built environment.

Types of Walls and Attachment Mechanisms

From all of these benefits that vegetated walls can provide, how do they interact

with a wall and its materials? It is a balance of these benefits of reducing temperatures

and providing habitat for animals against that of the integrity of the building envelope

that creates either a great success or a dramatic failure. The type of vine is either self-

adhesive or matrix-dependent and determines what the types are useful for, or if the vine

is safe for different materials. The most critical aspect of any of the types of plants is that

annual maintenance be performed to remove vines from undesirable locations on the

structure.

Plants that are on a separate matrix from the building structure are typically

vining or twining vines and are not detrimental to the façade. The self-adhesive vines

need more scrutiny. There are two different types of adhesive mechanisms: some cling to

the surface with holdfasts while others are much more aggressive with rootlet systems.

Both types of mechanisms cling directly on to the wall without a separate structure

(Niemiera, 2014). With self-adhering vines, two material groups are made: masonry and

everything else. Masonry is excellent for self-adhering vines, although rootlet systems

will get into cracks from disrepair and can destabilize mortar over time. Holdfasts are a safer form of the clinging vines. Both types are a permanent vegetated screen on the building. "Everything else" includes facades such as stucco, wood and shingles. Climbers on these surfaces can retain moisture and cause rot. If the building surface is not made of masonry, it is recommended to use a matrix that the vines can grow on separate from the building itself (Niemiera, 2014). The work of Josh Stoneman makes a few suggestions on vines for direct use on buildings as compared to using a separate matrix. He looks at English Ivy (Hedera helix), Boston Ivy (Parthenocissus tricuspidata), Virginia Creeper (Parthenocissus quinquefolia), Trumpet Creeper (Campsis radicans), and Creeping Fig (ficus pumila).

English Ivy as seen in figure 27-28, is an invasive species and can smother other species, thus it is not recommended due to its ecological impact and its very aggressive rootlet system. Boston Ivy is native to East Asia, but does not grow over other species and is not classified as invasive, thus it is a good choice for direct application on buildings since it uses the holdfasts and not rootlets. Virginia Creeper (Parthenocissus quinquefolia), is a close relative of Boston Ivy, native of the Eastern US. It uses holdfasts as well and it good for direct applications with annual maintenance like Boston Ivy. Trumpet Creeper is very aggressive with adhesive stems, thus it is good for matrices separate from the building. The Creeping Fig is not suitable for a Zone 6a, 6b climate, but is a good choice for direct applications if kept away from paint and wood (Niemiera, 2014). From this list and the list from the Virginia Nursery and Landscape Association, a number of vines will be picked and matched for use in the framework, as some of the vines overlap on the two lists and should be considered highly useful for inclusion.

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Table 27: An example of Boston Ivy and its different colorations. Image provided by Alex Niemiera.

Figure 28: English Ivy flowing over the top of a retaining wall along a road in Switzerland.

Seeing is Believing: Europe Travel Exploration and Recordings

Travel 2015: Switzerland

In 2015 I had the opportunity to go back to Switzerland. The Preparing the Future Professoriate Program went to a number of cities including Zurich, Basel, Bellinzona, and Riva San Vitale to study different higher education programs; I also was studying vegetated assemblies in the cities we went to visit.

In Zurich it was common to see vines growing over balconies and carports. When the vines were over balconies it was obvious that they were manicured and grew from hanging pots and railings (such as figure 29 of a balcony in Zurich near downtown). This limited amount of growing medium keeps the plants manageable and picturesque. These systems are additive and not integrated into the building envelope. In a few instances vines completely took over a structure such as bridge. This vine was very robust and the main vine was a thick as a small tree and grew out of the ground, but attached directly to the load-bearing masonry. The masonry was well taken care of even though the vine had completely blanketed the surface. Finally there were some structures where the vegetated system was integrated into the building. There were facilities for an adjacent park and the vegetation softened the concrete building. These turned out to follow three main types of vegetated assemblies: simpler where plants attached directly to the surface, intermediate where plants were part of a matrix system, and complex where plants were integrated into the building envelope.

Much of the travels focused on Swiss higher education campuses. In Zurich we visited three separate campuses, first Zentrum, then Irchel and ETH's Architecture building. It could be a product of the trip and traveling, but many of the more robust

vegetated assemblies were often in more public places. This could also be due to the fact that such systems are expensive and need consistent maintenance. Many of the systems used either some species of Ivy or a variety of honeysuckle. This is rather interesting since those are two species that were listed as a part of the species available from Virginia nurseries. These two species consistently provided good cover and added depth to the building surfaces. They often appeared to be finite areas of nature, reminding people of their connection to nature while in a large city.

Figure 29: Vines and flowers over the edge of a balcony in Zurich, Switzerland. These were common and have the least amount of growing medium, but were highly manicured.

One version of vegetated assemblies that appeared at the Irchel campus was the concept of vine tracery. Tracery is when the vine dies back for the winter, or during unfavorable conditions and leaves a series of main vines without leaves. This tracery forms lines on the building envelope. This is an opportunity of design as well, given that vines could be trained to specific locations with enough maintenance and effort.

Basel had vegetated assemblies either as decorative, or performative, and in either function, provided a break in the urban landscape. Blacksburg does not have this critical mass of humanity, however the idea of taking vegetation and giving a place a more calm and serene sense of place based on the ability of the site to hold a type of vegetated assembly is interesting as a concept for use in the framework.

We took the train between major destinations, something that I am immensely grateful for. In transit between Basel and Riva, a section of highway across the river was covered by a massive vegetated roof (figure 29b). This is only a portion of that structure which covered four lanes of highway traffic. The scale of this project was amazing. Most of the other projects so far had been small and contained to a single wall or structure, yet here it was blended into the landscape and the local environment rather than added to the facade of a building.

This shows the symbiotic nature of the building and the landscape. The project not only responds to the site and the unique need to hide a rather disruptive highway from damaging a beautiful view, but also contributes to the area. While it is difficult to see, there is an entire herd of sheep grazing on the structure (more to the left) and a waterfall on the right. The project could have very easily hidden the waterfall, but instead it was on display. Though it is only conjecture and economically far-fetched, having the project

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play some role in the local economy by providing grazing land for livestock is a very interesting idea.

Figure 29b: A covered highway seen from the train while in Switzerland. The scale of the project was enormous, and must have been quite costly; however it blended the highway into the landscape beautifully.

In Bellinzona we visited Castelgrande. The restaurant pavilion (figure 30) rests near the vineyard in the middle right of the first image. The trellis system forms a matrix for summer grapes to grow and provide shade for the space almost lost in the size of the castle. The grapes were trained to a wire matrix and then allowed to cross freely over time through the welded steel frames. The project itself was not the most grand, but the place around it added to its atmosphere. The company, light breeze and cool shade made the food taste that much better.

Figure 30: The restaurant pavilion at Castelgrande in Bellinzona, Switzerland. The grape vines we provided wonderful shade and a pleasant atmosphere.

We stayed at the Villa Maderni in Riva for the second half of the trip (figure 31). On the site was a new modern addition with a vegetated roof. The vegetated roof I am sure performed well, however it was not able to capture the atmosphere that the trellis in Castelgrande innately had. Is there a way to combine the atmosphere of the space with the performative qualities of integrated systems? Surely there has to be. The vines that track the trellis and the sedum work in different ways, but there could have been something greater had the vegetated roof been thicker and could have been a gathering place for students. By adding an intensive system the roof could have been a peeling of the landscape and been a connection to the original villa. This critique is done in hindsight, but what other interventions could there have been?

Figure 31: Villa Maderni and the addition of a modern vegetated roof. I stayed here during my Switzerland travel in 2015.

Vegetated Assemblies and Color

We have begun to find the intersection of the building envelope and vegetation. The body of knowledge is formed though understanding written texts and the thing itself, in this case the experience of built vegetated assemblies. We know that vegetated assemblies have the ability to play a performative role, as well as an atmospheric one. However we can go one step further and provide a personal dimension of how our own understanding of these systems changes over time and what is important to us when we interact with them. In the first travel trip very few of the images were strictly of vegetated assemblies, however after refining what the line of inquiry was, a focused understanding of vegetated assemblies became apparent. From knowing more about the vegetated assemblies themselves, we now ask how color plays a role in the design of these systems. With color we can begin to see the convergence of a building system with a desire to understand a technique and theory in a certain application. It is the intersection of these two topics: vegetated assemblies and color theory that will drive the development of the design framework.

2.3 Finding a Topic: Color Theory

Overview:

Knowing the intent of the design framework and its philosophy and then combining it with another topic brings up the concept of the adjacent possible. The adjacent possible shows how ideas combine and what becomes interesting and fruitful in the boundaries of topics. This can be a metaphysical boundary but also a physical boundary. Some of the work I do trying to create and combine topics comes from experiential and full-scale construction work. For example: with the colors of the materials I have, how do these colors influence my current project?

While I might be used to combining ideas and materials, I wanted to branch out and develop my interest in these experimental building assemblies with a technique or theory from design. In this case, color theory caught my attention in its ability to meld well with nature and plants. Plant colors vary widely over the year and are a dynamic, living system with amazing potential in color and design. So, I have chosen my topic to be color theory. By bringing color theory in, I use it as a means to limit and ground the discussion around vegetated assemblies and frameworks, providing a specific set of conditions for the development of the framework. We have the ability to combine vegetated assemblies and color theory to develop ideas. The possibilities of the boundary between the two topics can now greatly develop and influence the framework and future lines of inquiry.

Historic Color Systems

We should begin with how color as a theory began, looking at how the theory developed. Much of this synopsis of the history of color circles and their associated theories was compiled by Faber Birren, who was an industrial color consultant and recognized as an expert in that field. The history of color goes back to antiquity. Intellectuals such as Pythagoras, Plato, Aristotle, and da Vinci all contemplated the nature of color, but it was not until Sir Isaac Newton and Goethe developed color theory that a systematic attempt was made to characterize color and spectrum (Birren, 1969; Holtzschue, 2006). While Newton focused on color and light as a part of science and physics, Goethe saw color as something to be observed and devised his color theory to disprove Newton, but fundamentally agreed with the totality of color in a color circle (Renner, 1965).

Later, J. C. Le Blon uncovered the primary colors of red, yellow and blue. In 1766 an English engraver, Morris Harris, made the first full hue color chart in The Natural System of Colors from primitive, mediate and compound or tertiary colors (Birren, 1969). Goethe believed that yellow and blue were primary as did Aristotle. Goethe believed that, "… yellow came from lightness and blue out of darkness. All other colors, including red, were blends of them" (Birren, 1969).

M. E. Chevreul featured the red, yellow, and blue theory in Impressionist and Neo-Impressionist schools of painting. In America, Louis Prang, Milton Bradley, Arthur Pope, and Herbert Ives, who were prominent educators, made the red, blue and yellow theory part of American color and art education (Birren, 1969). Other types of color circles have been developed, however the red, blue and yellow has been favored the

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most. In 1826, the German scientist Helmholtz expounded upon the work of Tim

Young's theory of color vision to make a red, green and blue (violet) color system

(Arnheim, 1974; Birren, 1969; Holtzschue, 2006). In 1923 Michel Jacobs, a painter and

teacher set a theory of principles of color harmony based on red, green, and violet

primaries similarly to Helmholtz and von Bezold. Finally the color circle of Albert H.

Munsell also traces back to Helmholtz (Birren, 1969).

How does history influence our designs? It is the context, the shoulders of giants

The work of Bloomer, Falk, and Küppers in the 1970s and 1980s continued to

evaluate color theory. Then work of Steven Bleicher in 2005 continued this tradition of

refining color theory and its response to increasing technology (Bleicher, 2005). The

constant is that while the color circles and color classification vary, they are all based on

the same layout of characteristics, which will be defined later in the section.

So why are there so many different types of color circles? Birren explains that,

"there are three sets of primary colors and therefore three good reasons for different types

of color circles" (Birren, 1969). He explains that pigment primaries are additive, that red,

yellow and blue will form other hues. Light primaries are subtractive in which red and

blue can form yellow. Vision primaries are medial formed from red, yellow, green, and

blue and where all of them mixed together will form grey (Birren, 1969). Later in this

study the concept of mixing colors and methods of representation is discussed further.

How does history influence our designs? It is the context, the shoulders of giants

that came before us, the lines of inquiry that span generations and our teachers that

influence our methods and modes of thinking. The many different color wheels and

schemes show that there is no one way to think about things. The way of deciding how to

engage a topic, while guided by a community, originates with an individual. The

decisions that we make are grounded in our thoughts and what appeals and makes sense to us. We frame our own minds and thoughts according to how we see the world. We as designers have the opportunity to take an incredible amount of information that the discipline and adjacent disciplines have developed and shape it into our own architecture, our own design. In my architecture I have chosen to see how I interact with the world of color and nature.

Viewing Color: The Eye and Mind

As with color circles and the numerous ways to categorize color, it is understandable that color theory in reference to architecture and vegetated assemblies should be phenomenological, and that our observation of phenomena is based upon our perception of space and objects. Eugene Raskin, author of *Architecturally Speaking*, explains that: "to treat architecture without considering the psychological and physiological characteristics of those by whom and for whom it is created makes no more sense than a discussion of the Bach fugues between two baboons…" (1966). This is to say that architecture when viewed by the individual is a relative concept; so is color theory when viewed through an eye.

We, as designers must approach architecture and subsequently aesthetics and color theory considering our own preconceived notions and abilities. Therefore, in this study color theory is considered in terms by being limited to the perceivable world of the individual's or researcher's eye. Though the eye receives light and perceives color, colors theory establishes known relationships between color and the hues of color so that remain

consistent, and their method of use is organized. Without this basis for organization and use, nothing would be determinable and everything would remain relative.

Another important thing to consider is that when an image is viewed, it is placed on the individual's retina. As the individual interacts with an object or architecture the eye must interpret the information it gathers continuously (Raskin, 1966). The image is seen by the eye, and perceived by the brain (C. M. Bloomer, 1976). This is to say that when we observe a phenomenon, it is filtered by our own physical and mental characteristics. As designers we cannot have an exact representation of the space: instead of reproducing an image as a camera, we create moods and representations. The process of design is inherently biased towards a visual process. Though the process is dominated by the visual, other senses are still observed. It is vitally important not to reduce vision, color, or representation to simply a picture. Furthermore, the objective of this study is not to completely predict or validate an individual's perception of the space, but influence the decisions of how the designer goes about representing the space.

If we continue to evaluate color theory in the context of how to engage vegetated assemblies, French philosopher Merleau-Ponty in his book Phenomenology of Perception separates and distinguishes his philosophy from the mindset of Descartes and Kant. Merleau-Ponty, in reference to Kant and Descartes, says, "I could not apprehend anything as existing, unless I, first of all, experience myself as existing in the act of apprehending it" (Merleau-Ponty & Landes, 2011). However, Merleau-Ponty contends that in the observation of phenomena, perception and judgment are not equivalent. Finally, Merleau-Ponty suggests that the surroundings, the world outside the observer, become imprinted upon the observer through perception. This will become important during the study as we

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need to observe our surroundings and objects based on our previous experiences that have been imprinted upon us from our past perception and experiences of the world.

Our own interactions with a phenomenon influence our observations, and the concept of color theory in relation to vegetated walls takes its roots in Goethe's method of interacting with and perceiving phenomena. Laws of nature, such as light and color will always exist, but an organ such as the eye must be present to manifest the physical condition. The eye does not cause light and color to occur, but allows it to appear to us.

Thus the physiological theory of color proposed by Goethe is different from the laws of optics proposed by Newton (Goethe, 1971; Steiner et al., 2000). Goethe also inspired his student, Schopenhauer, who attempted to define the role of the retina in vision and color in terms of the subjective and proposed complementary colors due to afterimages (Arnheim, 1974). In this vein, the characteristics and conditions of plants in vegetated walls will be studied by the conditions observed by the eye. The study looks at what and how color phenomena arise, and how these phenomena are perceived.

The study will be conducted through the observations from the eyes. So how will this affect the observations and perception of the study? According to David Falk from the University of Maryland, there is a delay to the eye when introduced to new phenomena. Our eye then responds to these conditions to give the individual a representation of the space after a lapse in time (Falk, Brill, & Stork, 1986). Light can create space with depth and shadows, but the way in which we interact with light and therefore color in our visual perception stems from, but is not limited to, brightness, form, texture, depth, transparency, motion, and size. This allows a human eye to distinguish one object from another, and recognize and interpret scenes (C. M. Bloomer, 1976; Falk et

al., 1986). These delays and residual images on the eye play a role in how an individual perceives space and color. The information collected by the eye creates a representation of the space in the mind. The results become the way that we, as designers and individuals, perceive the visible world.

Before we talk specifically about color in vegetated walls, there are some characteristics of the eye that are important to understand. Foremost, the brain processes collected information while emphasizing changes in the surrounding space and sorts this information. Falk explains that neighboring regions of the eye can inhibit each other. This effect of lateral inhibition can be explained with the case of a white square appearing brighter on a black background and a black square appearing darker on a white background. He further suggests that in the processing of visual information within the retina, which decreases the effects of uniform changes in illumination, enhances the effects of edges called the Crail-O'Brien illusion (Falk et al., 1986). Therefore, when constructing and designing vegetated assemblies, it is not only important to consider the edge as a design intervention, but also from the eye's need to differentiate space. The edge not only can define the space, but also the character of the internal field of vegetation and its color.

Afterimages will also augment the perceived color of the vegetated assembly. Falk describes two types of afterimages that will affect the perceived space: negative and positive afterimages. First, prolonged stimulation to a set of conditions desensitizes the eye and leaves a negative afterimage. Second, an intense light will overstimulate the eye and leave a positive afterimage (C. M. Bloomer, 1976; Falk et al., 1986). An example of an afterimage as related to color is found in the polarized tint of ski goggles. For example

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if the tint is an orange color, when the goggles are removed a bluish hue remains for a short period of time. The effects of afterimages could change the appearance of certain types of plants based on proximity and intensity.

Just like the goggles, if you look at the color of a plant long enough, this can affect the appearance of nearby plants, as your eye may adjust to the color of one plant, augmenting another. This is not good or bad, it simply is, however this is easily fixed by spending time between viewing every plant. Further, since none of the plants will be viewed through a color filter this should be a non-issue, though it brings up interesting work for the future.

Some Examples of Color and Perception in Design

When an individual interacts or engages with a vegetated assembly, a specific space and depth influences the individual's perception of that space. Architect Steven Holl, explains the concept of parallax which helps the individual understand space. Holl describes parallax as "the change in the arrangement of surfaces that define space as a result of the change in the position of the viewer" (Holl, 2000). We as individuals rely heavily on parallax as it creates depth cues in order to understand space (C. M. Bloomer, 1976). However, for a two dimensional representation, we rely on ambiguous depth cues of apparent size, perspective, variations of light, shadow, color, and sharpness to define space (Falk et al., 1986). This will become important in representing the designed space using computer simulation of vegetated assemblies later in the study.

With experience, designers can use patterns on two dimensional media to imply overall depth using overlays and superimposition (figure 32). Based on the writings and

studies of Josef Albers, other considerations, such as color interacting with other colors, the interdependence of color with form and placement, the quantity of color, the quality of each color, and boundary conditions, also need to be addressed (Albers, 2013). Both Albers, and Arnheim, a perceptual psychologist, describe the concept of using overlapping figures to imply depth (Albers, 2013; Arnheim, 1974). In superimposition there is a specific case called transparency.

There are two types of transparency, first when light can physically pass through; the other is perceptual transparency through media and methods of which Albers has many examples in Interaction of Color. The illusion of transparency is created after looking at the fields of color long enough. The closer the middle field is to the true mixture of the two other colors, the more this effect is seen. This kind of illusion exposes a type of mixing called partitive mixing, where adjacent colors can begin to mix together. These themes of perceiving depth, texture, and qualities of space in Albers' work, with the characteristics of colors will be critical to vegetated assemblies.
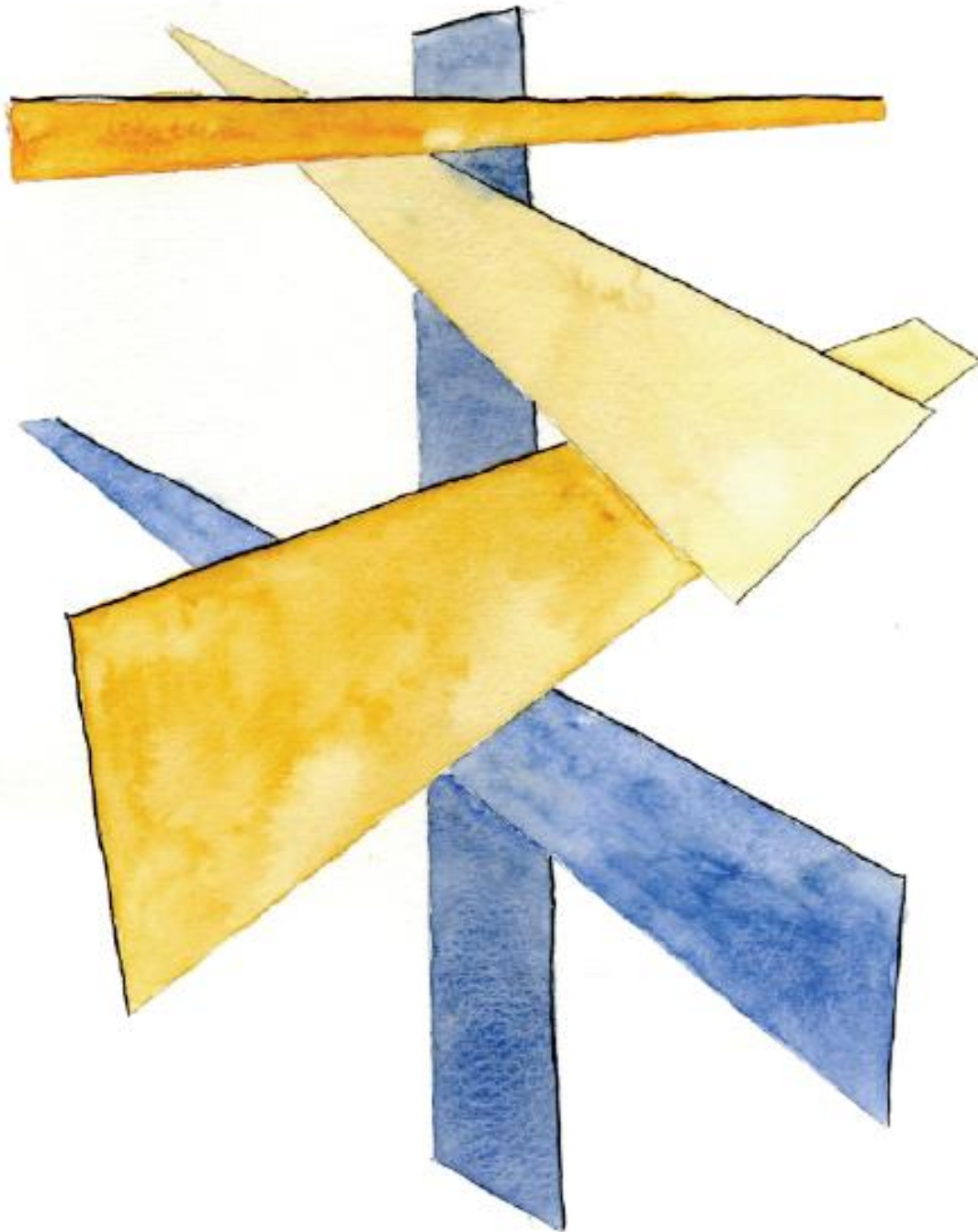
Figure 32: Watercolor studies of superimposition as described by Albers using the complements of orange and blue as determined by contemporary color theory.

From this study in figure 32, we uncover a few key aspects to design. A line is the simplest form of divided, or with multiple lines, enclosed space. A line delineates and

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creates an edge. Lines also relate to the context of the medium of the two-dimensional

frame in which they rest. The eye is attracted to an edge condition and then lines become

critical in design and color. Piet Mondrian, a Bauhaus painter and educator attempted to

reject references to physical space, but the distinction between objects and the space

around them remained (Arnheim, 1974). In the principle of interposition that Albers and

Klee explored, using fields (Albers) and lines (Klee) depths can be created or rejected

based on position.

This concept of proximity and position to create or deny space and depth will be

critical to understanding color and its resulting effects. Lines can also create volume

when transferred into the third dimension (Hogarth, 1955). This idea of lines creating a

volume was also explored by Moholy-Nagy in structural and allied constructions

(Arnheim, 1974). Klee also looked at how lines could enclose space, making a distinction

between internal and external spaces (Aichele, 2006). Though not distinctly figure-

ground, this idea of an object and an area contained by a frame introduce the concept of

figure-ground (Arnheim, 1974). Figure-ground principles give qualities of depth and

delineate space or volume to an image or composition (figures 32 and 33).

Figure 33: This is of a simple figure-ground composition where depth is implied by overlap, however it appears flat. Figure 32 is of constructed volumes to develop space and depth trough implied volume of the figure-ground space similarly to Moholy-Nagy, but in watercolor.

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So how are colors described for their depth and qualities? We could define color solely by wavelength; for example the color blue is between 455 and 485 nm (nanometers), which is a range of wavelengths and not a single band. A single band or wavelength of color is termed monochromatic light. However defining a color by something that is not perceivable to the eye is not a viable descriptor. Over time, three dimensions of color have been used to define color. We can define color by hue, its main color which distinguishes it from one spectral color to another. We can define color by saturation, its purity of color or how much of the color is near the dominant wavelength. We can define color by lightness, its percentage of incident light reflected from the surface. These three characteristics: hue, saturation, and lightness, that define color to the eye can be arranged on what is called a color tree (Falk et al., 1986; Munsell, 1913). These groups can also be defined as hue, saturation, and brightness (Arnheim, 1974); hue, intensity, and value (C. M. Bloomer, 1976) or hue, value and chroma (Munsell, 1913).

While we cannot determine how an individual will interact with a space or color as explained previously, we do have the ability to suggest a perception of a space. Using the combination of historical precedents as well as design experience, architecture and by extension vegetated assemblies, can begin to imprint the individuals around them by maintaining a particular atmosphere and innate connection to nature. These resulting atmospheric qualities are derived from the perception, intentions, and experience of the designer's hand. The space and shape that a design creates can be a means of identification that is more consistent in the face of environmental changes than color (Arnheim, 1974). However, the possibilities of combining shape and color in design, be it

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a vegetated assembly or architecture in general, is worth noting. Luis Barragàn, architect and the 1980 Pritzker Prize laureate, speaks not only of beauty (aesthetics) and color, but also of gardens. These motifs, these themes will be critical to understanding how designers can use space, color, and light to enhance a vegetated wall or assembly. Armando Chàvez Cervantes, the chairman of The Fundación de Arquitectura Tapatía Luis Barragàn, FATLB describes Barragan's view of architecture, "To see and make with what exists, with an open, revivified vision, in the aim of revealing to us a new universe, his universe, enveloped by magic, mystery, enchantment, light and color." (Alfaro, Garza Usabiaga, Palomar Verea, & Barragán, 2011). Barragàn was a master of combining a connection to nature and color with a sense of place.

The characteristics of color reviewed in the literature (hue, saturation, and lightness) can be quantified and scaled, but solely quantifying color does not relate to an architect attempting to represent a space in a two or three dimensional manner.

For an architect, the characteristics of pigments, medium, paper, and methods combine to give characteristics of color and create aesthetics of design. Thus, our plants (pigments), our assembly (medium), our space (paper), and our design (methods) must be in relation to each other and thought of in a cohesive whole. Although color theory can be the focus of the study, many other aspects such as contrast, assimilation, a sense of place, a sense of beauty, and perception must be applied and allowed to mix and complement each other.

Color Mixing and Harmony in Representation

There should be a dynamic view of the space, not a static view in our minds. The space that we design changes over the years, with the seasons, the weather, the number of people present, the lighting conditions, the expression of material aging, and much more. The subsequent representations created by the designer need to show a way of experiencing the sense of place proposed by the representation, and the possible built construct. The designer should represent a desired experience or mood to the space. The representation should be an approximation of the desired physical stimulation combined with a mental response, filtered by the memories and innate nature of the individual. The individual creates a personal phenomenon of interacting with architecture, one that we can never completely know, but can attempt to represent.

Utilizing all of these ideas of vegetated walls, knowing their characteristics and historical context, and evaluating these walls based on color theory, we now can re-imagine a designed space. We, as humans, perceive and attempt to generate an image of balance, or harmony. Referring back to Biophilia described by Edward O. Wlison, and the "primal image" described by Pallasmaa, then we can begin to piece together a desire for harmony and balance that is also found in nature.

The architect should seek a composition that is in balance, especially in reference to color theory. When simulating a space, the production of the representation and color balancing play a critical role in the final result. You simply cannot mix plants by color the same way a printer makes colors. There are differences between the three-dimensional world of the built environment and the two-dimensional world of graphic

representation which make them not directly translatable. However, representation can and does inform the final construct.

As Arnheim explains, colors can be determined by three different dimensions: hue, brightness, and saturation (Arnheim, 1974). These three qualities show up in color pyramids by J.H. Lambert in 1772 and in color graphics of Philipp Otto Runge in 1810. What is derived from the work is the inter-related nature of hues. Arnheim contends that this type of color harmony is incomplete, only focusing on connection of the hues, and neglects separations of color. Ruskin, as described by Arnheim, find that this is mainly found in the instability of colors that hot and cold hues are in relation to the new colors placed on the canvas, and with each stroke new associations are established, that hues and colors are relational and interact (Arnheim, 1974; Birren, 1969; Holtzschue, 2006; Renner, 1965).

Furthermore Albers describes this in his work in the *Interaction of Color* (Albers, 2013; Arnheim, 1974). Itten also describes color harmony as the interaction of two or more colors (Holtzschue, 2006). He states that "the concept of color harmony should be removed from the realm of subjective attitude into that of objective principle" (Holtzschue, 2006; Itten, 1961). This is countered by Albers who states, "What counts here— first and last— is not so-called knowledge, but vision—seeing." (Albers, 2013; Holtzschue, 2006). Goethe found that harmony was present when the totality of color was present in a composition (Goethe, 1971; Renner, 1965). Renner, a German educator and designer, viewed as a harmony of a combination of a few main colors, and each hue should be in relation as a subordinate or coordinated color (1965). While art will always

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be subjective in nature, it is interesting to see the interpretations of color harmony are dependent on the artist as well.

The color studies and philosophies of color harmony differ by the artist. Albers viewed cold and warm colors to coincide with dark and light. Itten saw red-orange and blue-green as temperature opposites, that red was warm or sunny and blue was cold or shady. Kandinsky saw colors as shapes that yellow was a triangle, blue was a circle, red was a square (Arnheim, 1974). This concept of using multiple words in language to describe similar hues via different thought processes is inherent to color, that an image or hue is meant to be seen and represented, that words cannot describe and image in its entirety.

Though much of color could be seen as based in impressions, there is a method to the use of colors in color theory. Birren speaks of the color harmonies developed by Chevreul in 1839. These six color harmonies can be summarized as the harmonies of adjacent colors, of opposite colors, of spilt compliments, of triads, and of a dominant tint (Birren, 1969). This method of color harmony addresses the incomplete nature described by Arnheim of only viewing a similar set of hue as a complete composition. What Arnheim discussed is termed the harmony of adjacent colors by Birren and Chevreul, for example yellow, yellow-orange, and orange.

However light and color interact and the space that a composition is presented in is as important as the selected harmony of hues of colors. The shortcomings noted by Arnheim are that the harmony of opposite colors as in blue and orange, of split complements as in orange with blue-green or orange with blue-violet, of triads as in red, yellow and blue, can be influenced by a dominant tint such as a light source washing

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colors with a light orange from an incandescent bulb (Birren, 1969). Birren also explains

that the eye looks for simple and clear divisions of color. Perhaps this can be found in the

ingrained human eye's tendency to focus on edges and color divisions. Compositions that

are vague or blurred are somewhat disturbing but can be captivating as in the work of

Mark Rothko; however while unusual, there is an order and method to the compositions

he creates, thus developing their own harmony together with particular balances and

proportions. The eye will notice total dis-harmony and will be disturbed until balance and

proportion are once again evident (Birren, 1961).

Holtzschue, after explaining color harmony in depth, suggests four near-universal

observations about color harmony (2006): The complementary relationship between hues

is a strong basis for harmony, but it is not the only basis. Any hues used together can be

harmonious. Even intervals between colors are harmonious. Even intervals are pleasing

whether they exist between colors of different hue, different value, different saturation, or

any combination of these qualities. Color compositions are most harmonious when the

level of saturation is relatively constant. Complex compositions, with a great many

colors, tend to be most successful when there is a dominant family of analogous hues that

is supported by lesser areas of their compliments. This series of observations combined

with the harmonies developed by Chevreul and distilled by Birren, and further described

by Holtzschue makes a solid foundation for the study of color and color theory. These

will be used to define color theory for the development of the decision support

framework.

Comparing Two Types of Color Mixing: Light and Pigment

Since only in specific cases are representations monochromatic, mixing color and understanding the harmony or contrast in color is essential. When mixing specific color hues in light, they should give white (complementary pigments in paint will yield a grey), and when placed in proximity to each other these color pairs enhance each other, becoming complementary colors. Architects such as Barragan and Legorreta use color to their advantage in order to make a composition of colors. Both architects use color as a symbol of emotion of the world around the individual and specific to the cultural and geographic location (Legorreta Vilchis, Attoe, Brisker, & Box, 1990; Mutlow, 1997). These two architects certainly use other motifs in their architecture, and color serves to enhance their stance in architecture.

This is not a hurdle to overcome, but a dynamic to be embraced and understood. The color palette for the design needs to be considered along with the kind of color mixing that will occur in each method of viewing to maintain a harmony at all stages of the design. When thinking about colored mixing, there is additive and subtractive mixing as shown in figure 34 (Albers, 2013). The two methods of how light and pigment mix in fundamentally different manners. Light will mix in an additive manner to achieve white while pigments will mix in a subtractive manner to achieve black. In additive mixing, the intensities of wavelengths combine to make another color and include: simple addition, partitive mixing, and color mixing. The first kind of additive mixing is simple addition. Simple addition is when colored light overlaps and combines wavelengths to make a new color.
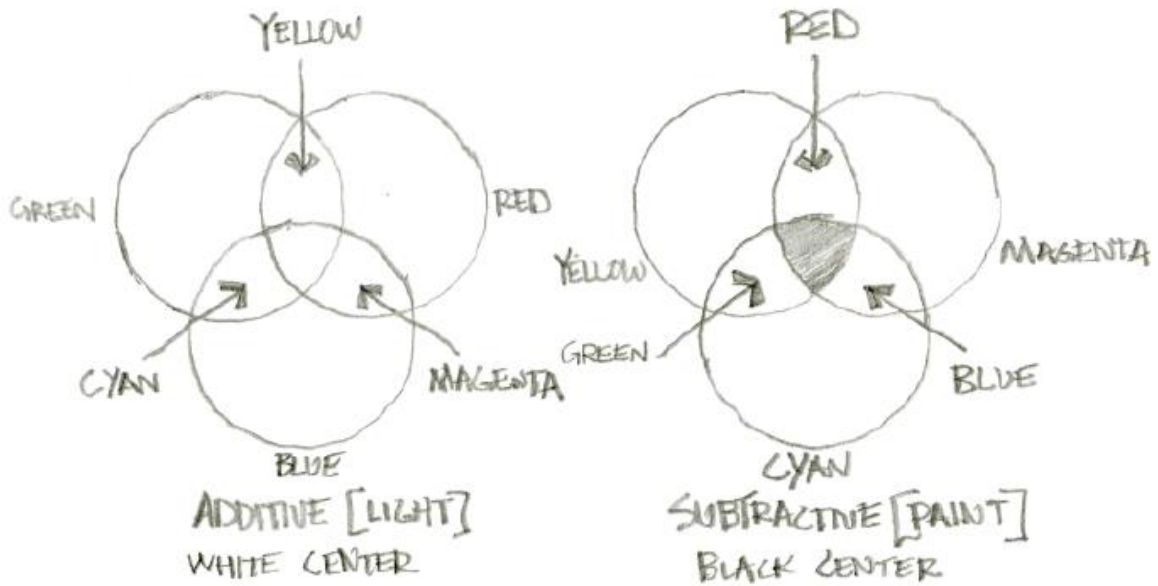
Figure 34: The two methods of how light and pigment mix in fundamentally different manners. Light will mix in an additive manner to achieve white while pigments will mix in a subtractive manner to achieve black.

Subtractive mixing occurs when combining filters or dyes to admit some wavelengths and block others. However, subtractive mixing will depend on the light source and its distribution of light (Falk et al., 1986). Furthermore, a particular scene will look different under different light at different times of day.

If two artistic pigment colors (blue, yellow) are mixed they additively combine to make a new color (Birren, 1969; Falk et al., 1986). When light strikes the pigment on the page light travels into the pigment, and all light other than what is reflected is absorbed and subtracted out. Light is also then reflected off of the media behind the ink, back through the pigment again. The light from the pigment and the light from the page are then additively combined in the eye. If designs are done digitally, colors in printers can be cyan, magenta, yellow, black (CMYK), which is called four color printing; however red green blue black (RGB) is used to project color from monitors. (Falk et al., 1986).

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These different color schemes produce different colors, thus the color on the monitor is different from the color printed on the page. These different types of mixing light and color are a result of using different forms of light, pigments, medium, paper, and methods combine to give characteristics of color. When designing with color theory in mind, the color balance of the computer and the program (such as Vectorworks, Revit, or Maya) used to render the space is also an important consideration.

Watercolor study from Josef Albers' *Interaction of Color*

This study was conducted to see the interaction of light and pigments. The way watercolor behaves combines both the interaction of additive mixing in the pigments, but also the subtractive mixing of light through the layers of the watercolor painting. This study was conducted in conjunction with the analysis of vegetated assemblies in regards to color theory. The particular false color study used themes of perceiving depth, texture, and qualities of spaces with color that were critical to representing and understanding the drawn spatial representation. These qualities of color and texture will then later be applied to vegetated assemblies and their representation. The purpose of this specific study was to help myself and other students who participate in its implementation and to determine how theories of design translate into different media, in this instance watercolor instead of colored paper as was used by Albers, both in performance and aesthetic quality.

In order to understand the work of Josef Albers, it is first important to understand his own work as a designer and artist. Albers studied and taught at the Bauhaus until 1933 when the school was closed by the Nazis. Albers then moved to the US and taught

first at Black Mountain College, and then became the head of the design program at Yale. When Albers moved to the United States he began to paint more, devoting most of his career from 1949 on to a long series of paintings called Homage to the Square (Morris, 2011). In the work Albers attempted to achieve a totally flat surface using different shades of a family of colors. These colors react with each other, appearing to enlarge, diminish, or change hue when viewed. His 1963 treatise, Interaction of Colors is a seminal text and his work greatly influenced artists.

This is not a critique of the work that Albers has provided. That would not prove helpful in learning about color and the ability to utilize or adapt it in design. Instead the review aims at seeing what is offered and then coming to an understanding of the methods and information provided. It is first critical to understand information and then review it though a particular lens. Then, over time and experience can one begin to understand the subjective and relative nature of color and its interaction. Albers very quickly explains that, "Color is the most relative medium in art." (2013). In the work I have seen and in the projects I am currently developing, scores of different colors and hues are used. These colors can be enjoyable to some and then found displeasing by others. It is our own individual interaction with color that determines our appreciation for a composition of color. Only through trial and error have I begun to understand the subjectivity that can be found in contrasting hues and tints of color. These observations and experiences into learning and understanding color result in a phenomenological understanding color and its presence. Therefore color and its theory is something that can be taught, perceived and understood differently by every individual.

Albers then continues by explaining that the name of a color can and does invoke different recollections of the color (2013). This concept is interesting because even in the specific language of the individual we can find variance in the interpretation of color. These subtle differences in color can sometimes only be found in a particular language and do not translate into other languages. The interpretation of the color can also be based on the person's remembrance of color visually. However it is important that this difference in the interpretation of color is not negative, but rather an indication of how widely varying the hues and tints of color are and how they are perceived by people. It allows for there to be as many interactions of color as there a people to interact with it; that color is a realm of representation and interpretation.

He finds that successful studies of color require representation, and therefore are not as often misunderstood (Albers, 2013). He explains that in some instances it is not important to achieve color harmony, but that color is understood (think of the work by Mark Rothko). The study of color, even a particular one such as red, has so many different possibilities that limits have to be placed on the field of colors such as black. Albers conducted this by using studies in separate pairs to show desired effects. Even in the studies based on pairings and families of color, it is difficult to distinguish lighter versus darker in close interval of hues and the interaction that each hue has with adjacent hues. Figure 35 shows how small increments in hue changes can create a different color over a gradient.
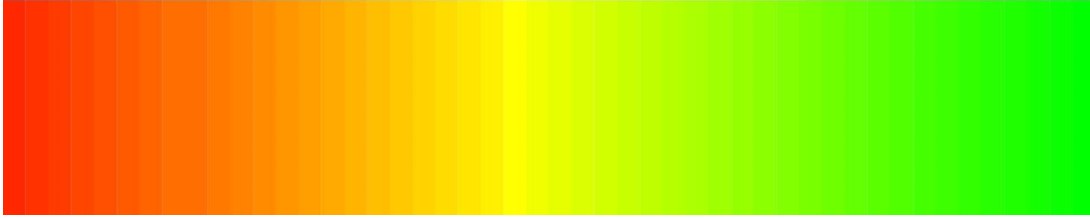
Figure 35: the change of hue through incremental steps from red to green. Some steps between colors within a hue are almost indistinguishable.

Albers describes how the eye interacts with colors is different than the lens in photography. For example, afterimages can be created by the eye with the overlapping of different hues. He explains that the eye has scotopic seeing as well as photopic seeing, and can adjust to low light conditions. He mentions that photography can alter color balances and that it turns darks darker and lights lighter, creating a scarcity of middle range greys (2013). Photography has progressed since his studies and has changed to include digital photography. What is similar across the medium is that the light that enters the lens of the camera is what is recorded and the mechanisms to do so will always alter the color. Just as analog technology changed the resulting image, digital process of changing an image to information also affects the clarity and brilliance of colors. This augmentation of images as compared to the original is less apparent, but needs to be addressed when copying, printing, and using non-original images.

Since the eye is more complex and flexible than a camera, Albers suggests some methods for how to train the eye to detect and differentiate hues such as gradation studies which use a stepping of grey from white to black, looking for smooth steps in scales (2013). In my own education this method was employed to teach me and my peers how to create, differentiate, and organize different greys. We were also instructed to try to find the whitest white and the blackest black among the tiles, which was difficult as

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competing shades either reduced or enhanced the relative darkness or lightness of a particular piece.

After looking at the process of differentiating the varying greys, Albers describes the idea of trying to identify the middle color of two different hues (2013). This is very difficult, especially if the pair is a set of complementary colors.

The method of lighting in a space can alter the visible colors. For example you observe a shirt in the store that is a specific hue and then when the shirt is taken outside, light with a different color rendering index, namely the sun, is introduced which alters the color. While this is a specific example of how the change of the appearance of one color can change to two, Albers speaks of how color differences are caused by hue and light. He felt that it is more interesting to make two colors look the same, not one color looked different (2013).

After doing the exercise above, I noticed the next concept that Albers explains: the idea of simultaneous contrast. This is an afterimage that remains after exposing the eye to a particular color for an extended period of time. For example, red on a white surface yields green and orange yields a blue. He suggests that this is due to the light receptors in the eye, that after staring at a particular primary color for an extended period of time, the eye fatigues, and with a quick adjustment to a more complex secondary or tertiary color, an after image appears. This kind of result can also be made in very abrupt contrast in different levels of light. For example, while I do not recommend this, staring at the sun or right after a camera flash an afterimage of a purple hue occurs. This can also occur through colored filters. If you stare through a red filter, and then removed, a green hue remains. Or for example in figure 36, if you stare at the red square long enough and

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then look at a white filed, some of the red will remain as an afterimage. These are three different reds selected from figure 35 and are indistinguishable between each other.

Figure 36: Three different reds that were used to show how the eye fatigues and then an afterimage of the color is projected onto the next viewed image. This is most visible when shifting from the red to a white field or wall.

Color Hues in Watercolor

Albers does most of these studies in colored paper in order to have an even amount of color throughout the object used in his studies. There are three concepts from Interaction of Color that are important to realize about color mixing. The subtractive mixture that is created by pigments is not as light as the lighter color nor is it as dark as the darker of the parents. The mixture result is dependent on the proportion of the colors used in the mixture. Finally, when a color is read above or below another, an illusion of space or depth is created (2013). In any given situation, a color can be defined by at least two characteristics: color intensity or saturation and light intensity. In the study below of Frank Lloyd Wright, a watercolor collage was done in the three sets of complementary colors and resulting range of intermediary hues. In such images color harmony was desired, but in this color study as a whole, such harmony is not a necessity.

A case study was done with Mario Cortes' watercolor class at Virginia Tech in the Spring of 2014. The students were asked to color two complementary 7.5 inch by 7.5 in squares that would then be cut into 25 smaller squares for use in a different

representation of the colors. The purpose of the project was to show how value (the amount of black) and hues could be used to make an image out of a regular grid, similarly to how pixels operate in screens and monitors. The one difference being that such screens will use RGB or CMYK to make a color-correct image, while this study was in false color. False color is when the hues or colors of an image are changed from its actual expression; however, the value and depth of the image is retained. This allows the image to be read without having true colors.

Why is it important to have a limited scope of colors and their complements? It is important because this makes the designer think about the relative nature of colors. Following is all four of the tiled images that were made. The left two are the ideal images, made only with colors that exactly matched the value (amount of black) in the original image (figure 37). The right two reflect the realistic setting, where the tiles available could not be duplicated as needed. This difference teaches the eye to see relative differences in depth, eliminating the false color of the initial images, reading the underlying depth. It also teaches the designer how to create an image with intensive limits placed on the products available.

Figure 37: Two different false color studies, a computer-made ideal version to the left side and its black and white image to show depth, and the physically made composition to the right with its black and white image.

Since there is a limited amount of each tile of value made in the class, the colors that are

placed next to each other need to have the appropriate difference in value, but not

necessarily the same hue as the ideal representations made by the computer program.

Through a process of making and iterating the final image, an approximate image of

Wright is made out of a grid of smaller squares. Using tiles of a darker value delineates shading, while tiles of a lighter value fill brighter surfaces. It is the process of placements and then assessing the image that creates a final composition. If the false or not realistic color hues are taken out and only the value of the colors remain the depth of the image is retained, still showing the image. This concept of creating depth with value, but false hues will be important in developing the depth and aesthetic qualities of the living walls in relation to color theory. These steps then become part of the method for teaching the aesthetics of living walls in a studio environment.

Summary: Color Theory and the Adjacent Possible with Vegetated Assemblies

The watercolor studies with nature and false color value studies (figure 37) helped to inform the conceptual infusion of color into my understanding of nature and plants. Vegetated assemblies have the advantage or possibility of using plants and flowering colors over the times of the year to create a dynamic composition of color. These assemblies can use nature to inform form while the architect is the form-giver. From the review of the literature, the study will use the three main aspects of color: hue, saturation, and value, to allow color theory to describe a composition of plants in an assembly. If this is combined with the concept of figure and ground, the depth of leaves and their shadow can create a screen, a wall, an opening.

While much of color theory can appear only aesthetic, color theory and vegetated assemblies are performative as well and aesthetic – restorative properties in visual access to plants, and certain colors used in spaces resulted in faster recovery and fewer used medications. This is important to understand that it is the combination of technique and

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its implementation (color theory) that combines with an adjacent interest in an architectural assembly (vegetated assemblies) to better understand how we ought to design them. This normative design process looks at a number of characteristics of the plants, the project, and the surroundings to design to the context of the project and of the site. The framework grew from topics that had consistently been present in my work. So how is all of this significant to the process of developing, making, validating and then discussing the framework of vegetated assemblies and its implications?

2.4 Significance of the Literature Review

It is about using what is around in the world to design and make beautiful vegetated spaces. In many cases beautiful does not mean large or outlandish, but being of a place. Our work should reflect that vegetated design and architecture are compelling interventions into the profession. The background into frameworks, specifically the one here, revolves around the existing knowledge in the literature and the experiential knowledge of the designer. This is how much of the methodology and results will grow. The information that is found in the existing body of knowledge is then utilized to form an addition to itself using the iterative process of previous design experience. This makes the product of the work also a process for others to make their own processes and build experience. This particular framework is on vegetated assemblies and color theory, but has the potential to be more or to be used in other topics of architecture. Previously we have used the literature on vegetated assemblies and color theory to develop ideas. Now it is the possibilities of decision support that lead the process of making a vetted and helpful framework for sharing knowledge. The framework then also questions how this

ought to be done as a normative design process to make a composition of object (figure

38).

Figure 38: Design is of a place. What were the decisions that went into making this installation in Riva San Vitale? Was it a barrel and pump that could no longer be used? Why here? Even though some questions cannot be answered, the installation is beautiful.

Significance of the Literature into the next steps of Design Frameworks

The framework has a beginning of characteristics and considerations that will be used in forming a system or process for designing vegetated assemblies. These are found at three levels. First is design as it is used in architecture namely the personal design process that a designer develops over time through experience. Second is at the topical level where vegetated assemblies are described in relation to color theory and how color theory can inform their design along with specific assembly requirements. Third is the plant or component level which is the plants or parts of the assembly. These three levels are parts of two main tracks or processes. One is the overall iterative design process; the other is the data analysis of collected information. Each of these have techniques that require practice and time, perhaps mastery. In the design process these techniques can be watercolor or markers, line drawings: types of methods that inform our resulting representational manner. In the data analysis process these are the mastery of conceptual techniques and synthesizing information from a body of knowledge. This informs the implementation techniques found in the general design process.

Framework Design Methodology

These different levels of considerations and tracks suggest a method for not only outlining the framework, but also how to limit its growth. There are an almost limitless number of techniques and topics that could be included in the framework. This framework will serve as an introduction to topics and design processes for others to later augment as a visual framework that someone can follow and interact with.

Influence on the Resulting Framework

By limiting the framework, we also do not overwhelm a student with information. This will be done by allowing a student to follow a path of their choosing through the framework for example color theory, plant biology or vegetated assemblies, and then make a decision on their own. Each of these three topics will have two layers of depth: one to introduce each major topic, and then a more detailed additional subtopic. While all of the topics are important, students can decide what is important to their project rather than being told what to do. This ability to decide is the most important part of not only the resulting framework's use, but also the methodology of the design process it will be integrated into.

Possible Framework Validation Processes

Once the framework has been developed, the next step would be to review and later validate it. This should happen at multiple levels: personal, paired, group, and then class or studio. While the framework will have influence on the profession, its target is the students. The way a student learns and the way a professional practices are quite different. To have the considerations of the profession in the framework, accreditation guidelines were reviewed and then the framework was designed to be integrated into a class. For example, the knowledge in the framework would be useful in building facades and systems. The process of validating the work includes these levels of review as well as review from external publishing sources such as conferences and journals.

Implications in Teaching

The process of validating the work through using the framework in teaching environments also raises a question: how do you teach and how ought you teach? This will bring together experiences from within the discipline of architecture and from general contemporary pedagogy practices. Experiences from architecture and from the graduate school combine these areas of interest allowing traditional methods of the design process to become informed by contemporary tactics and new opportunities. Over time, the framework will be used in different settings to determine its worth as well as increase its ability to help others to design vegetated assemblies in relation to color theory.

Chapter 3: Methodology

3.1 Methodology: Developing the Artifact

Overview:

Interpretation had a major role in the dissertation and in the evaluation of the observations of the students using and interacting with the framework. The researcher is the most vital link to initially synthesizing information concerning the connection students have with it and with others in their personal design process and architecture. For this to occur, interpretivism must be seen as an extension of phenomenology, generating experience by systematically evaluating and reflecting on a series of personal and student works through the decision support framework. The educator then becomes a node for knowledge in reference to the studio environment, while the decision support framework became a knowledge sharing device. In figure 54, there is an overview graphic of the applied methods used in the dissertation.

Background Methodology to Develop the Framework

There were a number of stages in the development of the decision support framework for aiding in the design process of representing the vegetated assemblies and teaching this topic to students. The process started with a review of the literature to find established methods of defining, observing/testing, and interacting with color theory, plant biology, aesthetics, and design decision making through representation. The literature review revealed the importance of the interactions of seemingly unrelated topics and how these interactions yield new insights. From this literature review, concurrent projects were conducted involving the construction of full-scale vegetated assembly

structures at the Research and Demonstration Facility (RDF) at Virginia Tech including the Solar Garage (a carport for the Electrical and Computer Engineering Department for their inductive charging of vehicles research), the Solar Lounge (a shading structure and vegetated assembly testing modules for the entrance to RDF, the Vibrations Testing Lab and the VT FIRE Foundry), and TurtleTown (a shading and vining structure for a residence in Blacksburg, Virginia). A series of plant species photos selected from a larger library from Dr. Alexander Niemiera, a professor from Horticulture, informed the types of plants that could be used in the design of such structures. From these three methods: the literature review, full-scale construction and photography, the preliminary framework was designed. The immersion of students and other colleagues served as initial testing of the decision support framework to determine its usability toward improving design decision-making. This stage used the researcher and 2-3 other "designers" or colleagues to develop the initial decision support framework. A final member checking or questionnaire stage was completed to gain a consensus for the positive impact on design decision-making using a maximum variance sample of at least 6 to 12 designers using a design charrette and surveys. Figure 39 shows the different categories these designers were sorted into.

Maximum Variance Sample Experience and Method	Computer Design	Analog / Hand-Drawn
No Previous Experience with Vegetated Assemblies		
Previous Experience with Vegetated Assemblies		

Figure 39: The different groups of reviewed individuals for the framework. These groups were devised to see the experience and type of work produced, however only descriptive statistics were used during the dissertation.
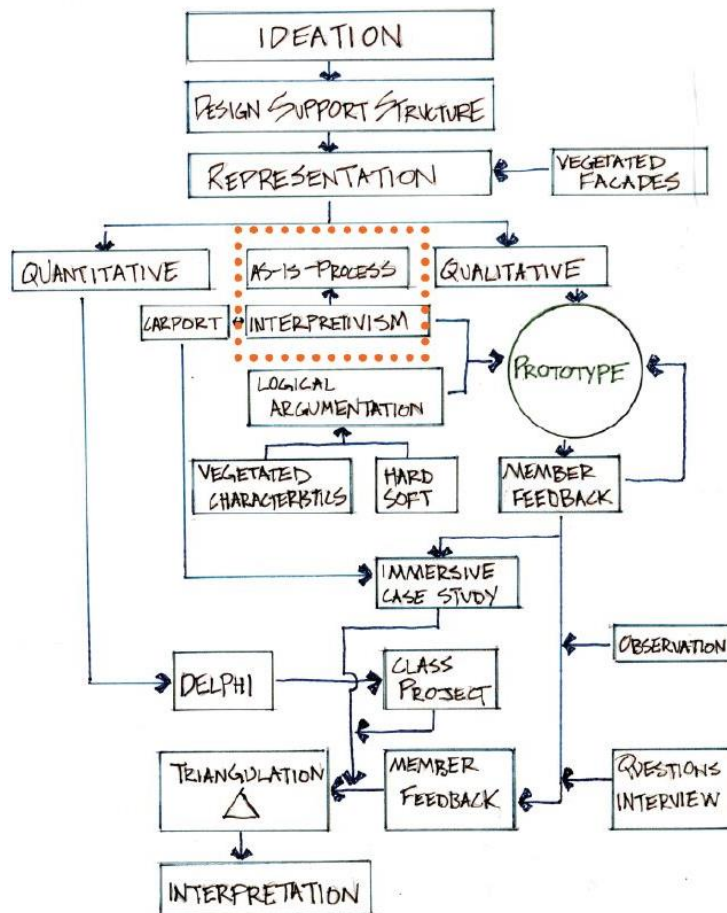
Figure 40: The visual process of the dissertation moving from ideation to the prototype vegetated assembly framework, summarizing information from the literature review.

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Of course there would be more than one way to represent vegetated or living walls. The diagram (figure 40) visually represents the methodology of the dissertation. It was beneficial to determine some method of how to start the ideation and representation process. This process and resulting framework was triangulated for effectiveness and usefulness through the interpretation of the researcher, immersive case studies (carport studies) and interviews (questionnaire), and the member-feedback (studio phase). The carport studies later become the Solar Garage and Lounge design-build projects. The core of the methodology however was the interpretation by the researcher of existing design processes (the as-is) and the developed framework.

The best method for developing the framework before its use in either a studio or immersive case study was to have multiple attempts at running a questionnaire. At first the questions was run without the presence of a framework after a typical studio project. Then a preliminary framework was established off of these questions, and then implemented in a small exercise with a questionnaire afterwards, the information from this questionnaire formed a second iteration of the framework which was then used in both another studio exercise and a studio-like course for more feedback.

These studio or studio-like situation allowed the researcher to receive more experience in the teaching method and to refine the representational approach and prototype framework. The more preferable was the questionnaire, allowing for a group of 8-12 student design experts to use the framework for a number of different design cases. The studio-like course required much more time and not all students were familiar with design method. However, both groups were able to sort through the steps necessary to design the vegetated systems according to color theory, plant biology and ecology, and

aesthetics in a short time frame of approximately an hour. Afterwards questions and

information, along with any design work gathered during the questionnaire, was used to

inform another iteration of the decision support framework. It was the whole process of

developing and then analyzing the framework and its implementation in a studio that is

critical to the development of the prototype and design process for the future education of

designers. In figure 54, there is a detailed chronology of the applied methods after the

general explanation of methods in the main methodology chapter.
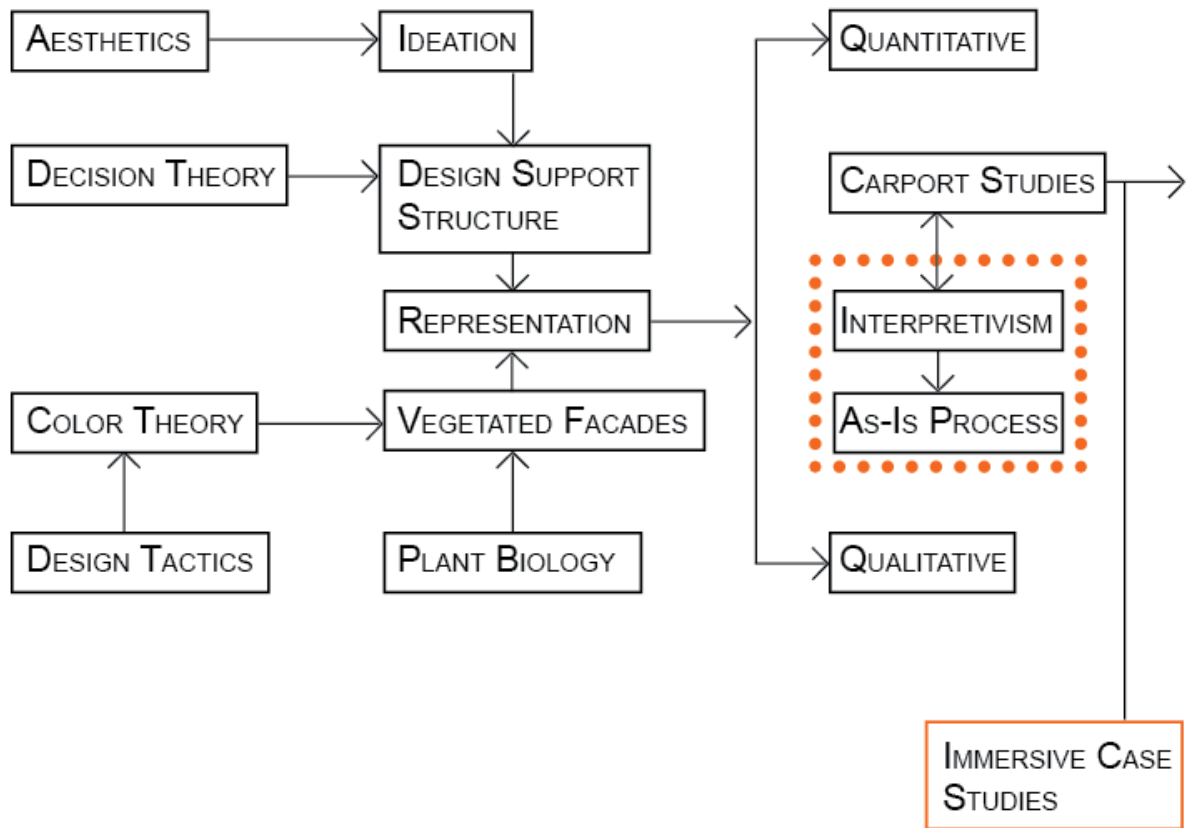
Figure 41: As in figure 8, we begin to refine the process of the dissertation finding inputs for ideation, the impetus for not only design, but research and most other undertakings.

Though much of architectural research focuses on the physical outcomes of design, research on the process of design and the practices of both students in academe and professionals in firms is just as crucial. This philosophical method stems from three beliefs. First, the re-enlivement of people and places, that there is a need for the inclusion of vegetated walls for the re-enlivement in the built environment. Second, that then teaching and allowing interaction with vegetated and living walls enhances human life. Third, that the topic of inquiry is the built environment which enhances human life through biodiversity or biomimicry from the designs of the analyst/designer/researcher. These ideas are summarized as design tactics in figure 41. This is done through a personal, phenomenological lens, that the designs iterated are based on past experiences. This process of ideation, representation and then iteration, through experience is supported by a mixture of qualitative and quantitative research using case study verification and experiential learning. The question being: how can a framework assist or improve decision making, measured for success by a more informed decision on the part of the framework users as a method of knowledge sharing. This allows for the systematic, but not necessarily linear, process of interaction and iteration to come to a directed creation of knowledge.

Triangulation is the method of using multiple methods to confirm assumptions made in the usefulness of the framework. For example, by combining the work of previous decision frameworks by Dr. Elizabeth Grant (2007) and tool prototyping by Dr. Kongkun Charoenvisal, (2013) a prototype and its decision framework can be made and then verified through studio work, immersive case study in the form of full scale construction, and member checking. Each of these three paths overlaps each other and

checks for inconsistencies in the performance of the process or the methods in which to teach it to others as shown in figure 42.
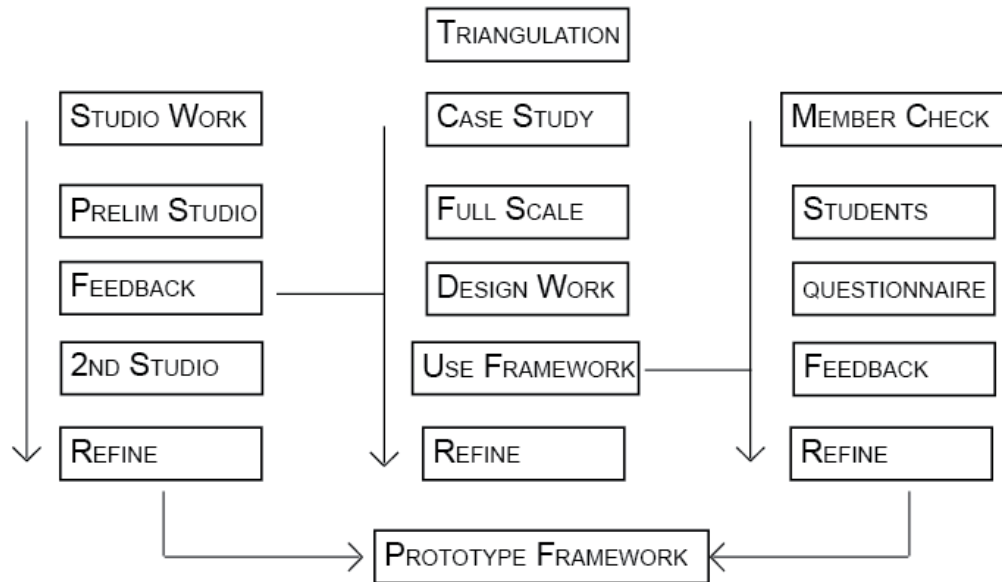
Figure 42: The visualization of the triangulation process using studio work, immersive case studies and member-checking to refine and develop the framework.

A decision support structure is created through understanding decision theory. This theory is the method for how decisions are made, in what order, and which take precedence over which at each given point in the process. The general concept is that the inputs of color theory, plant biology and design tactics, such as materials or clinging mechanisms will be used to provide a framework to build upon the previous work by Dr. Elizabeth Grant (2007) and Dr. Charoenvisal (2013). The first step is to detail the work and find all of the parts and pieces to developing the framework and the resulting digital application in theory. This process also requires understanding the methods in representation that will occur in the framework as a part of a larger design process in the main project.

The digital application needs a fleshed-out version of the decision support system to not only develop the particular design process but also to use as a guideline for when users are trying to implement it in their design process. This decision support system is different from a decision-making framework which defines a decision. This decision support system or framework informs the designer within a set of chosen criteria in relation to a larger design project at hand, while leaving the final decisions to be made by the designer. This framework has two parallel tracks, the first is the method of how the system will be framed and the other is the actual gathering of data in respect to color theory, plant biology, and design tactic (structure, materials, and attachment mechanism). Depending on the situation there are other factors: design methods (hand-drawn or computer-aided) and purpose (decorative or performance).

Adapting the systems approach developed by Tim Jewel (1986) found in the work of Dr. Grant (2007), we find that the framework for vegetated assemblies can be incorporated in a more specific manner as compared to the general design framework he employed. Grant explains that these projects within the framework are often open-ended, or 'wicked problems' as explained by Nigel Cross. As projects use the design support structure they will evolve as data and criteria become more defined. Once again, this supports the fact that the design support structure and later the digital application are both a part of the design process, but not a replacement for the decisions of the designer. This framework is simply that: a support mechanism, not a replacement for the designer.

Presenting the As-Is studio method to Vegetated Assemblies

The main focus is not to determine for the students what method should be used, but to be able to help students in the method that they choose in the beginning when trying to represent design projects and vegetated or living walls. For example, by having knowledge of watercolor and mixed media the professor can direct students in a knowledgeable manner, or direct them to someone who can help them even more. The main purpose is to facilitate the ability of the student to learn and develop as a future professional.

When using hand drawings and hand modeling, a student's specific representation style is embedded in the work. The stroke of every line reveals an architect's mindset and care in their craft. The purpose of the professor is to guide the further development of this work and its potential. The same can be said for computer programs. These programs serve the student in a similar manner to the hand. Each drawing and representation is unique to the student; however it is from the digital realm. This digital style can make it more difficult to see individual differences when using similar programs. For this reason the types of software used in the studio are common, but easy to learn. Google SketchUp is free software for download, but has the least amount of detail and features. Grasshopper is tied into software called Rhinoceros, which is a 3-dimensional modeling software mainly used in academia, and less in the professional arena. The goal is to have student work with an easy to learn or familiar software with a minimal learning curve; however the final products from it are of very high quality.

Architectural design is inherently a decision-making process of which the making of new ideas (ideation) and representation are at its foundation. Designers typically move

from ideation to representation and then to multiple versions of a design (iteration).

Moving from the more abstract step of ideation, representation allows the architect to move from an idea to issues of quality of space, materials, construction, or in this case color theory and vegetated assemblies. With the continued and increasing use of computers for design, digital representation, and simulation, ensuring the design process does not become prescriptive, formulaic and driven by the computer, is critical.

The current steps in architectural design typically follow these steps, they inform each other, but proceed generally in an iterative manner to deliver a set of drawings to the client (figure 43). The developed decision support system or framework will target a specific part of the as-is studio method and attempt to inform students during this process and influence decisions, but will neither make decisions for the student, nor influence the fundamental aspects of the existing design process. In the future a more developed tool could be developed to inform representation. The as-is steps are: Site analysis, pre-design or schematic design, design development, construction documents or contract documentation, negotiation and bidding, then finally construction and contract administration. This process then culminates in as-built drawings. Teaching and studios in academia are focused on the pre-design/site analysis, schematic design, and design development, and rarely make it to the construction document phase.
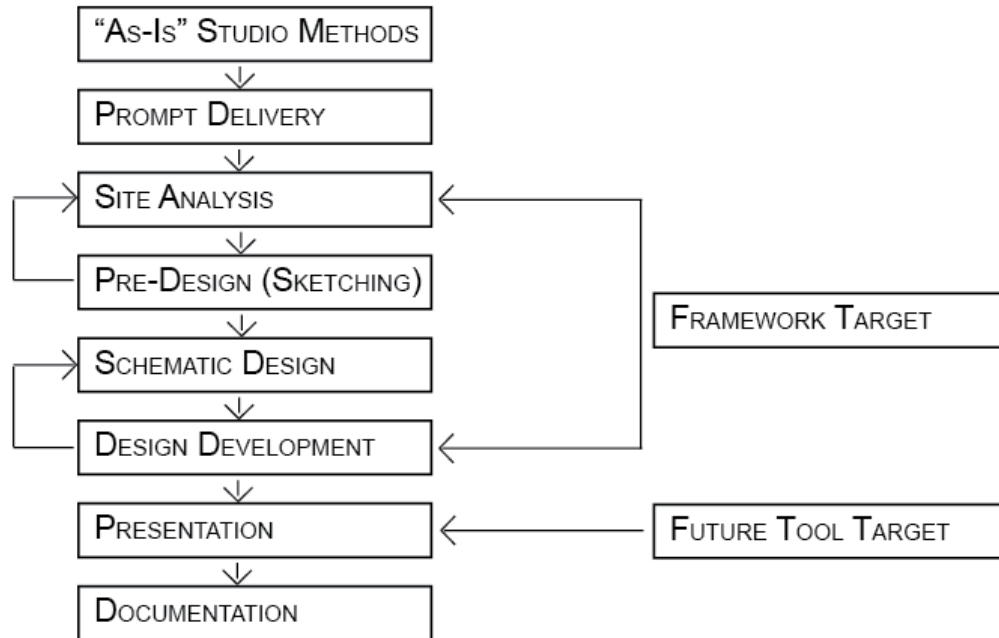
Figure 43: Current As-Is process for the design process in studio. This also shows the parts of the design process that the framework will influence.

Using Vegetated Assemblies in the As-Is structure?

In a studio, a prompt or brief is given to the students, and is used as the basis for design. This brief typically has base parameters for the project, its location, and any central themes that might be suggested to explore in the design process. The students then might visit the site to do site analysis and sketch out preliminary designs in a sketchbook. Then they might begin to represent these ideas in more refined representation at scale, but not typically in the rigid method of construction documents. Often these designs are drawings that resemble plans, sections, elevations, axonometrics, renderings or perspectives. Then these will be reviewed in presentations where the students share their work with the class, professor and interested third parties.

Typically these presentations happen more than once over the semester to discuss progress and other ideas that could refine the process. The core theme is that these projects might be completed for the purpose of the studio, but are meant to serve as a continuous process in exploring design to develop a personal or specific architecture for each student. This is not always the case as some schools have developed a master-apprentice method in which the students begin to mimic the methods used by the master. For the purpose of the this study, the methods employed will be those by the Virginia Tech teaching body as they are less restrictive and allow for a wider range of design styles and representations.

For example, when students are given the choice, will their method of representation be by hand, digital, or both? Technology has given students many opportunities and methods to design that simply were not available until recently. For example Photoshop, which is a flat rasterize program; and Grasshopper, a Rhinoceros plug-in, and Google SketchUp. At Virginia Tech, a group of students were given a two week project in the 2nd Year studio with the criteria to use vegetated assemblies. Their work was reviewed in relation to what types of design representation and methods were chosen and used by the students in support of their design decision making.

This research has at its foundation the evolution of iteration and representation, trying multiple avenues and confirming assumptions, which is a core process in a studio. This was so that the programs can be determined accurately for the larger study which is aimed at changing the way buildings are designed by creating a prototypical tool for the representation of vegetated assemblies, in this instance vegetated walls and facades and how they relate to color theory. The dissertation focuses on developing the framework

itself for a digital tool in the farther future. This future tool would accept a 3D model or photograph as input and then re-represent the elevation with the selected plants. These students and this study provide the foundation for that research.

The first tests for determining what information to include were done in Mario Cortes' laboratory. This first project used the teaching method of the second year studio and the two-week project module to determine how students interacted with a project based on previous experiences. By using a series of two-week projects, students were in an iterative mindset, and be able to make decisions about projects quickly, using the constraints provided by the brief and site efficiently. This project will also be a learning experience for the researcher, to learn how to lead a studio without support. It is important to take out the uncertainty of teaching experience as much as possible to limit its effect on the students during later and larger implementations of the new studio frameworks and the use and revisions of the prototype framework. Following is the studio prompt for the two-week project involving an amphitheater near the Duckpond on Virginia Tech's campus. The project is designed to get the students thinking about a larger site context than a singular location and the implementation of vegetated facades.

In summary this two week project will serve as the basis for the entire study in relation to triangulation and what methods to implement in the decision support system and much later, the prototype tool. However, the way in which this was done was as equally as important as the intent for developing a knowledge sharing device and its ability to inform, rather than make decisions for students.

Method Review for Implementation: Interpretivism and Tactics

The method used in the dissertation has been verified by five different peer-reviewed publications titled: *Fusion of teaching and research: design support tools and vegetated walls*, presented at ARCC 2015 in Chicago; a second publication titled: *Student-Driven Design in Architecture: Interacting with Reclaimed Materials and Passive Solar Techniques*, presented at SOLAR 2015 at Penn State in College Park; *Learning by Doing: Applying Vegetated Assemblies in Architecture Studio*, published in the November 2015 issue of Interface, by RCI, a roofing consultant's trade journal; *Educators as a Filtering Information Node: Design Frameworks*, presented at Passive Low-Energy Architecture 2016 Conference, in Los Angeles, and most recently in *Turtletown: design for your own backyard*, as a series of three blogs for Home Energy, a Berkeley, CA based magazine in 2016. The methodology explained here focuses on the theory that went into the study design.

The work from the first project in the studio informed the method of teaching and the method for the prototype design tool in the second studio. The content from the journals and the books of the first studio were critical in understanding, evaluating, and then improving the design methods and tools that can be employed by students and professionals. The process for reviewing the journals and books includes a combination of interpretivism and logical argumentation. From this first studio, a second studio was developed followed by a studio-like course environment (this is shown in further detail in figure 54).

This process uses three stages: data collection, coding, and memoing. What is interesting is that the stages are not complete at any time and can be returned to as new

information arises or new data is collected and reviewed by the researcher. As with

design, this is an open and iterative process to develop a decisions support system. In

figure 44, the mapping of interpretivism and tactics is shown for the development of the

decision support system or framework. The main process is to the left side, while the

main aspects of each step are detailed on groups on the right side. This process informed

the studio exercises and studio-like courses.
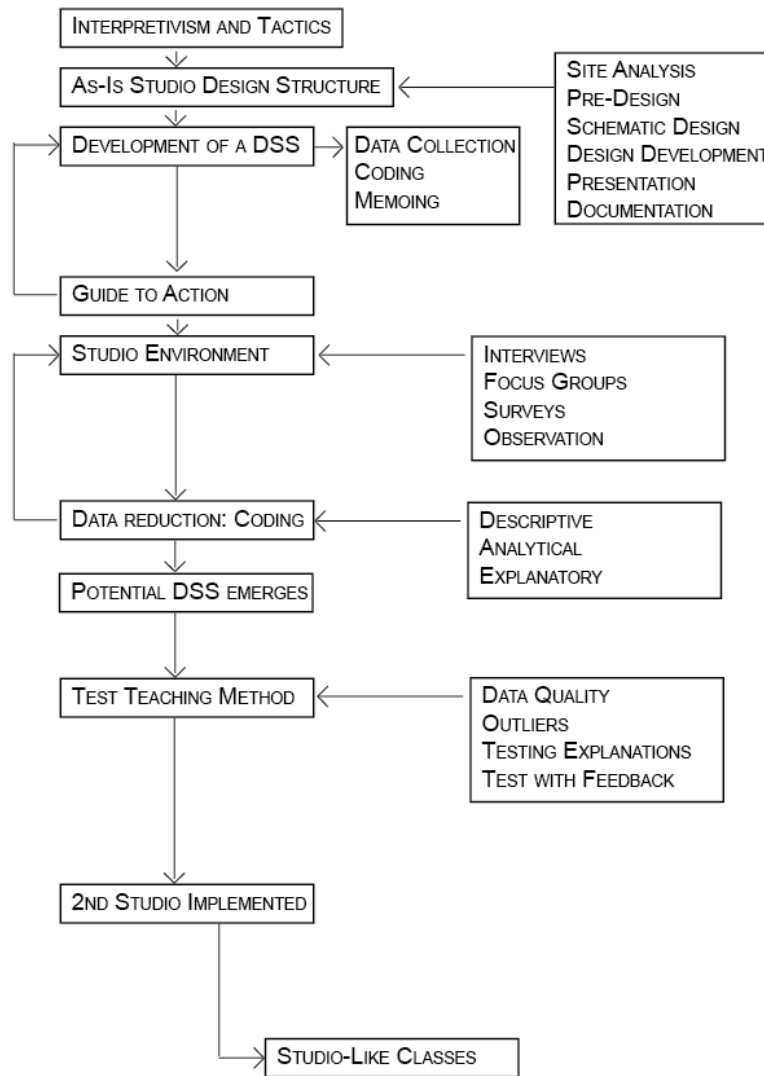
Figure 44: Mapping of Interpretivism and Tactics for use in understanding as-is structures and the inclusion of decision support systems (DSS) or frameworks within their existing methods. The main process is to the left side, while the main aspects of each step are detailed on groups on the right side.

Interpretivism, as described by Tim Schwandt in Groat and Wang, is the attempt to resolve "the paradox of how to develop objective interpretive science of subjective human experience" (Schwandt, 1997). To interpret something correctly, context must be given to not only what is observed, but the observer as well, thus the phenomenological nature is still key to Interpretivism. As Schwandt explains, "the inquirer constructs a reading of the meaning making process of the people he or she studies" (Groat & Wang, 2002; Schwandt, 1997). With the journals and the books, much of the content was interpreted in the context of the other journals, the studio, and the student.

When the students are interacting and working on the project and the journals, they worked with the journal in a self-reflective manner, rather than a simple chronology of events in the design. It was better to have them understand and articulate the spirit of the project and their experience with it and there was a unity of self and the educational and design environments. As Groat and Wang explain, "in studies of a phenomenological nature, such use of words may also be data" (2002). It is not just the words that can come to express the phenomenological interaction students have with the world, but also drawings and representations of architecture. When the journals and books were reviewed all of the content was coded and analyzed, as designers express themselves more often in representation, rather than simply words.

There are a number of tactics that can be used to create different sets of data and then reduce this data and code it for use in memoing a theory. Figures 45-47 reflect the data gathering stage of the framework and method which in this case were associated with the questionnaires. These figures are based off of the tables presented in Groat and Wang from Miles and Huberman (Miles & Huberman, 1994) (figure 45). The next stage

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is the data reduction and coding of what is gathered from the semester long studio study. Some of the data will be collected over the course of the semester and others will be garnered through the submittal of the final journals and project books with more examples in figure 46.

Tactics	Interactive Nature	Non-interactive Nature	Use In a Studio
Interviews	Personal Histories		"What is your personal architecture paper" Position Statement
Focus Groups	Discussions in small groups to test method Participants help construct questions		Studio Teaching Method Studio Presentations Student Journals
Surveys	Projective Surveys		Desk Crit
Observation	Student Observation	Notes of Behavior	Personal Journal Desk Crits Presentations
Artifacts		Interpretations	Books and Journals

Figure 45: Tactics for use in the studio and studio-like environments for developing the decision support system from the initial work in studio and the questionnaires.

Tactics		In Studio Method
Descriptive	Noting patterns and themes Seeing plausibility Clustering Making metaphors Counting	Midterm Presentations Final Presentations Desk Crits Personal Journals
Analytical	Making contrasts + comparisons Partitioning variables Subsuming particulars into generals Factoring Noting relations between variables Finding interviewing variables	Personal Statement Final Books Relations between student books
Explanatory	Building logical chain of evidence Making conceptual + theoretical sense	Books and Journals tested against the desired method

Figure 46: Tactics for reducing data and coding to find meaning in journals and books for developing the decision support system from the initial work in studio and the questionnaires.

The data was reduced from the student's work and was organized through interpretation to allow for future studio successes. These different tactics (figure 47) for coding, reducing, memoing, and then verifying the studio process and the prototype tool were critical to complete before the implementation of the second studio. This process of coding and memoing will need to be duplicable if more studios were to be implemented in succession in the future (see figure 54 for a detailed graphic).

Tactics		In Studio Method
Data Quality	Checking for representativeness Checking for researcher effects Triangulation Weighing the evidence	Multiple studios Multiple journals and books Multiple desk crits per student
Outliers	Checking the meaning of outliers Using extreme cases Following up surprises Looking for negative evidence	Comparing books and journals with positional statements Review preliminary books with student prior to final submission
Testing explanations	Making if-then tests Ruling out spurious relations Replicating a finding Checking out rival explanations	Cross examining all of the books and journals to each other to develop coherent methods and theories
Testing with feedback	Getting feedback from informants	Student review of teaching method in the journals

Figure 47: Tactics for testing the teaching method and framework for developing the decision support system from the initial work in studio and the questionnaires.

Design cannot be done overnight, the flexibility that a semester-long studio gives will be critical to developing of a working theory on teaching such methods to students. Also, this level of flexibility will allow for adjustments over the course of the study should new variables of interesting methods arise. Finally, the researcher needs to be sensitive to the artifacts that the students develop towards 'their own architecture' and the activities of the researcher do not impede the studio and allows proper development of designs and strategies. This method will create a large quantity of data and without a step-by-step procedure, the data cannot be used to its full potential. By participating or teaching a studio as completely as possible, with student life and design, a useful design tool and method can be developed.

After using the coding, data reduction, and memoing method, the second two-week studio module and associated exercise and questionnaire was implemented as a supporting step in verifying the teaching method used in the first studio (see figure 54). By reviewing what the students found to be useful or unnecessary, the methods of teaching, using the studio conducted in the context of the studio culture of Virginia Tech, both the teacher and the students worked together to create a positive and effective learning environment. Of course much of this was determined at the time between the first and second studio. Much remained the same, but tweaks were made based on the results of the first implementation of a studio. This process hinged on the fact that more experience in teaching and using the prototype decision support system or framework then resulted in a more cohesive teaching style for informing the students.

This review of the first studio method in relation to the second method is how teachers can continue to have a learner-centered approach to teaching, configuring the studio and adapting it to the students' needs rather than for simple convenience of the teacher. This is why the procedure was to use the analysis from the first studio to inform the second. The same studio prompt (figure 48) allowed for a whole new set of ideas with the same vegetated wall requirement, increasing the potential for new ideas centered on a theme. Changes were made to make the prompt clearer but the analysis of the work from the second studio was kept similar to be able to compare the two years.

UH 3004
Focus Project: The Choreography of a Living Wall:
A Framework for a Living Wall

Fall 2015
Instructor: Kenneth Black
400X Cowgill Hall
kenblack@vt.edu

This project seeks to explore the boundaries between nature and its application in architecture. This project will serve as an exploration into what a vegetated wall can be when designing an amphitheater at Virginia Tech in the context of a specific site.

The project is located near the president's house up the hill from the duck pond, across the road from Hillcrest Hall on the site of the old WPA amphitheater. In the project it would be ideal to be able to explain its sense of place, so please visit the site when reacting to its conditions. It is under the tree cover inside the red box in the image. This project has the opportunity to serve as a place to engage in thought and metaphysical space. Treat the project as an extension of the surrounding area.

Some things to consider are issues of sustainability, vegetated walls, and water recycling for the living wall and amphitheater intervention. The project interventions can be made of any materials.

Finally, each student will also maintain a work journal that describes their process and evaluation of the studio and professor (Ken). This is essentially a word document that shows what you did each day, how you did it, and your thoughts on the teaching method (expectations and results). Please keep track of all you work as you will need to turn in a digital copy of the work in the form of a portfolio presented at the end of the project period.

Program:
        Metaphysical Room 100 ft2

Figure 48: Example Prompt for a 2nd year lab. This site has been used for a number of projects including the metaphysical room, amphitheater, and museum of water on the Duckpond. In this prompt that only programmatic requirement of the amphitheater was to a have a single, 100 square foot room within the site.

Fusing Research with Common Studio Methods

While a prompt (figure 48) guided the work of a studio between the teacher and the student, the use of a teaching philosophy was important to the guide researcher/teacher through their own teaching. This philosophy is something that evolves over time and responds to new experiences. Taking the tactics and methods explained by

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Groat and Wang (2002), they can be adapted for use in a studio, design exercise, and questionnaire.

Next is to implement a studio where the students feel confident that they can explore without risk. Students are inherently worried about their performance, and we as teachers must show that learning is not always tied to assessment. Then a known and explained studio culture is necessary to understanding the expectation of a studio to the students beforehand. In the syllabus there can be the project prompt so that the studio can begin with a project in mind. During the studio period a journal or sketchbook is kept to chronicle decisions and express thought on the project and studio. Finally, in some studios each student will produce a book on the work done during the studio as a final method of representation after final review presentations.

From this overview, in the future a curriculum will be established for a studio application using vegetated facades. Before the end of the dissertation two studios experienced a teaching method based on how color theory interacts with vegetated facades and how this was applied to both hand and digital representation. The work created from the study period will be used as references for the development of further studios, teaching methods, and representational methods for the researcher or professor. The work will also see if any students engage the vegetated walls in regards to color theory without direct instruction (see figure 54).

The elements of a studio are critical in determining the ability of students to not only learn material, but design to their full capability. To review, I believe the necessary components to a studio include a known studio culture, prompt, journal (sketchbook), reviews, and final book. A judicious amount of professor involvement without being

overbearing is necessary to develop interactions among students and between students and the professor, and to have helpful presentations and meaningful desk crits. All of these help to develop the student's ability to speak to and represent their design work. The concept of a studio is important to a greater understanding of design through exposure and experience. These studios should not be forced; there is a time and place for all experiences.

In the curriculum set forth by Virginia Tech, setting a vegetated assemblies studio would be best during either semester of fourth year for those students who do not participate in Europe travel. The second half would better serve the students as an introduction for thesis. This would turn fourth year into a new experience rather than being perceived as a requirement for thesis year. Given the limited nature of the ability to teach such a course the more likely scenario is a charrette or short design project with 2nd year students. This is because these students are just being exposed to the design process and there is a culture of shorter, faster design projects where one could be about vegetated assemblies.

The first element is the studio culture. This document serves as an introduction for the students to the new studio environment. Typically it is a reference for the student, but is commonly filled with information should the need for it arise. While this is something that can be written down, it is also an atmosphere that the teachers and the students all provide for each other and is reinforced by the activities of the school of design as a whole.

The sketchbook facilitates the student's ability to be self-reflective, and to be able to review their personal work and design method. The students will record thoughts or

sketches over the course of the semester. These recordings should pertain to the studio

project or to similar concepts in design. The purpose is to have the students be able to

articulate and write about their own and their studiomates' projects. They should also be

able to chronicle the method and design process they implement to the project design.

Finally, the journal will allow them to critique the teaching method used in the studio in

detail and at leisure rather than only at the end. Again, this journal will be a part of the

participation grade, but not reviewed for content until after grades are completed. This

allow for candid and honest review of the teaching method and process without perceived

repercussions. An example prompt for a studio could be as shown in figure 48. These

concepts will be discussed further in the results section as the development of how a

prompt ties directly to the work that is then designed.

The final studio book is a compilation of work from the semester. This final book

or box is separate from the journal. The difference between the book or box is that the

book is a bound copy, while the box is set up more like a series of plates. These plates are

the equivalent of stand-alone pages. The box also becomes an opportunity to design. The

book will allow the student to write about the project, show a series of work, to practice

for the thesis book for documentation. The book will cover the topics the students explore

in relation to the site and vegetated wall. It will show the site proposition, design process,

and final product of the design. The open format and page size allow the students to

explore different methods without being confined to a particular set of requirements.

The work from these books was used to see how students implemented the

decision support system or framework, while infusing their own personal architectural

style. The images and work was used in the research so I, as the researcher, asked for

permission from particular students to use their images and work for analysis. From the

collection of these images and the self-reflection on their individual methods, a synthesis

of the different methods was devised and used as an introduction for subsequent studios

update and revise the decision support system and to informed future attempts at how to

use decision support structures as knowledge sharing devices.

Mapping a Decision Support System into a framework

   This is the beginning of how the decision support system was used in terms of a

developing a visual framework and its verification. The next concept was the use of a

questionnaire and exercise to inform the development of the prototype interface map. The

questionnaire was used at multiple stages to verify the direction of the research. This

series of tests took 'experts' that evaluated the usefulness and the interface of the tool and

determined next steps of the direction of future development. The initial chaotic map of

the prototype framework interface is below without any student input in figure 49 and

with review in figure 50.
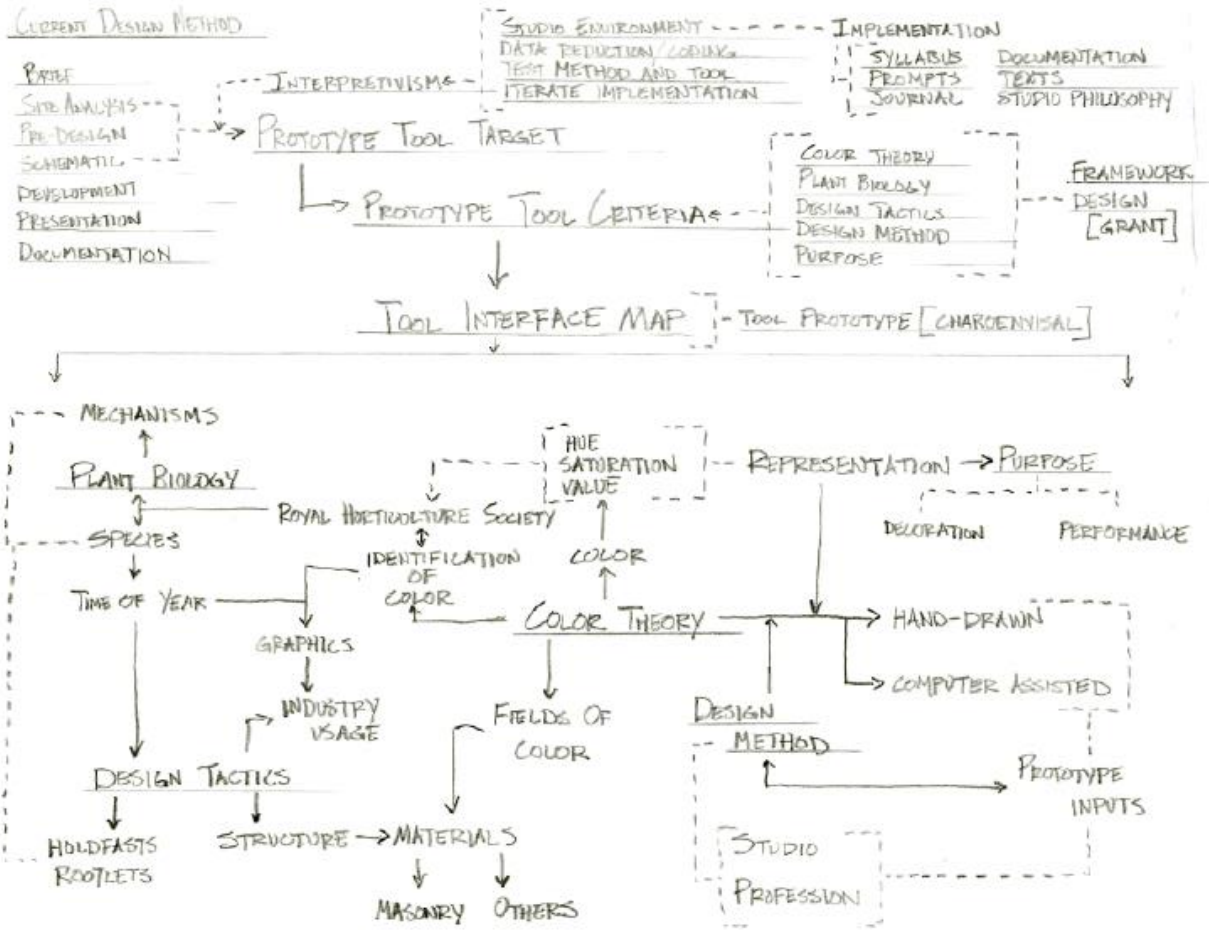
Figure 49: The initial interface map for the framework without any review or visual refinement from the researcher or the questionnaires and comments from the student exercises.
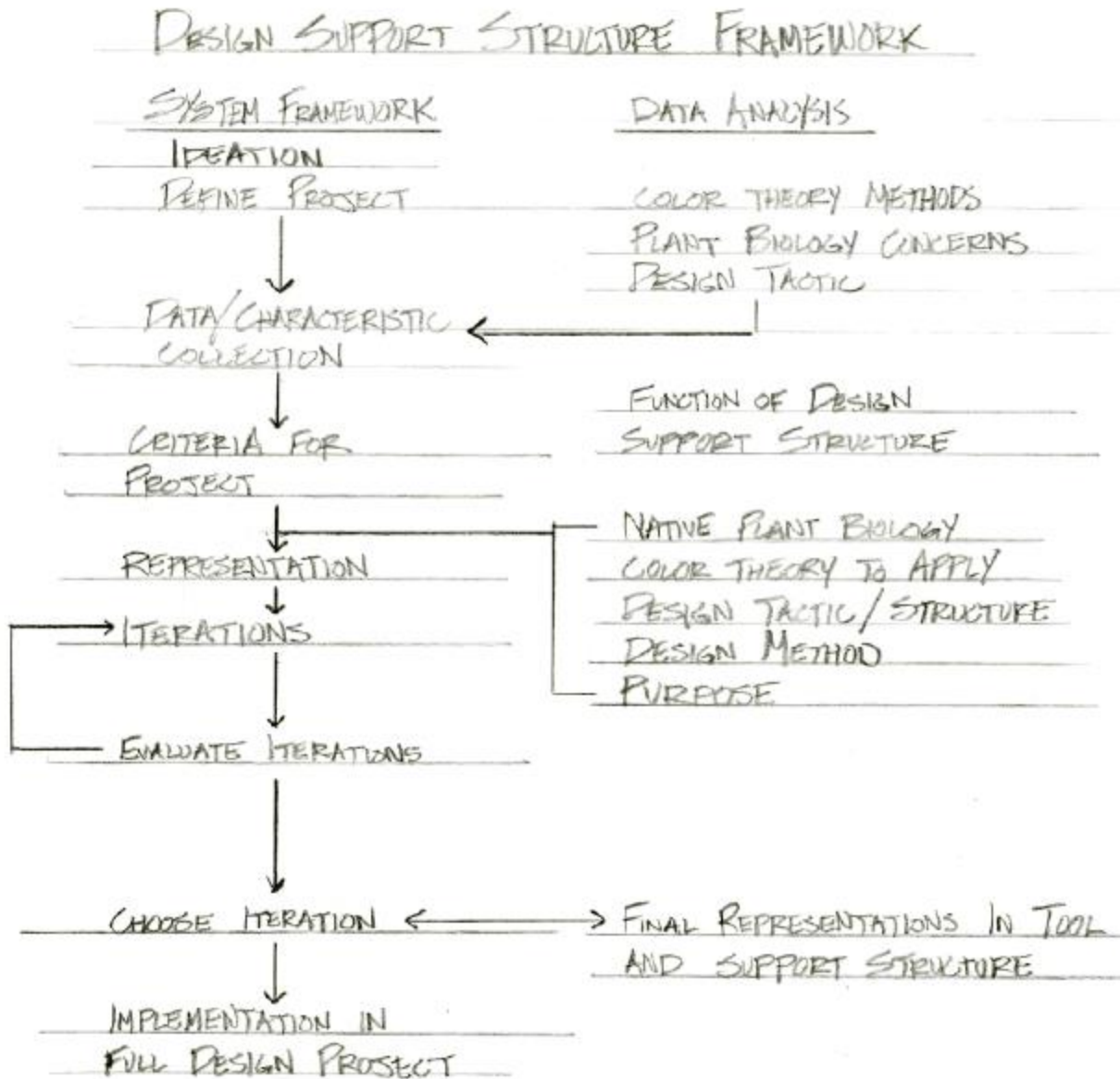
Figure 50: This is the basic preliminary framework serving as a summary for the following work after refining the initial chaotic interface map in figure 49.

Using this map, a process and framework was developed to allow users (the student experts) to engage the criteria explained in the framework section (color theory, plant biology, design tactics, design methods, and final purpose), in conjunction with interpretivism and the as-is design methods in a studio environment.

How to Show a Cognitive Process: Business Process Modeling Notation

With all of the information that has been gathered, what would be the best way to present it so it is easily read? It could be presented as paragraphs of information, but many people might not find information quickly. The framework needs to present a process in an organized manner, hopefully using a standard that many people know or could easily recognize. One such method, Business Process Modeling Notation, will be used for this framework.

There are also multiple methods that the framework could be represented. There could be a physical version and a digital version. The physical version would operate as a series of appendices. However this might be a little cumbersome, especially when bound in a book. There could also be a digital version on the internet, but not everyone might have access to this, especially in poorly served areas. Therefore both a digital and physical version were made, used, and tested to serve the needs of as many people as possible.

This means that the framework relies heavily on sight. Furthermore, due to the feedback and demand for audio or video tutorials or even simpler explanation, the framework will have other methods of representing the thought process. Depending on the method of tutorials used, the framework mainly will be seen visually, but also could be recorded to be heard. The recorded version could also have visuals, but would not rely on them to convey information solely. For the dissertation, a physical version and a digital version with more in depth examples were made, while future video and audio tutorials are planned as extensions after the dissertation research.

The goal of the framework is to help designers to make decisions, not to make decision for them. The role of decision theory is important in the work and its outcome of a physical and digital artifact. First is determining which of two cited representational methods to use in the framework. The literature serves as the basis for what standard graphical representation method would be included in the framework, so a method of graphically representing the framework needs to be selected. There are two main options: IDEF (Integrated Definition) and BPM (Business Process Modeling) as graphic process mapping techniques. IDEF seems to be more of an engineering standard, with a more rigid set of graphics and organization, often used in Department of Defense applications. The model and its graphics are very concise and detail can be added until the level of rigor desired is established. This is simultaneously its greatest strength and weakness, as often only subject experts can fully understand the breadth of the graphics.

Furthermore, the model is so abstracted that it might be difficult for new designers to understand the sequence and activity-based work associated with each fundamental step of the framework (Knowledge Based Systems, 2010). For these two reasons, BPM is a more desirable choice, being perhaps less intimidating, having more graphic variance and less rigidity.

BPM is more open to graphic variance and larger groupings, rather than more of a program-based flow chart that IDEF creates. BPM, and its notation (Business Process Modeling Notation, BPMN) come from systems engineering, to determine suitability for modeling a process of a business for improvement (Dufresne & Martin, 2003). This mindset is similar to how I, as the researcher, view this dissertation: as an improvement of a process, not creating a new process. BPM will also allow for the analysis of the

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design method as a process so it can be understood in greater detail for every student and how they chose to implement the framework in the larger process of design. Figure 51 shows the graphic pieces that were used from BPMN to represent the processes from figure 50. The five main pieces are ideas or concepts shown by boxes, pathways between these concepts shown by arrows, decisions to be made shown by diamonds, possible associations shown by dotted or dashed lines, and beginning and end shown by circles.
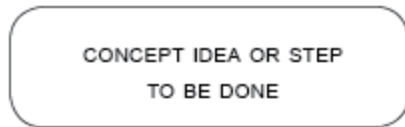
A box is used for ideas or steps that are important top the process at hand. These can be placed within a larger series to sort streams of larger processes within the overarching theme.

An arrow is used to show the pathway that ideas are considered or completed within. Often this makes many decision support systems appear linear, however iterative loops are often common as well.

A diamond is used to denote a decision to be made in order to proceed. In the case of the dissertation this is the desire to use or not to use the framework or include vegetated assemblies.

A dotted arrow shows where different concepts may have associations that influence decisions or information that is useful to each step of the process being completed.

A circle is used to show the beginning and the end of the process that is being shown.

Figure 51: This shows the graphic pieces that were used from BPMN to represent the processes from figure 50. The five main pieces are ideas or concepts shown by boxes, pathways between these concepts shown by arrows, decisions to be made shown by diamonds, possible associations shown by dotted or dashed lines, and beginning and end shown by circles.

Given that the framework was constructed using the principle of Business Process

Modeling Notation, the preliminary framework was redone with the proper notation as an

example of the proposed method. The content of the framework was not changed,

however the initial flow of information and inputs and outputs was vague and confusing.

This does not mean that it cannot be understood, but rather if a student was going to use

the framework, it must be as clear as possible. Techniques and methods, such as a

framework like this, can be eliminated very quickly if graphic representation was

overwhelming, unclear, or taxing to implement.

This was the reason BPMN was chosen for implementation in the graphic

representation of the framework. Through the use of different flow objects, activities,

gateways, and connections, (boxes, arrows, diamonds, and dashed arrows respectively)

information was understood through the graphics rather than from an expert level

intuition as different levels of detail can be separated into other frameworks or annotation

(White, 2006). Though there were a wide variety of graphics and BPM could be just as

complicated as IDEF. However, BPM gave the researcher/designer more opportunity to

design a beautiful graphic, rather than a completely standardized one.

For the purpose of the dissertation, the methodology tenets of BPMN will be

used; however the modeling software that a particular company uses or produces will not

be used. This is due to the fact that color types and graphical representation are limited,

and the programs themselves are restrictive. More pragmatically, I, as the researcher do

not have the time or expertise to code the graphic completely. However, by using the

proper graphic standards set by BPMN 2.0 (the latest version) a future student could

easily translate the program across and into a prototype tool from the framework or the digital website.

To introduce decision theory in the dissertation, a summary from previous work begin the discussion of using decisions in design. This text is from *Fusion of teaching and research: design support tools and vegetated walls*, presented at ARCC 2015 in Chicago (Black, Jones, Cortes, & Grant, 2015).

> "Second, decision theory or decision-making theory is centered on the processes and steps that go into determining proper choices, based on a series of criteria. Decision theory resides in situations where one is making a decision in response to a problem without a clear, single answer (Hansson, 2005). While this definition of decision theory is more general, there are specific constructs or methods related to design, including design support structures (DSS) and decision support processes (DSP). These structures are less about making the final decision for the designer and more about supplying the designer with information with which to make an informed decision (Cross, 2007, 2011). The experience of the designer helps him or her to use the DSP to design more effectively."

What is the theoretical basis for making decisions outside of design? Frameworks are not new to decision theory and often serve as a supplement to a larger question, often as a support structure. For the dissertation the terms framework and decision support structure or design support structure have been used interchangeably. A design support structure is

created and maintained by decision theory. This theory is the method for how decisions are made, in what order, and which take precedence over which at each given point in the process. The general concept is that the inputs of color theory, plant biology and design tactics, such as materials or clinging mechanisms will be used to provide a framework. This dissertation will focus on the framework and not a prototype tool. At Virginia Tech, two dissertations pertain directly to the process of making a framework, and then later, transforming this framework into a prototype tool to compare to the previous work by Dr. Elizabeth Grant (2007) and Dr. Charoenvisal (2013).

As projects use the design support structure they will evolve as data and criteria become more defined. Once again, this supports the fact that the design support structure and later the prototype tool are both a part of the design process, but not a replacement for the decisions of the designer. This tool is simply that: a tool, not a replacement for the designer. These two tracks that were developed of the system framework and data analysis are explained graphically initially in the figure 50. This framework in figure 50 shows not only the framework, but also the next steps that would be completed with the creation of a prototype tool to represent the vegetated assemblies.

This occurs at 'choosing an iteration', as the representations of the decision made by the designer would be composed by the designer, not supplemented by a prototype tool stopping with the initial framework proposed by the dissertation. This separate representation would be done by hand or another CAD program. Figure 52 shows the development of the decision support system by taking figure 50, updating it for content and the revised comments from students and its use, then applying Business Process Modeling Notation as the form or graphical representation to a systematic approach.

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DESIGN SUPPORT STRUCTURE [FRAMEWORK]
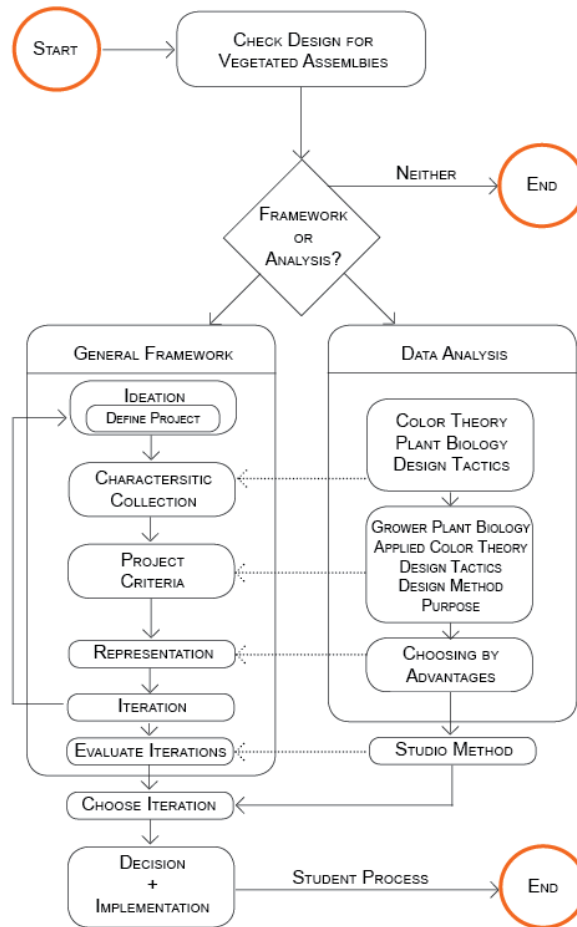
Figure 52: This is the graphic representation using the Preliminary Framework for designing vegetated assemblies in reference to color theory [overview] using Business Process Modeling Notation.

This decision support system or framework is different from a decision-making framework which defines and makes decisions. A decision support system such as this framework informs the designer within a set of chosen criteria in relation to a larger design project at hand and allows the decision to be made by the designer (figure 52). This framework (figure 52) has two parallel tracks, the is the method of how the system will be conducted and the other is the actual gathering of associated data and information in respect to color theory, plant biology, and design tactic (structure, materials, and

attachment mechanism). Depending on the situation there are other factors: design methods (hand-drawn or computer-aided) and purpose (decorative or performance). The framework continues to use the main topics found in design of ideation, representation and iteration to inform the use of the tool and its criteria. This framework shows the five main aspects to the development of vegetated assemblies in relation to color theory. These five main aspects are native plant biology, color theory, design tactic, design method, and purpose. The graphic in figure 52 shows how each with further explanation, relates to the subtopics that are present in each major criterion.

From this framework (figure 52) more detail would be added and the notation refined resulting in figure 53. This process of refinement used multiple studios, questionnaires and design exercises over multiple years to determine the use of the framework, in what types of courses and in what manner. This second series of testing of the process was implemented as a combination of a questionnaire and design exercise in a studio environment to measure the decision support system's effectiveness. A final questionnaire was used among student experts to see if the prototype decision support system was more suited for academic development or use in studio (see figure 54).

A survey was included in the use of the design framework based on the expertise of the individual. The survey included questions similar to the following, and used a Likert scale from with 1-5, one (1) is strongly disagree to five (5) strongly agree. Students from a 2nd Year studio in 2014-2015 I assisted with received this survey (as a post-then-pre questionnaire) after completing a vegetated assembly prompt (figure 48), over a two-week period without using any decision support system.

Part1
Did you include vegetated assemblies in your studio project?
Were you interested in vegetated assemblies before the project?
Have you used vegetated assemblies in a project before?
What kind of drawing techniques did you use? (You can select both)
What kinds of techniques did you use during the project? For example what kinds of pens of pencils or paper for hand-drawing, or what programs for computers?
I understand the considerations involved in designing vegetated assemblies.

Part2
A design tool for vegetated assemblies would be helpful in your design process.
Architects provide valuable insight to vegetated assembly design.
I understand the benefits and qualities of installing vegetated assemblies.
I understand how I can design vegetated assemblies in studio.
Building users provide valuable insight into the design of vegetated assemblies.
I understand the risks and complication to design be including vegetated assemblies.
I have familiarized myself with other projects that have used vegetated assemblies for the project.
What were some of the projects?

Part3
I know the general types of vegetation that will thrive on a vegetated wall.
I know the general types of vegetation that will thrive on a vegetated roof.
I know the general types of vegetation that will thrive on a vegetated facade.
I understand the difference between the various types of vegetated assemblies.
I understand the major obstacles to implementing vegetated assemblies.
Vegetated assembly suppliers provide valuable insight into vegetated assembly design.

From this initial exploration to how the process was currently performed in the studio without the assistance or use of a decision support framework, the framework can begin to reflect the nature of the design process. This framework was introduced back into the studio environment with the same students in the Spring Semester of 2015 in a design exercise to see how the design process was influenced and assisted by the addition of the framework and its improvement using the framework in a shorter one-day design exercise. The student only received paper versions of the decision support system, which was appendix pages A1-A6, the only pages available or developed at the time.

This exercise helped to determine if the prototype framework is balanced and does not favor a particular type of style of design. One of the main driving factors is to confirm that the prototype tool does not favor a particular system or method of design, and is a scaffold for design support. After this phase of reviewing the prototype decision support system (A1-A6 in the appendix) in a studio on theoretical projects, the framework was used on the RDF projects in order to more thoroughly understand about the developed process through the use of immersive case studies. This process allowed the researcher to learn more about the design process while using the framework and how it related to the actual constructed building and its relation to plant biology, color theory, design tactics, design method, and purpose.

After the framework and process was reviewed through the use of the immersive case studies, the framework was revised again and then used in another questionnaire stage the following year in 2015-2016 form the 2nd Year studio I was assisting with. This involved using experts in the form of students who have architectural design experience. This 2nd Year studio covered the students at the beginning of their prospective design careers, who could benefit from the decision support system. The same questions were used as in the first studio exercise and questionnaire and in the second, later, revised studio exercise and questionnaire design, as well as any questions developed from the use of the framework in the immersive case study. From this second questionnaire and exercise, the framework was revised and the used again in another studio for a final implementation before considering for use in studio as a design support structure without the researcher's presence or supervision. At this time the framework would still be in its infancy, and would be continuously developed over time (see figure 54).

3.2 Summary and Significance of the Methodology

Four major steps were used to validate the work and to revise the framework decision support structure. First, the as-is or existing studio environment needed to be understood to determine what was critical in its design. This resulted in three peer-reviewed publications verifying the intent of the framework: "Fusion of teaching and research: design support tools and vegetated walls", then "Student-Driven Design in Architecture: Interacting with Reclaimed Materials and Passive Solar Techniques" and most recently "Learning by Doing: Applying Vegetated Assemblies in Architecture Studio".

From this initial beginning the framework was reviewed by students over two years to determine what worked and what needed improvement. The students went through the use of the framework in the survey and indicated what areas they worked with and then what would have assisted them better through a hour-long questionnaire while using the framework. Some of the major issues were the lack of time to utilize the whole framework, the desire for more examples of past projects that used the framework, and in what manner they could use the framework.

From this critique, three major case studies were developed to better explain the framework along with updating the original interactive web application. The three case studies were Turtletown, the RDF Wall Project (Solar Lounge), and the Solar Garage. These projects are under review for publication; one in an online magazine called Home Energy (Turtletown) the other for a daylighting competition (Solar Garage). All three of these case study projects are full-scale constructions. The framework was also reviewed in studio-like courses such as the Metaphysical Room with the University Honors

program which resulted in a peer-reviewed publication titled: "Educators as a Filtering Information Node: Design Frameworks". This class is still being taught in the colloquium UH 3004 series in the Honors Program. This work reviews the process of translating studio into non-traditional settings, and learning how the framework might help inexperienced and experienced designers to work together.

All of this combined to influence the revision of the framework for the second version of the online web application, free to the public. This revision largely had to do with the representation of the framework from Business Process Modeling Notation to a more recognizable interface and the inclusion of design and plant examples. While the process and methodology of the resulting decision support system is straightforward (figure 54), the significance and implications of teaching future professionals is astounding. One of the most important qualities that a designer must have is the ability to be self-directed and interested in the profession. This is sometimes assumed, rather than confirmed or instilled in students. We, as educators assume that students are interested because they chose to be in college. Every student is different and the means and reasons for being in the studio are different. Therefore the method and final overview framework (figure 53) are there as a means to an end for showing students their own potential.
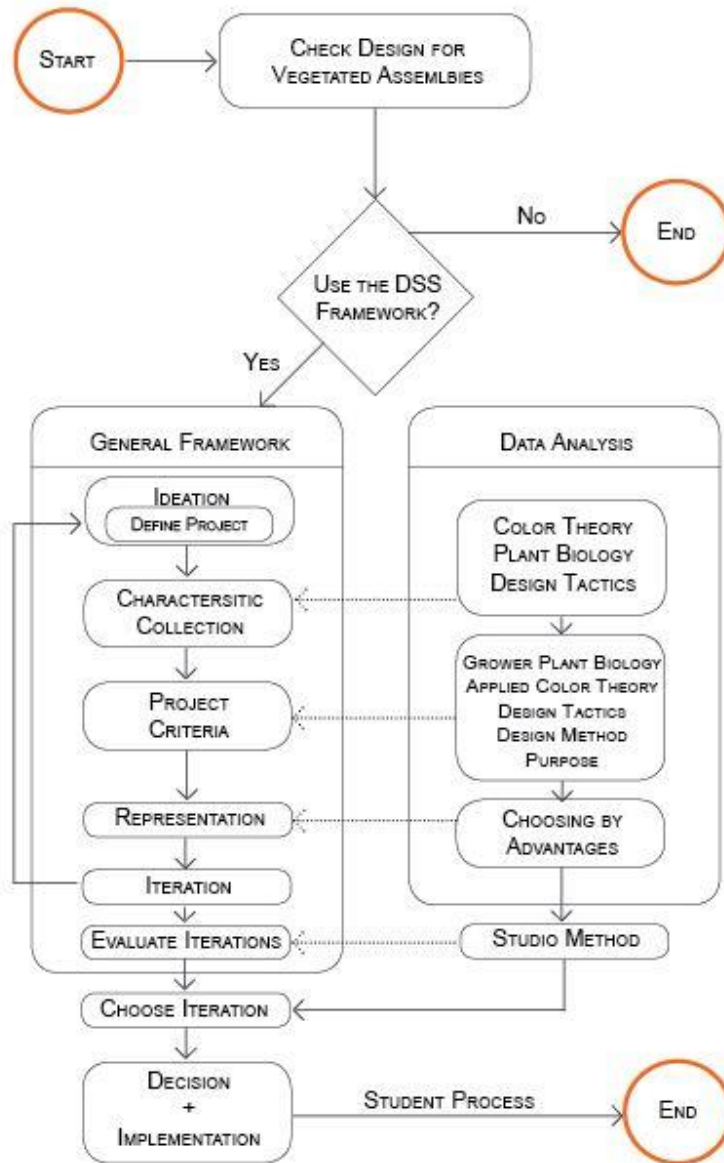
Figure 53: This is the final overview decision support structure developed through the work of the dissertation. Many other pages were added to the whole decision support system, resulting in a large appendix system and digital website. These pages are shown in the appendix and the website is available currently at www.livingwalldesigner-prototype.org.

2013

Spring 2013
Undergraduate Thesis: Dimensional Architecture
Beginning planning of the Master's Work

Winter 2013
Master's Project: InHabit
Final Planning of the Solar Garage Project

2014

Spring 2014
Watercolor Studies and large scale protrait
Leaves, Frank Lloyd Wright and abstractions

Summer 2014
Writing first three chapters:
Introduction, Literature Review, Methodology
Topic selected: Color Theory, Vegetated Assemblies

Fall 2014
Preliminary Proposal to committee
Master's Conferred December 2014
ARCH 2015: Second Year Studio 1 Questionnaire

2015

Spring 2015
ARCH 2016: 1st Design Exercise Ends
ARCC Publication

Summer 2015
Higher Education Study in Switzerland
SOLAR Publication

Fall 2015
Preliminary Framework: revised A1-A6 Completed
ARCH 2015: Second Year Studio 2 Questionnaire
UH 3004H: Metaphysical Room 1

Winter 2015
UH 3004H Studio-like Course interpretation complete
Interface Publication

2016

Spring 2016
ARCH 2016: 2nd Design Exercise Ends
ARCH 3056: Large Scale Class Study
UH 3004H: Metaphysical Room 2

Summer 2016
PLEA Publication
Immersvie Case Study: Turtletown Finished
Immersive Case Study: Solar Lounge Finished

Fall 2016
Full Detailed Framework Completed
Immersive Case Study: Solar Garage Finished
ARCH 2016: Second Year Studio 3
UH 3004H: Metaphysical Room 3

Winter 2016
Complete rough draft Dissertation Book
Website livingwalldesigner-prototype.org complete
ARCH 5045: Teach EDR Course

2017

Spring 2017
Edit Dissertation
Home Energy Blogs Publication
Defend Dissertation
ARCH 2015: Co-taught, no Questionnaire
UH 3004H: Metaphysical Room 4

Figure 54: The chronology of the dissertation showing the order of the different years of the 2nd Year studio, studio-like courses, large scale lecture study, questionnaires and associated exercises, and resulting immersive case studies and publications.

This method (figure 54), developed not only a prototype decision support system or framework for designing vegetated assemblies, but also a newly developed process for designing vegetated assemblies for the researcher as a personal design philosophy in architecture. This lies in the concept of developing and refining your own architecture, its process, and representation. I personally use the framework as something to push back on as an example of what could be and ought to be, but is not necessarily an ideal architecture.

Phenomenology looks at how we interact with the world and how these experiences form our perception of the world. These topics of vegetated assemblies, color theory, plant biology and their synthesis give researchers a basis for interacting with a situation. It develops what is our filter, our lens, which informs our course of action. Every researcher as a lifelong-learner or student has a different set of experiences that leads them to be the person that they have become, are, and will become. In design there is a combination of what we want to become (desires, goals), what others see us becoming (reputation), and what we came from (experiences). These three things show us how people make the decisions that inform their own architecture and how it is perceived and developed.

Educators and students are not statistics in a system, but, that if we put in the time and effort, there is the opportunity to become an expert in our own spheres of influence. There is a struggle, but it is the goal of what educators and students wish to become that drives most to continue. By pursuing goals, we slowly alter our impressions of that which is within. For example, at the beginning of my undergraduate studies I had never drawn before – I chose architecture – and after eight years, I can no longer imagine explaining

something without somehow using images somewhere in the discussion. As a student, researcher, and educator, I have started to hear the stories of others and have the opportunity to see an entire lifetime of choices, actions, and learning infused into a person. These are lessons that can not only inform our own path, but can be transferred to others as we continue to teach, or practice our profession in the future.

Therefore the method of teaching and developing the prototype framework through a studio or studio-like environments allowed students to have an opportunity to create the method in conjunction with the researcher. This uses the process of teaching to define the method and implementation rather than impose a method on the students. By teaching more than one studio, these multiple iterations refined the researcher's the method of teaching. More teaching experience hopefully means that inexperience on the part of the researcher/educator will become less of a factor.

The most critical part of the method is that the students are equals in the research process and are an integral part, not just the subjects. The method allows for choice in the development of vegetated walls and the creation of an individual context for each project. The method creates a cohesive teaching method, but allows for a variety of final projects and design methods. The method is not looking for a uniform product, but a relatively similar method amongst the students by allowing for hand drafted and computer based designs.

Significance of the Method on the Role of the Researcher

The significance lies in developing a personal stance on teaching in architecture and a knowledge sharing device in the form of a decision support system. It is the

tradition of interacting with and understanding materials, of making and doing, that has been an enjoyable process of design. At Virginia Tech I have been highly involved in constructing projects at full-scale including a deck and planter system for vacant lots, experimental wall sections, a prototype wall assembly for a bus stop, with completed projects for a Solar Garage and Solar Lounge, with planned restoration projects for the 2003 Solar Decathlon House. This has required combining technical skill, with training certifications and learning, but also an experiential knowledge of building from using the wood shops at the Research and Demonstration Facility in Blacksburg.

In the process of designing at full-scale I have found that many students are interested in building. So much so that the newest funded project, the Solar Lounge, was proposed by students to me from a related studio project, reviewed and then submitted for and received funding. The exciting part is how students, after learning of these opportunities, took active measures to advocate for their own learning.

We, as designers, use what has come before as a basis for our current work. We inform it through iterative design while considering the place in which it resides. This is done through drawing and modeling, so we gain experience through our own personal engagement with the discipline. For me, my hope was that the framework would inform the decisions that students made while designing. There is nothing better than the spark and enthusiasm students show when they begin to enjoy the discipline that will become their life's work. I believe that the framework, as a decision support structure, did this through exposure to more information, resulting in improved and informed decision making, rather than questionable decisions.

Chapter 4: Results

4.1 Results: The Framework

Overview:

The thing in itself often does not show the time and effort needed in developing the object. The concept behind the framework and examples of students using the framework gives it meaning. The words, circles, and boxes on the page have a purpose: to give a designer information that will help aid in their decision making. If nothing else it is important to recognize that this framework is a decision support system, a way to frame the project, the work that a person designs. It supports, it does not make a decision for you.

Introduction to using the Framework

This support comes from experience and observation, things that we can build upon for the rest of our lives, and still have perspectives that elude us, or senses that deceive us. Because I am only one person, feel free to change or augment the framework as you wish, the one here is a general framework to help you get started and, over time as experience builds, there is the opportunity to fine tune it to your personal design method.

The key portions of the framework are presented here with short descriptions of each page. The decision support system or framework is presented in its entirety in the appendix. The digital version is also available online at livingwalldesigner-prototype.org, specifically more examples of work. The framework here starts off more general and becomes more specific as it dives into topics. The last part is a summary of the design process to help those who are new to an iterative design method. This portion asks the

reader questions to think more broadly about design and representation, specifically from

an architectural perspective.

There are two main types of pages, overarching themes such as plant biology,

color theory, or design tactics, with subsequent subtopics. Each of these has a similar

format with similar information in consistent areas of the page. Design is an open-ended

adventure. There is not one sole correct answer to a design situation and that is what

makes it so invaluable. For every designer there is a different proposal to a given task.

This process can be summarized in three steps, sketched out here in figure 55.

Figure 55: This process shows the three main concepts of the general design process, starting with
ideation, moving to representation, and then looping to iterations.

Finally, it is important to remember that when you design it is supposed to be fun,

enjoyable, and you give meaning to your work.

The framework is written in BPMN which is business process modeling notation.

This makes the framework look similar to a flow chart. This does not mean that to design

you must do every step and every topic to have a complete design, it is a reference. Major

topics are then explained in more detail in following pages. For example in Color Theory

there are hue, saturation, value, and graphics. As the designer you could choose do them

all, only one, or none of them, ignoring color theory in your design.

Appendices A0-A6 are topical overviews of the major topics. Appendices A7 -

A23 serve as introductory information to each of the topics for instance, hue. They are a

reference for projects, but the final decisions are left to you, the designer. After each, go back to the main topics A1-A6 to find other information. Appendices AB-AN are a review and introduction to the iterative design process for new designers. These appendices are an introduction to the design process and much of the information revolves around developing or using a personal process of designing architecture, but there are appendices that pertain to design in general and design representation of drawings both analog and digital.

The point of the framework is to serve as an introduction to these topics and also to assist those who have not seen or used a design process before. For this reason it is a reference to design and a decision support system. However it neither replaces the experience of the designer nor the teacher.

For those who have previous design experience, remember that the framework is designed to be a support mechanism not a decision-making tool. This means that the framework should influence the information that you are working with, but not overhaul the inherent personal design process. This information ought to be able to help you make a more informed decision, where improved decision making is the result of more information. Examples of using the process are found later in the results and validation (Chapters 5 & 6) in the form of the Solar Garage, Solar Lounge and the project: Turtletown. Turtletown is presented in more of a step-wise process in the result section, moving through using the framework as a visual example paired with written notation. The Solar Garage and Solar Lounge are presented more as final completed examples as immersive case studies.

This is important to understand. The framework is not a single step-by-step process, but a series of iterative loops that can be used to improve designs. As designers, the freedom to iterate and achieve different results from our peers is the basis for the profession. As with most reference materials, the framework can be simply ignored or used in a minimal way. The point of the framework is to inform the individual of the possibilities that color theory and vegetated assemblies have, and then provide the information to allow the designer to make informed decisions.

Think of the framework as choosing your own adventure in design. If you are interested in a particular topic turn to that page, if not, then find a topic that does interest you. While the full Vegetated Framework is in the appendices, we will introduce its development here and provide direct examples to its use and influence on design work. These include the Solar Garage, extended RDF Wall project (Solar Lounge), Turtletown and examples of student work whom I will call Tim, Jake, Ron, and James.

The Framework: Initial Development

We as educators are a filter. From many different experiences we take information and identify concepts and then translate this information to our students. This process should facilitate a student's ability to think and decide for themselves to develop a personal design process and foster the individual designer. In general there is a certain flow to design. While this might appear linear in the written word, this process can meander and fold back on itself as a part of the iterative design process and as tangents in design become interesting to the design or have a potential to inform the design.

Often we start by identifying our idea or understanding a prompt. Through ideas from our surroundings, objects, or past experiences, it becomes design inspiration. Then ideas are iterated and refined. Decisions are made, and feedback rendered to improve the work. This process of iteration is also applied to the framework as well as the designs developed from it. Figure 56 is the very first thought map of what should be included in the framework. Here it is presented as a part of the results, more information on its development is in the methodology (figure 49).
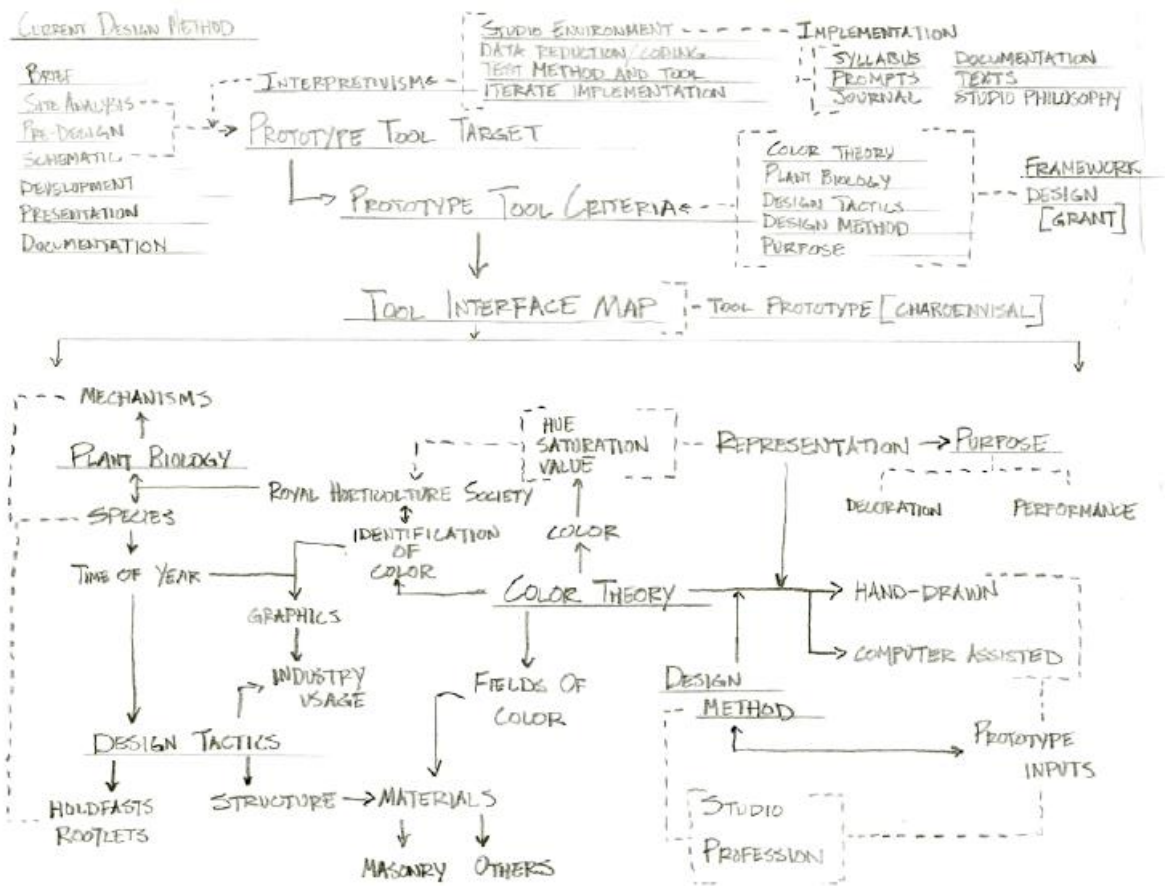
Figure 56: The chaotic map of all the considerations for the potential framework. At the time the interface was thought to be a decision making tool, not a decision support framework. This major difference of informing decisions still made by the designer in decision support, rather than making decision for them as in a tool, is critical to the framework.

The Framework: Logically Argued from the Literature Review

The overall organization of the grounding of the framework within the literature as a product of the intersection of science (quantitative), philosophy (qualitative) to be viewed through the lens of phenomenology as a way to engage the world, organized by decision support structures for others. This would produce the node and filter for how to engage the framework in education and mentoring. This process of diagramming was influential in developing the framework as a diagram is a graphical representation of an object or of an idea. In this case the framework would take on the responsibility for representing ideas and a personal design process for others to follow (see figure 19 in Chapter 1).

The framework: The Organization of the Dissertation as a Whole

This diagram (figure 57) has also been used to describe the dissertation as a whole in Chapter 1, it is presented here as the first time a consistent notation was used for a diagram. This version of diagramming used some aspects of Business Process Modeling Notation (BPMN), however it had not yet been selected from the literature while developing the methodology (see Chapter 3).
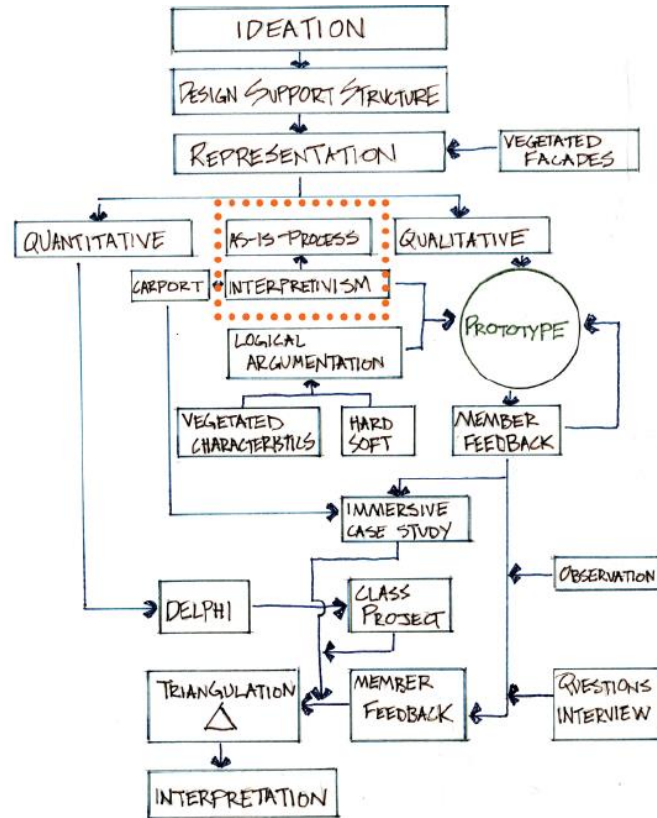
Figure 57: The first example of how to graphically represent the dissertation. By starting with an idea, the framework would be reviewed using multiple methods to validate and refine its content and use by students. This process combines design and research, another key aspect of the dissertation.

Each part of the diagram becomes an important part of influencing the framework. The following is a list of how these steps influenced the framework and at what stage. However, it all starts with an idea. The idea was what happens when, I, the researcher-teacher, am not available for the students? How do I assist in the development of their design process and support them? Can I represent my mind, my thoughts to others? That became the core of the framework: representing thought processes graphically.

A brief summary of the steps of the graphical representation and its implementation:

1: Ideation - Ideas come from somewhere, be it your past experiences, interests, or precedents in the discipline. This concept of developing ideas is the foundation for the decision support structure.

2: Decision support structure - a structure or framework that organizes thought in a graphical manner, it is a very robust diagramming system.

3: Representation - a series of methods, techniques and tactics for conveying information to others be it graphic or oral.

4: Quantitative and Qualitative - these are the two main families of what might be represented by the framework. Topics or design should be considered both in a qualitative (more subjective or experiential/categorical) or qualitative (objective or numeric) manner.

5: Triangulation - this is the process of verifying something in a number of different manners. Usually a minimum of three process or methods are used to verify the validity of something. In this framework immersive case studies, member feedback in the form of what would have been a Delphi, but instead was a questionnaire) and interpretation were used.

6: As-Is Process - what is currently happening? In order to study and understand the impact of something on a condition, the baseline or the norm is necessary. From this a process can be applied to determine a new normative process of what ought to be, rather than what currently is.

7: Interpretivism - the process of doing or observing to begin to understand a process, place, or thing. By using your previous experiences and understanding, observations are evaluated and recorded.

8: Logical Argumentation - this process takes what has come before, often in literature to define and argue for certain methods, process or tactics that were used or will be used in a study, or to inform the information that will be pursued in the work.

9: Member Feedback - feedback allows the process or goal of the study to be improved and better serve the intended purpose. In this case students were asked to use the framework using their design process to identify shortcomings and address them.

10: Prototype - this is the object of the dissertation. This is the framework in its paper appendix form that went through three reviews according to different students and class typologies. It went from a single page, to multiple pages, to both analog and digital. This process is explained next in further detail as both the content and representational method was refined and improved.

The Framework: Initial Revisions

The basic preliminary framework (figure 50) served as a summary for the following work after refining the initial chaotic interface map (figure 56) in the initial development of the framework. This (figure 50) was used by a thesis student in an independent study (whom we will call Tim), reviewing it for feasibility in studio or other individual use (figures 58-59). By talking with him (Tim) and interpreting his feedback, it included changing certain notation how arrows flowed, (especially the relationships between information and the representation of the iterative process) and the potential level of detail the framework should have. These changes are reflected in the refined Business Process Modeling Notation framework in the dotted rectangle.

The Framework: Condensed Version

The comments from students, whom we will call Tim, Jerry, Ron, Jake, and Sean, combined with the reviews from the second year of the Questionnaire led to the development of the digital website application of the framework to review its overall aesthetic and representation. This project further solidified and confirmed the issues of implementing the paper version of the framework as found after incorporating Tim's comments from the 2002 Solar House in the form of a general framework portion (as highlighted in the dotted orange box in figure 58).
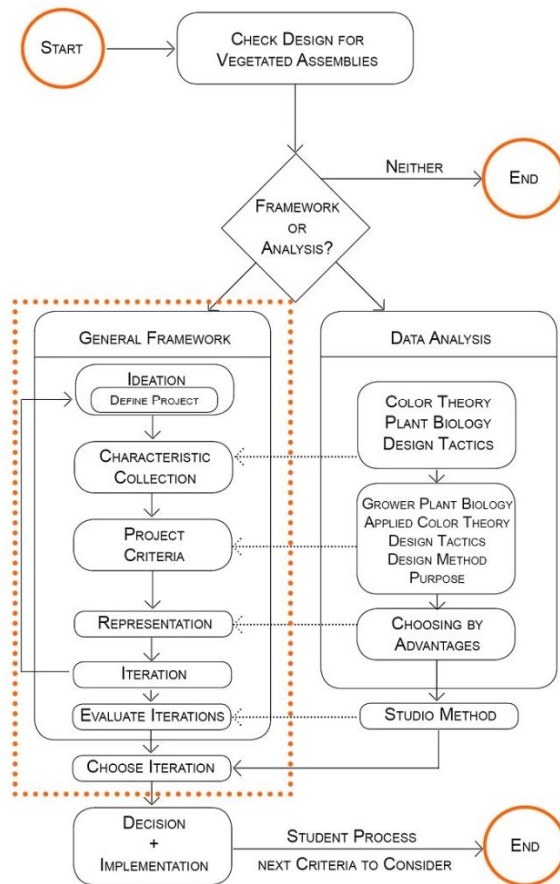
Figure 58: The condensed framework from the first round of implementing the framework in design studios as well as interpreting Tim's design process during his independent study. The portion that was influenced the most is shown with the dotted box. This was refined from figure 56, to figure 50 which served as an intermediary mapping step before it was digitized to make figure 58 using Business Process Modeling Notation.

The interpretation and conversations with Tim resulted in the framework shown in figure 58 during his independent study. The portion that was influenced the most is shown with the dotted box. This was refined from figure 56, to figure 50 which served as an intermediary mapping step before it was digitized to make figure 58 using Business Process Modeling Notation. The main difference between figure 56 and figure 58 is the simplification of the steps used to define the design process, shown within the dotted box, and the coordination of what will be termed as data analysis, but could also be interpreted as information or context gathering. At the time of the dissertation studies this two-path

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method of the framework was used to organize the development of more detailed pages

to each topic (color theory, plant biology and design tactics) and each step of a general

design process a student employs (ideation to iteration in the dotted box). Most of the

graphical simplification came from employing BPMN on the interpreted methods that

Tim used during the independent study.

The Framework: Subtopic Development

Moving from the discussion with Tim in his independent study, further use of the

framework in multiple years of questionnaires and usage studies developed the

framework from a few pages to almost 40 pages of detail into the design of vegetated

assemblies and color theory, as well as adding a general design process portion for non-

experienced designers. Figure 59 serves as an overview of where all of the student

influences can be seen in the expended version of the framework for vegetated

assemblies (A2). Following this are figures 60-63, which are specific examples of

students using aspects of the framework.

Specifically for the development of the expanded version of the framework in

figure 59, most of the expansion was conducted in the data analysis section. From color

theory, plant biology and design tactics came subtopic groups in plant species, climbing

mechanisms, color catalog identification and time of year, for plant biology. Hue,

saturation, value and graphics came from color theory; and structure, decoration,

performance, hand-drawn, computer-assisted, representation and design criteria came

from design tactics. Figure 60-63 shows selected works from the exercises that led to the

immersive case study Turtletown, shown later on in the results.
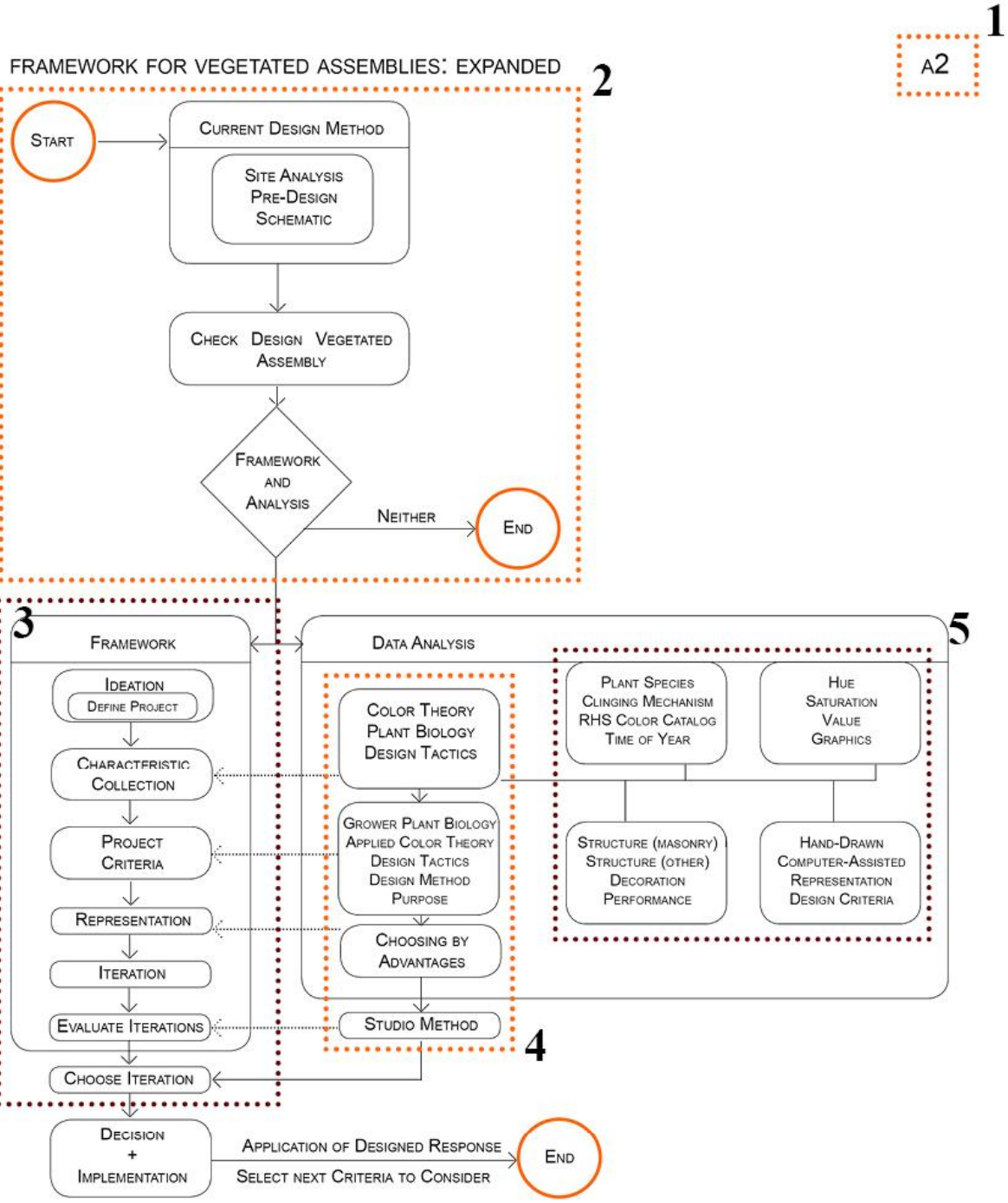
Figure 59: The different steps of the dissertation's methodology and how they influenced the development of the framework. The differently labeled sections (1-5) are explained in further detail pertaining to the sequence and use of the appendix page and the different parts that were added and developed over the course of the study using observation, interpretation, and drawn work from students.

Section of the Expanded Framework and their influences:

1: Appendix A2: This is the expanded version of the framework, showing the considerations that go into the main topics of color theory, plant biology and design tactics. Each of these considerations then has its own appendix of information that further explains its relevance to the topic and needed information. I typically use this expanded framework to choose which of the considerations of subtopics to bring to the forefront for a particular design. Sometimes it might be the desire to work with a particular species of plant, or its flower color based on a desired color scheme. Perhaps a particular structure is available and that informs what species to use based on the applicability of its climbing mechanism.

2: The original framework stripped of the mental map processes and topical considerations. This was developed to limit the designs of the framework to, at most, schematic design.

3: After introducing the concept, to a thesis student we will call Tim, the general design process was added to help those who may not have a solidified process, or who need assistance with developing design and tool techniques.

4: Prior to the questionnaires with students in the second year studios, topics were identified as knowledge domains that the data analysis or information gathering portion of the framework would need to address. These three domain areas of color theory, plant biology and then design tactics were then applied to reveal five others. Finally at this time, choosing by advantages was selected as the process to make decisions between iterations based on the information gathered during the design process.

5: After introducing the concept to students involved with the two years of the questionnaire exercises, the more detailed topics were added to the initial overall framework and an extra layer of detail was added to the framework. This expansion grew the framework from 6 pages to 38 pages total. This also included an expansion of the design framework introduced from the work and experience with Tim.

The Framework: students using the framework - Tim

The work of Tim, Jerry, Ron, and Jake, in relation to the framework follows. These projects were used to determine the refinement of the framework and how it might be improved. The work of Jerry and Jake are each from a different year of the student questionnaire exercise. Tim's work was over an independent study, and individual work from Ron, Jake and Sean was from studio and a discussion course. One project of the multiple works from Ron, Jake, Sean combines with my case study research to make the Solar Lounge project and is discussed in further detail in the validation.

First, Figure 60 is my interpretation of Tim's work as it would relate to the framework that he had access to. This is the Business Process modeling Notation version from Tim's review and where the work is informed by and informs the framework. This shows the relationship between the framework and the work completed for Tim's independent study on the renovation of the 2002 Solar Decathlon House. Tim's work was used to inform the whole general framework side and areas of data analysis.

Tim's work shows the general framework of exploring through representation. While color theory was not a consideration for Tim, the spatial qualities of a future gallery were, and by using perspective drawings, he could show a potential space. His methods generally included a combination of hand-drawn and the scanned digital collages with images from the site. Some themes emerged from understanding the context of the site and the specific nature of the project at hand and by collecting these characteristics he was able to propose a combination of known vining plant biology and the use of pallets as design tactics and methods that were chosen for implementation, specific to the project.
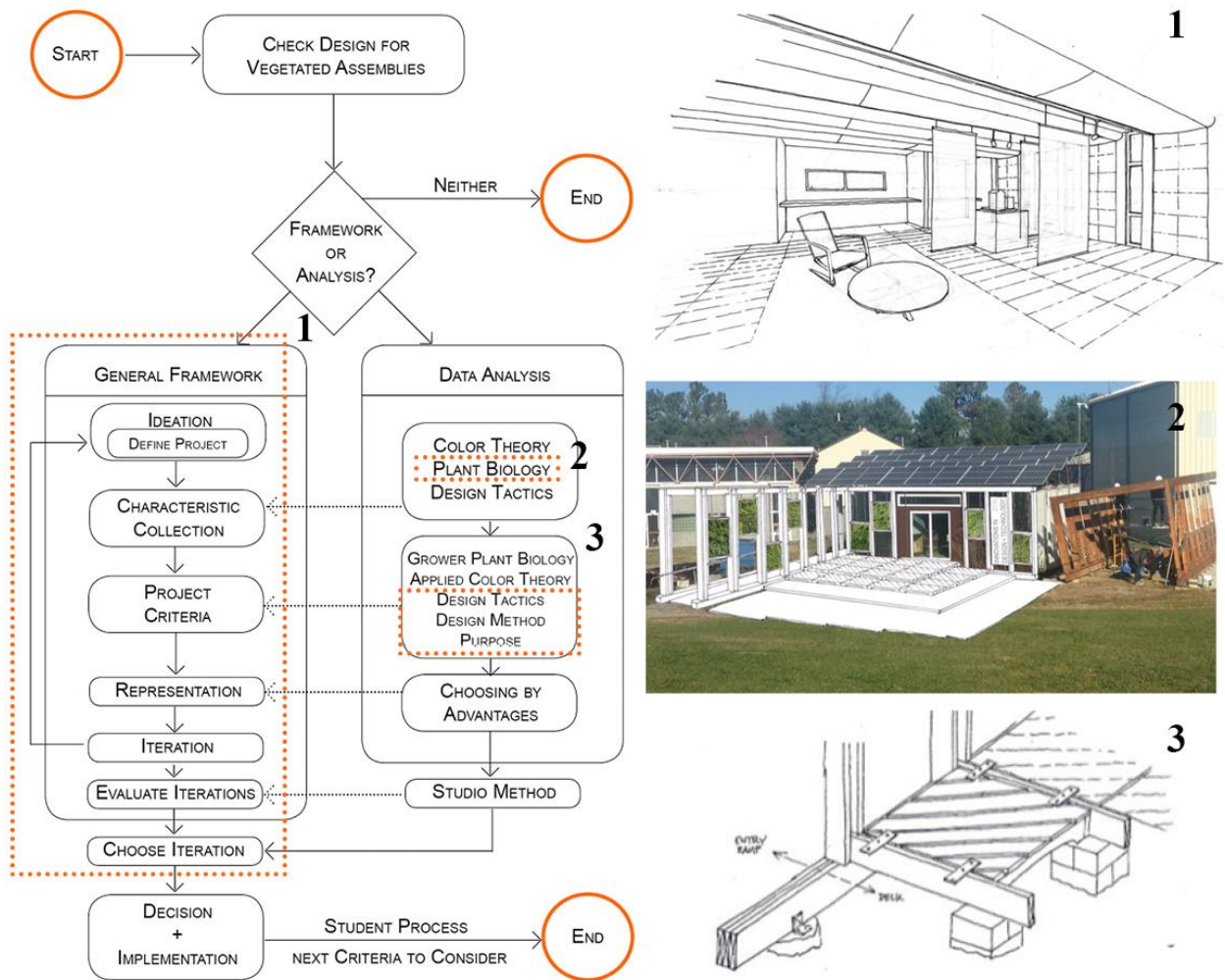
Figure 60: This annotated version of Tim's work shows the three main areas of how the work was completed in relation to the developing framework. 1: An internal rendering using the general framework process. 2: An external rendering showing potential plant modules to the Solar Garage. 3: Tim used reclaimed materials in the form of pallets to meet self-imposed requirements from the nearby context which included the Solar Garage case study (to the left in image 2).

Reviewing figure 60, the numbered annotations match different representations with their associated parts of the original condensed framework, which was the version available at the time. 1: An internal rendering using the general framework process. 2: An external rendering showing potential plant modules to the Solar Garage. 3: Tim used reclaimed

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materials in the form of pallets to meet self-imposed requirements from the nearby

context which included the Solar Garage case study (to the left in image 2).

The Framework: students using the framework - Jerry

This shows one of the questionnaire responses to the use of the framework in the

first year. Jerry's work focuses on the detail of color theory and marks what was

interesting to him and how this influences the designed space. He moves from a series of

sketches that work out some of the relationships that he wants in the project and then

presents the space in a perspective sketch. The appendix for color theory basics that Jerry

used (figure 62) for the questionnaire and design exercise fits into the full vegetated

assembly framework as shown in figure 61, 68.
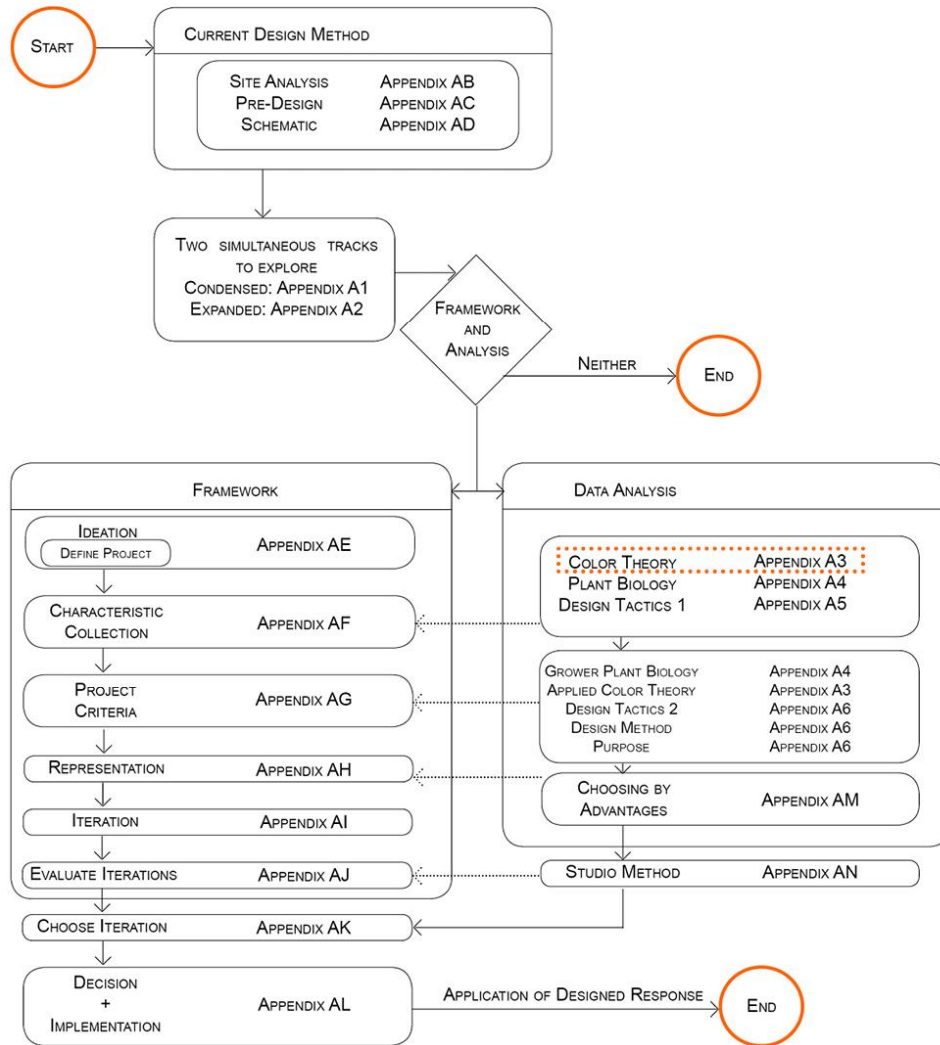
Figure 61: The overview of all of the appendices of the framework as they relate to the condensed framework (figure 58). Color Theory, highlighted by the dotted box is the framework Jerry used to organize his work and sketching.

While it is not on this part of the framework, representation is a fundamental part of the overall process of designing and allows us insight into his process. In figure 62, some of his comments include: considering the "differential of greens in grass and surroundings" and "What value of grey should the concrete be to reflect the surroundings". He also considers having ivy to climb the walls, but unfortunately did not specify the species. This shows the use of a secondary level of the paper appendix version

of the framework (as the digital version was not made at the time) which show greater

concern directed at color theory.
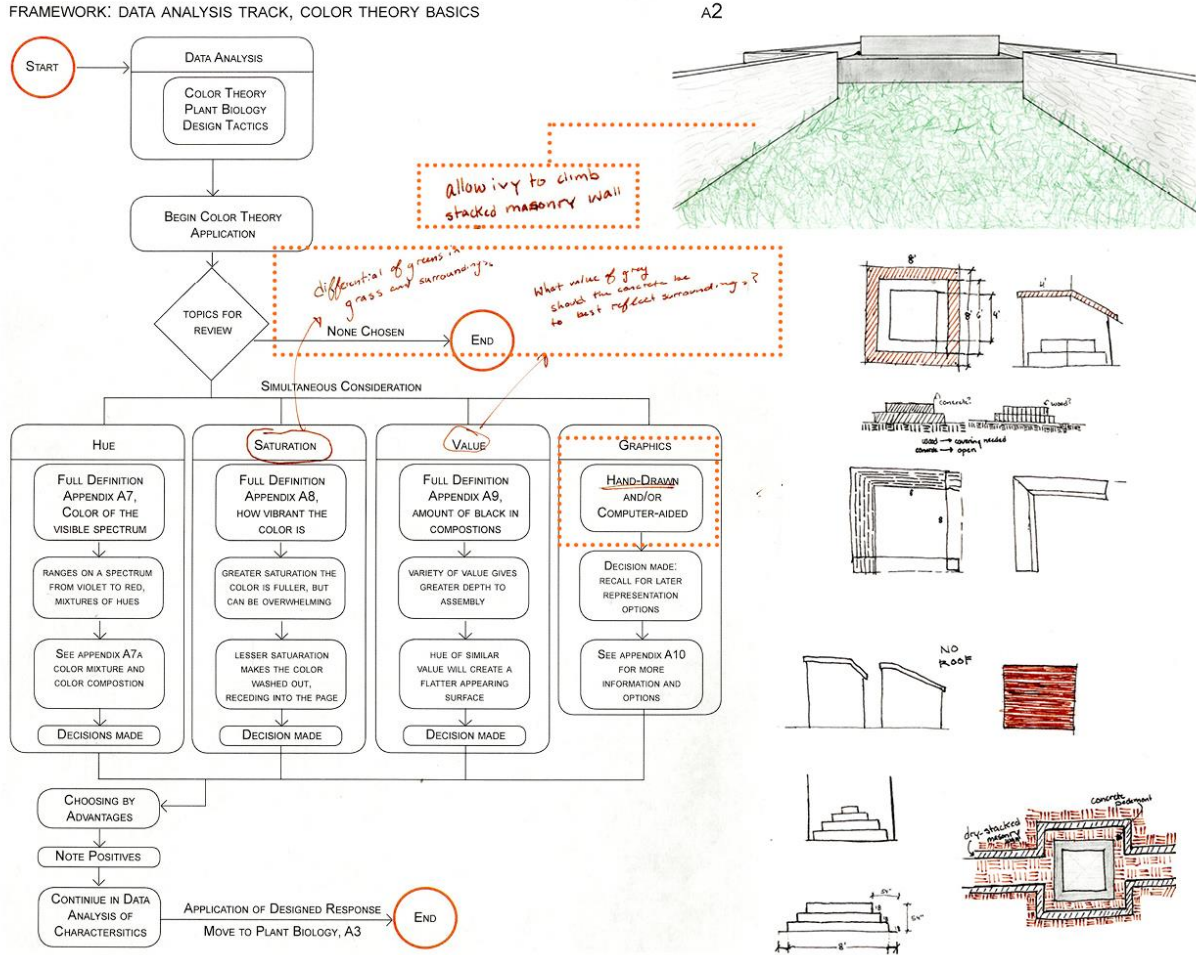
Figure 62: (Year 1 of the questionnaire) This is one example of the student work from a student we will call Jerry—a raised platform with a raised vegetated walkway. The thought process of the retreat was a calming walk through the space with a central gathering place.

The Framework: students using the framework - Jake

This work by Jake was done in the second year of the framework questionnaire. While the digital version of the framework was available, it was also done using the paper appendix version (only the initial 6 pages for the exercise). Jake has shown which parts of color theory that were important to his designs (figure 63). He directly labels

saturation, value and graphics, however the variation of hues in the representation of the plants suggests that this is also informing has work. The beginning of a structure for the vegetated assembly suggests that some aspects of design methods were also considered from the main condensed framework (figure 58).
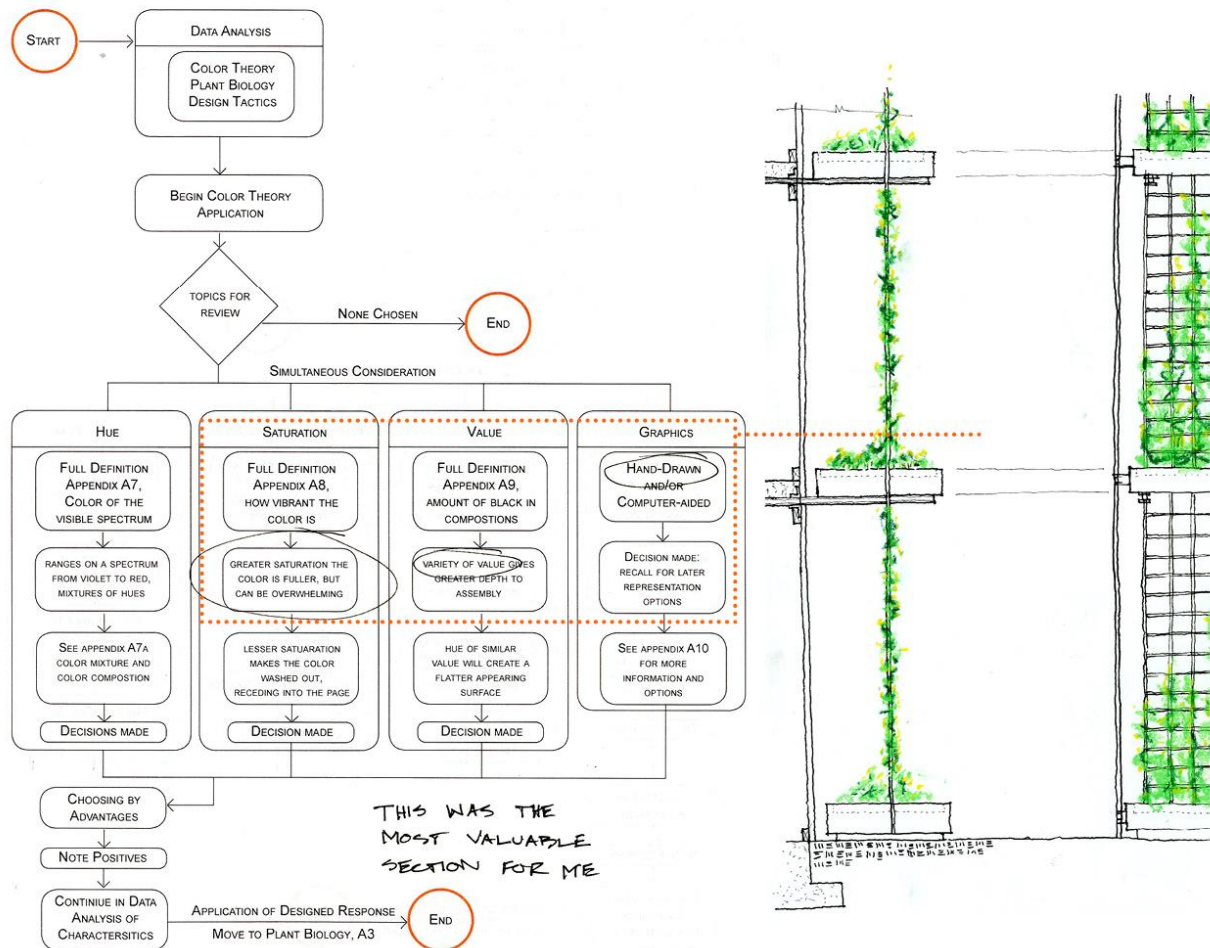
Figure 63: Jake's work looks at color as did Jerry's the year prior. Where is differs is in the type of structure designed, but also what media used to represent color. Jerry used colored pens while Jake used oil pastels after penning a drawing. Jake also began to think in more of a section, elevation manner while Jerry worked in a series of sketches.

The Framework: students using the framework - Ron, and Jake

These are the beginning of the Solar Lounge immersive case study done by Ron and Jake who were in the Honors course called the Metaphysical Room, which was the

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studio-like discussion course developed for the testing of the framework and development of combined design and non-design major design courses. These show the different in methods used to represent the different ideas (figure 64).
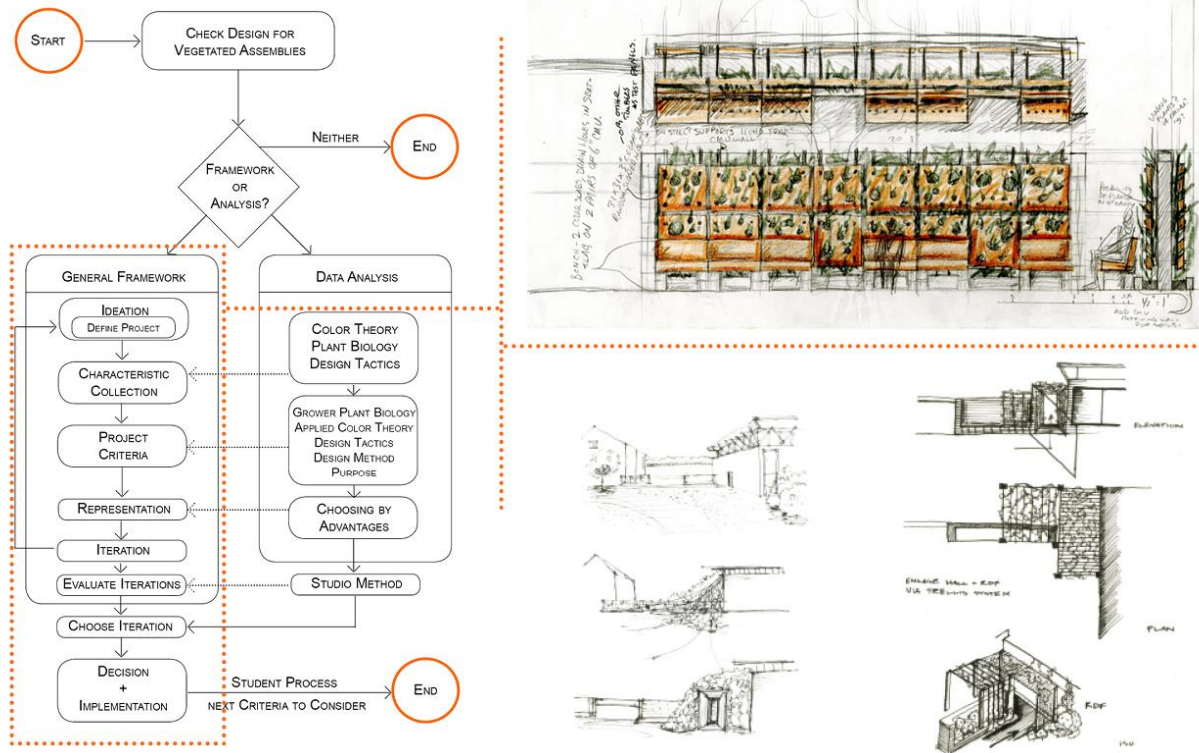
Figure 64: This shows how designers can approach the same project in different ways and design different interventions into a site or project.

These two students engaged the project differently. Ron (above the dotted line in figure 64) looked at material and its interaction with plants while Jake (below the dotted line in figure 64) too inspiration from nearby structures integrating a structure into a frame for vegetation between his intervention and the existing wall and building. The difference the interpretation of their (Jerry, Jake and Ron) work is done in more detail in the validation chapter however it is important to note that different students represent and engage the design process in different manners. Ignoring the data analysis aspects of the

framework regarding color theory, plant biology we find that design tactics and methods while using the iterative process of design become critical to the student's individual architectural process.

A personal example of using the Framework: Turtletown

We have all had an idea about the place we live and a desire to improve it in some capacity. But where do these ideas come from and how do we harness them for performance benefits? Do these projects begin to show to others our method of doing and thinking? I will start by describing a personal example and then expand to visually showing how I went about solving it. This way we can use this framework to guide or start engaging others in the design of beautiful and performative spaces.

So here is where we will start: I have a glare problem and it's uncomfortable. Light comes through the south side of my home and blinds me on a daily basis. I do not want it to be solved by typical blinds as I cannot see the outside and the wonderful backyard I have access to. In the summer I do not want extra heat, but in the winter I like the warm daylight that shines though. I also have a pet tortoise that is steadily outgrowing its current home. How are these problems even related? I have a glare problem and a voracious turtle. These are not even close to being similar types of problems. So how do I bring two seemingly different concerns together and find an interesting solution?

There are a wide variety of topics that combine to give each of us a personal take on the built environment. The built environment, for me, is the structures that we design for ourselves: our homes, our workplaces, our roadways, and so much more. The most interesting of these built environments are the places we make for ourselves. These places

have a very distinct character to them, even eclectic at times. This is what I will be talking about: designing a place, with others, that I would personally enjoy experiencing.

I am talking about the place where we use our interests, nearby resources, and our minds to make something that, in a way, is a physical example of what we enjoy. For example, a bird makes a nest with what is around: twigs, hair, string, mud and in the end a nest is built. I will call this project Turtletown. Judging from the name, you can probably guess where this is going. I think that Turtletown will be fun and perform to the requirements of the client (my fiancé and our turtle, Sheldon). In the end, what is important is that the project engages me as a designer and builder, and engages the client with the process of designing, and performs to the needs of the situation.

While this sounds a little out of place, we have all of the same considerations of a home present in a microcosm. We need to understand the performance and safety needs of the animal, its desired habitat and comfort, food sources, and its integration into the existing environment and site, cost, and maintenance over time. These same considerations are found in a typical home.

The particular project will be constructed near my home in Blacksburg, Virginia. Against the south side of the house, I have a plant bed that regularly grows weeds but nothing else. This plant bed is the right size for a spacious turtle pen, and is also the location of my glare problem. Needs, means, and resources combined for an interesting solution. For this reason, Turtletown will be founded in the weedy flowerbed in the backyard – established 2016.

Figure 65-66: Turtletown before (above) and after (below). The materials were all laid out and over the course of a few hours were completely installed in our backyard. In July the selected vining peas had grown quite vigorously on the lattice and the mixed wildflowers began to bloom starting with yellows, changing to whites later on.

Thinking of a Beautiful Turtletown

      I will start with a shell (no pun intended?) of the design process and begin to fill in necessary information (Figure 67). I have used this process with students to engage a topic they have not encountered before. It helps them to compile and organize their thoughts.
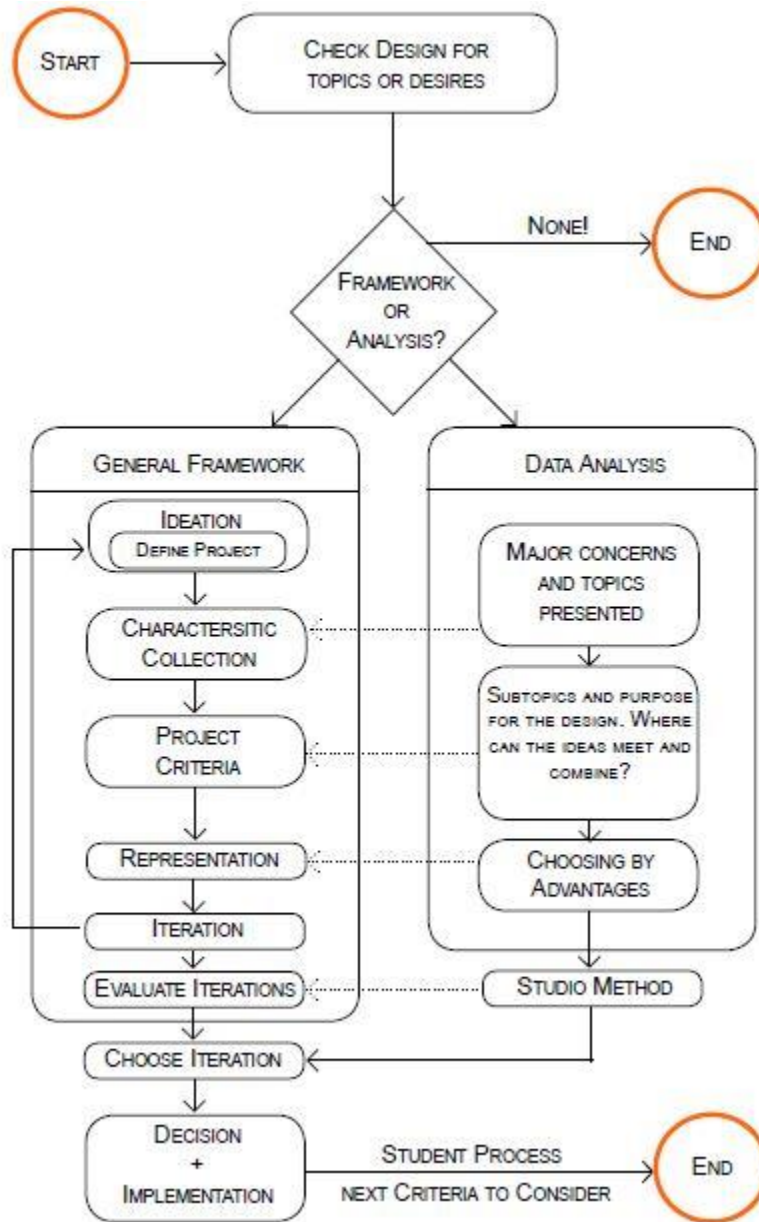
Figure 67: The shell or the framework before adding in considerations for the Turtletown design and development.

As professionals we can begin to discover what is meaningful to others, what troubles or concerns they have, and then begin to show them how we propose helping them. We'll start out with what we know. For example, as a designer and builder I enjoy working with my hands and I find wood appealing. What can I make with it? I also need to consider what the client will appreciate. I have two clients: the owner of the pet and the tortoise itself. While the tortoise cannot express its needs, its owner can.

These needs then begin to inform the framework that guides our work. It is important to remember that the design work that we do influences the life of the very people (and tortoise) being designed for. This is crucial to realize, as the quantitative performance of a space is important, however the comfort and perceived performance is just as significant. So what are the concerns that we now have by combining the needs of a tortoise and a shading method?

Our materials budget is limited; no mahogany for Turtletown. Untreated wood is needed, as tortoises can uptake chemicals very easily and be poisoned. Tortoises need a variety of temperature options in a habitat, as they do not regulate their temperature internally: sunlight for proper shell growth, a source of water; food; and protection from predators. This means that while the enclosure is outside, it is not acceptable to leave Sheldon out in extreme temperatures and at all hours, so a door is needed. The water source is used often, so more durable groundcover or stone will be needed there. Sheldon is an adventurous eater, so any plants within her reach inside the enclosure need to be edible. Finally, we will need to incorporate some sheltered areas into our design.

This is a good start, but are there any concerns about the place we will be designing in? Knowing the specifics of a place allow us to design in response, rather than forcing a particular design. I have spent a good deal of time learning about vegetation and materials, but the exact idea can be strengthened in a team using everyone's experience and knowledge. Do not underestimate area-specific knowledge and observation. The landlord explained that snow and ice fall from the roof in certain locations; rain strikes in a certain pattern making mud splash; do not pick a vine that could attach to the house; there are high winds at times that could strip the project. These are a few additional issues to keep in mind during the designing process.

The Larger Framework

I have been developing this method of using frameworks for a couple of years now and have been using it to teach others about how to include nature (plants) in different types of projects. The framework serves as a design support framework that provides some information, but leaves the final analysis and creative decision to the designer. The full adapted framework for color theory, vegetated assemblies, and the concept of the designed response can be found at: livingwalldesigner-prototype.org.

This larger framework goes into much more detail about the specific considerations, and these steps (used in no particular order) are dependent on each other. Here are some pieces that have general considerations in design that often help others. First is the framework related to the larger design process. The first example of how the process is available to those who have less experience in an area (Figure 68). This particular framework assists with vegetation, color theory, and the design process.

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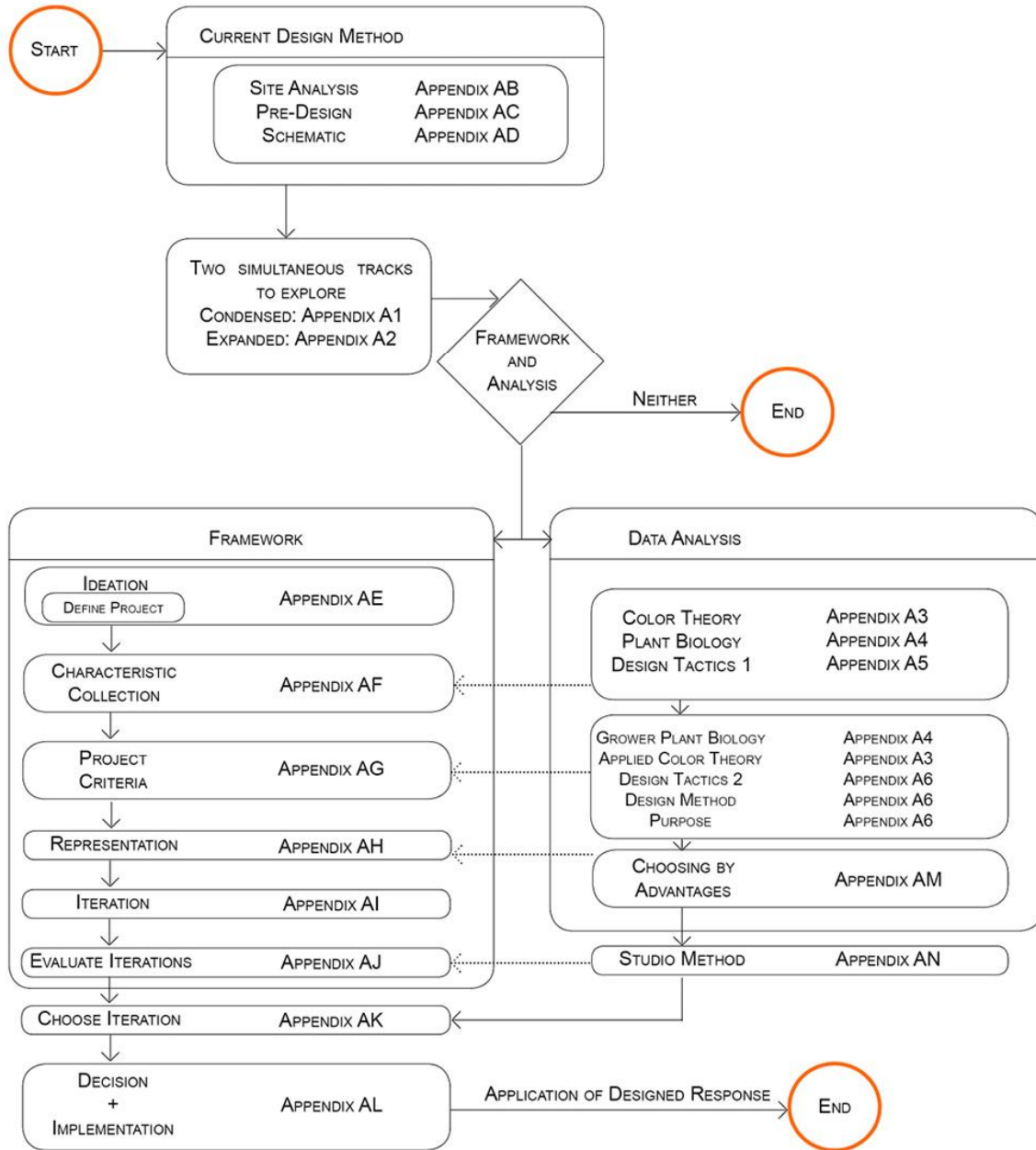
Figure 68: Appendix A0: This is a visual overview of the framework and where much of the beginning information can be found in following appendices. Pages that are A# (letter number) are focusing in vegetated assemblies and color theory, while pages AA (letter, letter) focus on the more general design process. I use this page to get my bearings by collecting information for the site analysis and pre-design for the current project and pick what topic will be the most important to me and then guide decisions for other areas of interest. For example, one project might be focused on color theory, and plant biology is picked based on desired color compositions.

The framework (such as figure 68) recognizes that information and the design process influence and informs each other. For example: I would like to design a certain aspect of the project, and I have an idea about material. What do I need to know to use wood in the project? Perhaps my project criteria are not defined yet, so it is necessary to see the framework (left) side first to discover what types of considerations would be needed. If I wanted to use this to develop Turtletown further, I might start with Plant Biology (Appendix A4 on the right side) to understand what sorts of plants might be able to survive in the area or what kinds of considerations would be good to know before buying a bunch of plants for the structure and to serve as food for us and Sheldon (the tortoise). We also need to know what types of plants are readily available in the area. Plants can be common cultivars or rare. A plant might have the best characteristics and be perfect, but if it is uncommon or will not survive, it is unsuccessful as a designed response. Looking at the table of contents (Figure 68, Appendix A0) we should move on to Appendix A4 (Figure 69).

Typical Overview Page

The overview page is what it sounds like (figure 69). It gives a little bit of information on a number of topics within a larger idea, in this case plant biology. The topics shown do not have an order of significance. What is central to the process of the framework is that the information is present and the designer then chooses which ideas or options are the most important or drive the design. These choices then lead to limit or define other considerations and serve as rules for the rest of the project.
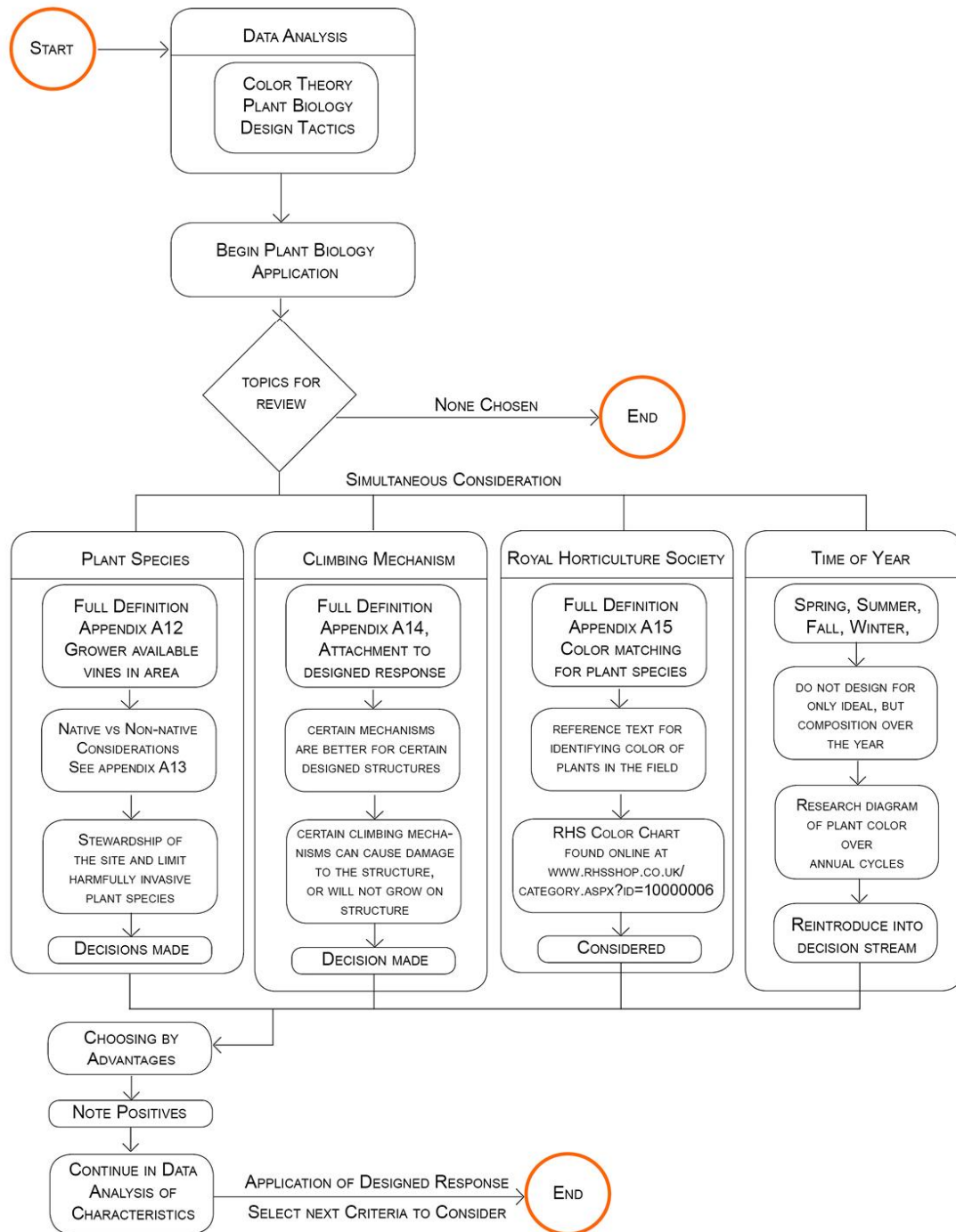
Figure 69: An example of the overview page to a series of topics that can be used to determine which subtopics merit more consideration. It is important to remember that the process is iterative and the choice to pursue topics in further detail remains with the designer, not the decision support system developed by the dissertation.

In this manner, plant biology serves to explain how a plant behaves and interacts with its environment and how this response is expressed as a physical structure. Think of a flower. Flowers have a series of structures that might look different and be different colors but serve very similar functions (leaves, stem, roots, petals, pistil, and stamen). This is an example of how the biology of plants is a rule that defines other aspects of the project. Each of these plants behaves differently and this is important to the development of the plants in the project, which might need more or less care or maintenance.

This question of maintenance and survivability relates back to our site, the materials (such as wood) and purpose (Turtletown and Sheldon's food) that we have chosen. But how can we know that a plant will be able to survive or be useful in our work? It is irresponsible to believe that a plant, or any design decision, will work without either experience or knowledge to back up our claims. Thinking of our plants, we need to know the species, as this can tell us common characteristics across many different individual plants and if they will survive and work with our materials. This will show us its climbing mechanism, colors, foliage over the year and much more. So we will end up checking Appendix A12 for now.

Typical Process Page

Using Appendix A12 (Figure 70), we have found the information that we need when looking at different plant species. Using the USDA plant catalog we can start to choose plants according to the type of project we are pursuing. There are three levels or types of designs. The simplest has plants climbing directly on the wall. The intermediate level has a trellis system that is designed for plants that are directly rooted into the

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ground. The most complex has growing media, irrigation, structure and more to recreate the living conditions of the plants. We need to have an enclosure for the tortoise, cannot have plants directly on the wall (per our landlord), and plenty of space to plant directly into the soil, so we are working in the intermediate level. This allows for the enclosure to also be the trellis system for the plants to grow on. From Appendix A12 (figure 70) we know that we need a twining plant as rootlet and tendril vines are not good for wood (our material) and we need a matrix so that we can see the tortoise inside the space.

If we review the different seeds and desired plants for Turtletown that are also readily available at department stores, we quickly begin to narrow the list of possible plants to use in the project by using figure 70. Two main options were the twining peas and Morning Glory vines. These two vining plants match the climbing mechanisms that would work with the designed structure of a wooden lattice that serves as a matrix for the vines. They also are able to grow in our hardiness zone and can grow in the rather poor soil and require relatively little maintenance and can be grown by new gardeners. The peas can be harvested for food and the Morning Glory vines have a vide variety of bloom colors. The peas are annuals and need to be replanted every year, while the Morning Glory vines are perennials and can grow back from year to year, surviving the winter; however it is poisonous to the tortoise. Since the Morning Glories are poisonous to the tortoise, we selected the peas, which lead to growing other plants in the concrete block edging (see figure 66) such as lettuce mixes and radishes.

This systematic process takes time to learn. There are a number of ways that the idea can begin to form and I highly suggest being iterative, or having multiple options. This gives the opportunity for refinement and inspiration. The most interesting

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conversations come between designers and the clients, particularly if both are engaged. The process described in selecting the peas for Turtletown is most dependent on the individual designer and has requires a solid amount to research by the designer to know what is desired, versus a simply listing of characteristics.
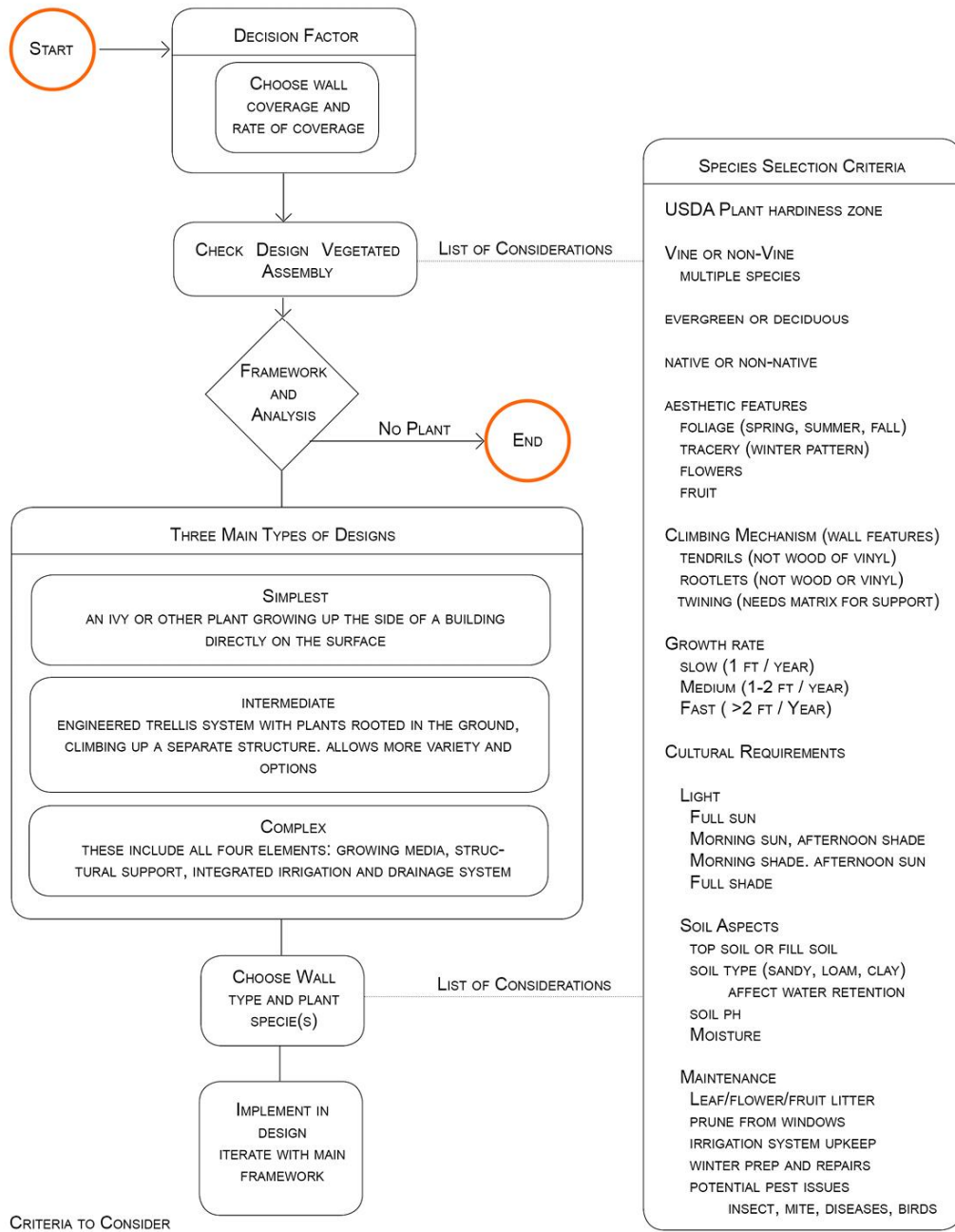
Figure 70: This used to select the two types of vines that might be used in Turtletown. It is important to take the type of characteristics that each of the vines have and then choose between the two options: vining peas and Morning Glory vines.

Giving Away the Process

The refinement of details also begins to guide how I can represent the project to others. I can use standard drawings to get the message across, and this is good for making the final project. However, volumetric drawings can bring it to life (figure 71-73). The whole point of this process is that it is now yours. Do what you want with it. Augment it and make it your own. Show others that they are critical to the design process. This connection makes all the difference.
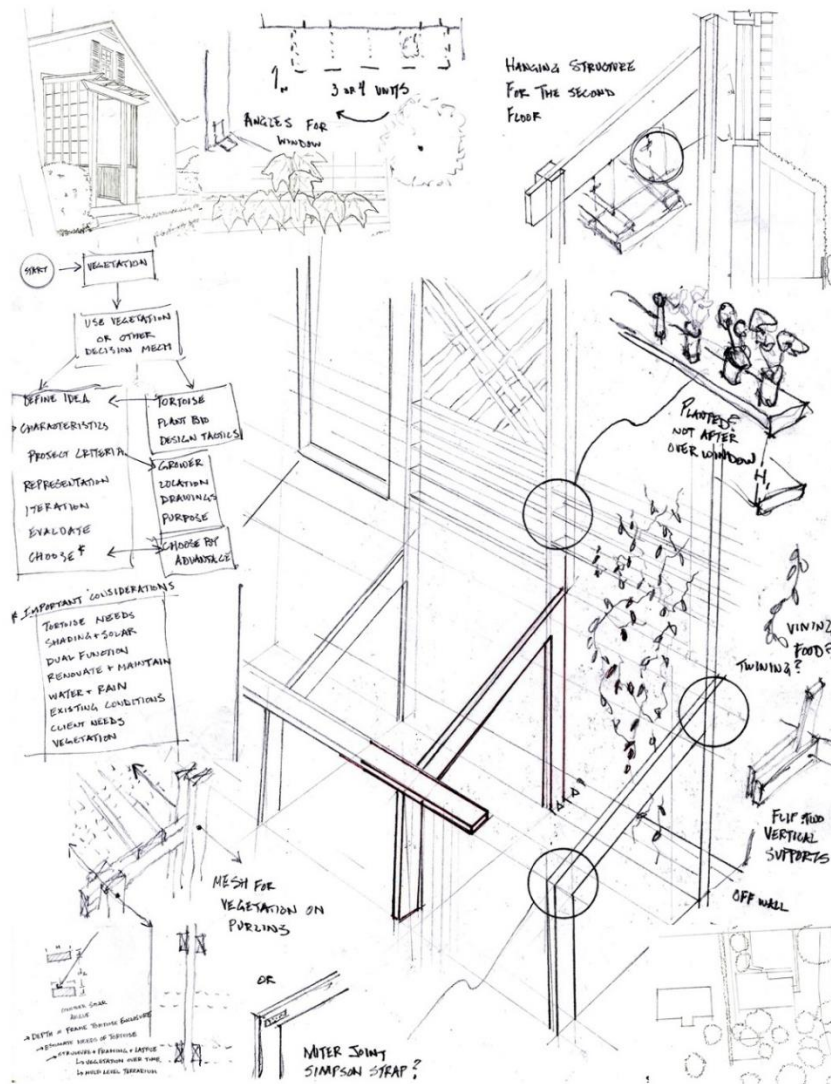
Figure 71: Collection of the process of the iterative sketching out the project
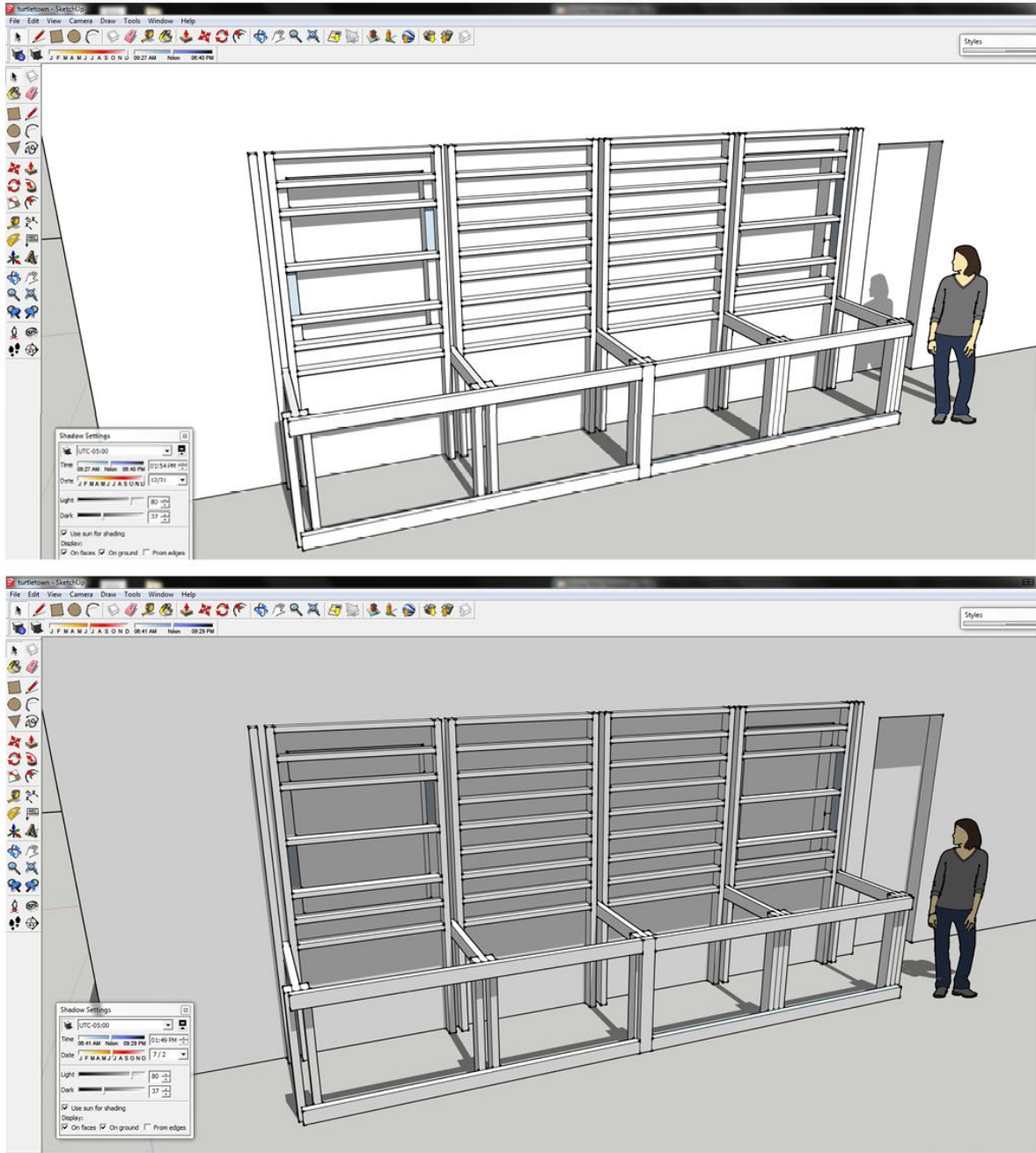
Figure 72: Fast digital shading studies of Turtletown using Google SketchUp. This is the December Full Sun example (top). This is the full shade example (bottom) using 2x4s and 14" spacing. Majority shading began in April and ended in October using a 9inch overhang. This resulted in a shading angle of 53 degrees for full shade as suggested in Heating, Cooling and Lighting as a fast reference.
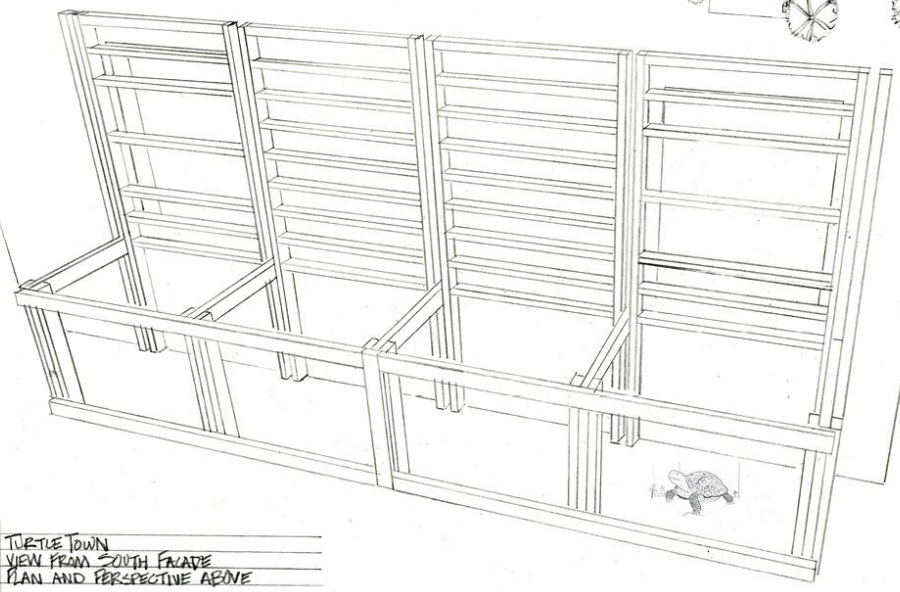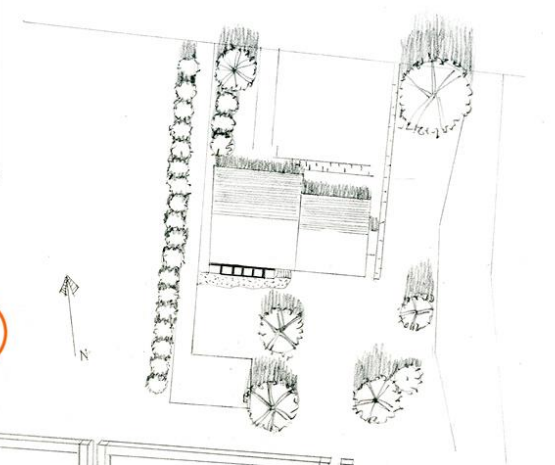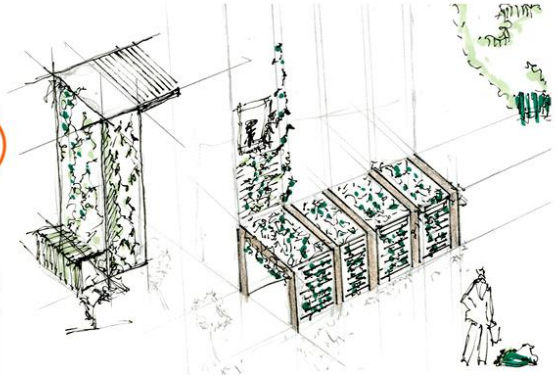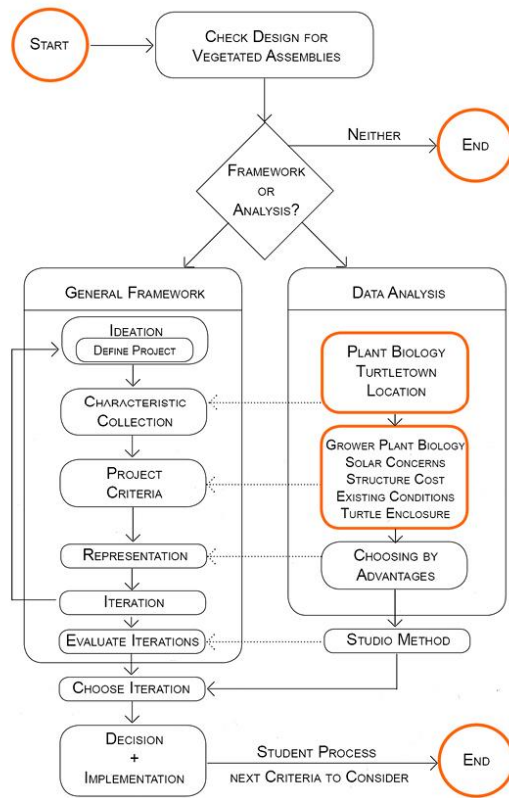
Figure 73: Collection of the changed framework for Turtletown. The drawings are the perspective of the full grown Turtletown that served as inspiration (upper right), the site plan (middle right) and the shading structure and turtle enclosure, Turtletown (bottom).

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Performance is a question that is constantly drilled into our forms of expression and designed spaces (figures 71-73). We obtain metrics for everything, sometimes forgetting that the numbers alone do not always define the space and the experience in it. The questions that were asked in the beginning of the project are for experiencing a place as we sense it and can begin to develop our method of thinking. This process of taking in the quantifiable, numeric characteristics of a place and translating them to the qualitative, experiential expressions has been condensed in this process to share it with others. We can find what interests us and moves our design and profession. These interests are then combined with our experience to make the vegetated design framework and Turtletown.

This is a process in which the method of getting there (the full case study from figures 64-73) is just as important as the resulting product (figures 66 and 73). This work was completed over the course of a three-hour charrette. I hope that this process helps you in your future work, or future home projects that also have a series of needs. For now, my glare problem is solved, and we have place for a growing tortoise with the intent of growing a twining vine on a wire mesh matrix.

Significance of the Appendix Framework System

This is the development of a system of representing the framework to others. At first the framework was one hand-written page, then a single page held to a graphic standard: Business Process Modeling Notation, next it became seven process pages of discovering what information would need to be included in the framework, finally it grew to 39 pages of information. This shows how quickly tangential information can

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overwhelm a system and that boundaries and limits are useful in filtering out information that, while useful, may not be necessary at a given time.

For this reason the educator is still the primary means of conveying information, that a person-to-person interaction is vital in the learning process. The educator can be a node and a resource that is primary to reference materials. Reference materials are great sources of information but lack the experience that designing and practicing provides through refinement. However this needs to be confirmed by my using the framework both personally and by others, in studio and studio-like environments, not only developing the initial artifact. In its most basic form the framework serves as a basis for the design of a program or tool in the future. It can be a foundation for other studio design works in the future if other designers apply the framework to other topics and later on can serve the designer as reference material. It also can serve as an example for students to reflect on their design process and diagram it out in a consistent graphical or representational manner, and represent different methods or paths that develop among different students.

This framework was developed as a paper appendix system, but it was not as interactive as it could or ought to be. This was reflected in the first use of the framework by students as Appendix A1-A6, and then later as the full framework presented, all in the paper version. By doing the work with time for validation from the target audience, a fundamental shift in its representation and use was brought to light and could be addressed in subsequent versions. This current paper appendix framework method works well for those who learn by reading, but ultimately falls short for visual or kinetic learners. However, there is great potential in developing the framework as a web application providing a more interactive interface, and as a middle ground between the

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framework and then a full program or plug-in into a modeling program in the farther future.

Students have tried the developed decision support system as the framework with only the processes in Appendix A1-A6 and no representation or examples and it did not go over well. At first, minimal examples were provided to not bias their designs towards any particular method. The comments provided confirmed that designers learn by precedent and by example, and that design is not linear. This means that thorough examples are needed. A few were unsure if they could choose to place importance on certain information or iterate a certain section more than once.

This confirmed that the decision support system ought to represent information and be compatible to a larger audience by detailing a process for a future web application or program, rather than only being in the Business Process Modeling Notation which appeared foreign to most students. This should seem obvious: people are not machines. Further, what would be recognizable in a web application is not apparent in primary process mapping. This is representation at its core: similar information that is conveyed in a particular manner will have varying results based on the methods of its representation.

So what does this mean for the framework? It confirms that everyone learns, interprets, then designs, and represents in a different manner. This is simultaneously a gift and a curse, but it is the foundation of the discipline of architecture. It is a gift because everyone will have a unique response to a prompt or project, but that individual processes of design are difficult to convey to others without discussion.

There is always room for improvement, for iteration. One of the main topics to consider is visual examples. Visual examples are the key to understanding the process and the reason for why information is important and how one might go about applying the information given. This was done with a preliminary example with the project Turtletown, and then a unified example was suggested by students in the questionnaire and design exercise. This unified example became the RDF Wall project which will be used through the framework as a visual example in the web application.

This is important because it confirms that when you become immersed in something you can lose sight of what it means to be new to a topic. This means that the work needs to be represented in a new way with a series of examples (developed by myself as a visual reference for using the framework) that helps students ease into color theory and vegetated assemblies. By developing a web application, the decision support system can be provided to students for free, anywhere, for those with internet access. By having it as both a paper and web application, students could choose the manner in which they interact with the information, just as they choose between hand-drawing, computer-assisted drawing, or a mixture of both methods.

4.2 The Evolution of the Web Application

Overview:

This web application is the product of all of the validation that was done over the last year through surveys, papers and case studies. The questionnaires (from both years of the 2nd Year Studio) served as an indicator for whether or not a paper or web application would be a more desirable solution. From the questionnaires and its analysis, case studies were picked to further develop the examples for the web application. These immersive case studies included Turtletown, the RDF Wall Project (Solar Lounge), the constructed Solar Garage and the Solar Garage re-visitation study. During the process papers were written to further explore and understand the usefulness of the decision support framework. From all of this work and discussion a web application was made and then revised as a part of the final results of using the framework.

Two versions of the website were created; only one is presented for its use as a web application. The first version was at first an intra-net site hosted on a single computer, developed in part with some computer science students. This version then moved to a blog platform, WordPress, and then was updated for better connectivity and speed. This version was developed around the original appendix method of the framework without change to the overall appearance. For example the appendix images were placed onto pages in the web application. The second version was the adaptation of the framework to the processes that were outlined in the Business Process Modeling Notation and the images of the appendix itself changed to a printable version of the website. This second version of the web application is currently available at livingwalldesigner-prototype.org. The website serves as a living document of the

dissertation and its interface with the rest of the world. This gets the work, the decision support system, out and can serve as a platform for the work that will be completed after the dissertation is complete allowing for updates to the method, content, and representation.

The First Version

The first version of the web application was launched in Fall 2015 from an intranet server located on one computer. It was slow, but reliable, and coded almost entirely by hand between three of us, me and two computer science undergraduates. They needed some experience in making a web application and I found myself without any computer developing knowledge. I learned a lot about how difficult coding is and the limits that a number of the languages have. This first version was coded in html5 and JavaScript angular, with node as the server side. These three coding languages were identified by the computer science students as languages they needed to learn as soon as possible.

The first major overhaul of this version came in the development of the overall site structure and the ability to use the site. The navigation method in the first version was clunky and every page was in the drop down menus from the topbar of the page. This resulted in the site not transferring at all to mobile, and only being able to switch pages through the topbar navigation with no links to any other pages. One would define this method of organizing the site overwhelming in that at one time the user could see everything at once. Without the menu limiting options based on topics there was no real way to know where to even begin.

Due to time limitations the two computer science students had to leave the project and it was determined that the site would be transferred to a WordPress blog. This greatly simplified the development of the site and allowed the content to go live on the internet and be reviewed for its appearance quickly and across all platforms (figures 74-78).
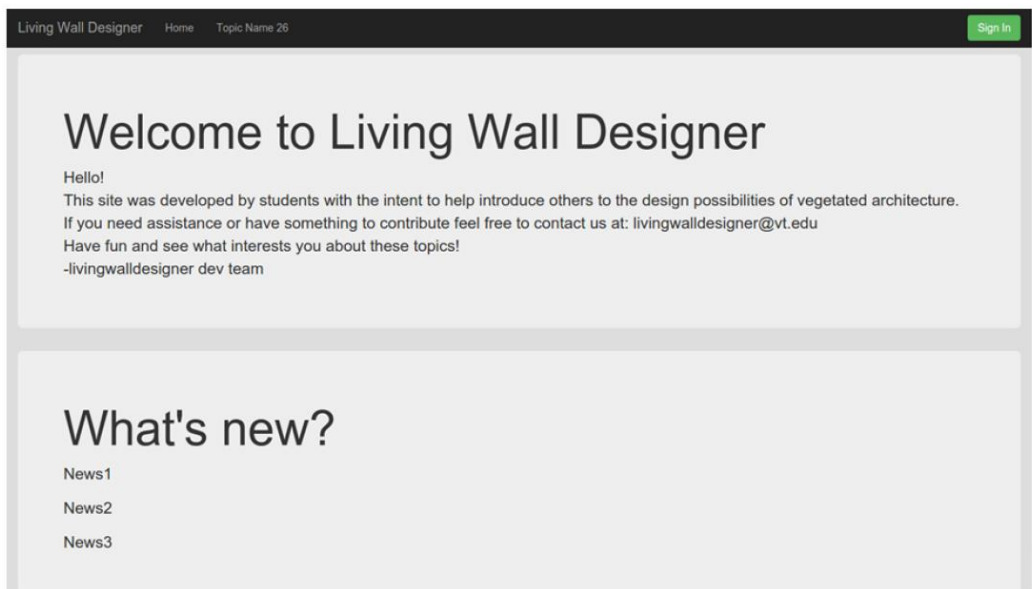
Figure 74: This is the home page for the first iteration of the web application that was hosted on the intranet server.
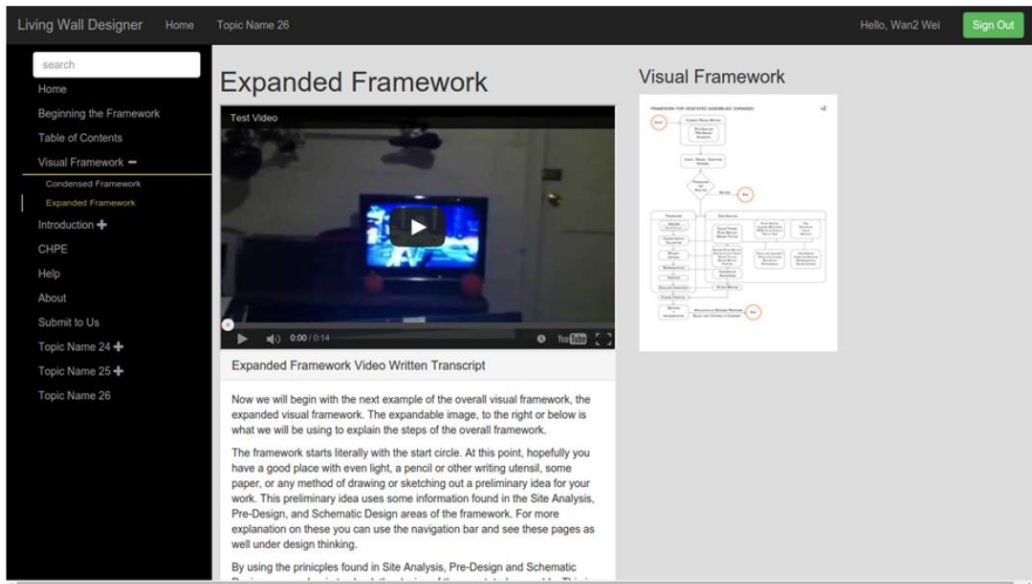
Figure 75: This is an example page of the web application. There was the plan to have video tutorials and a transcript below. The framework was then presented to the right of the main page. This was also the first time we changed the navigation method.
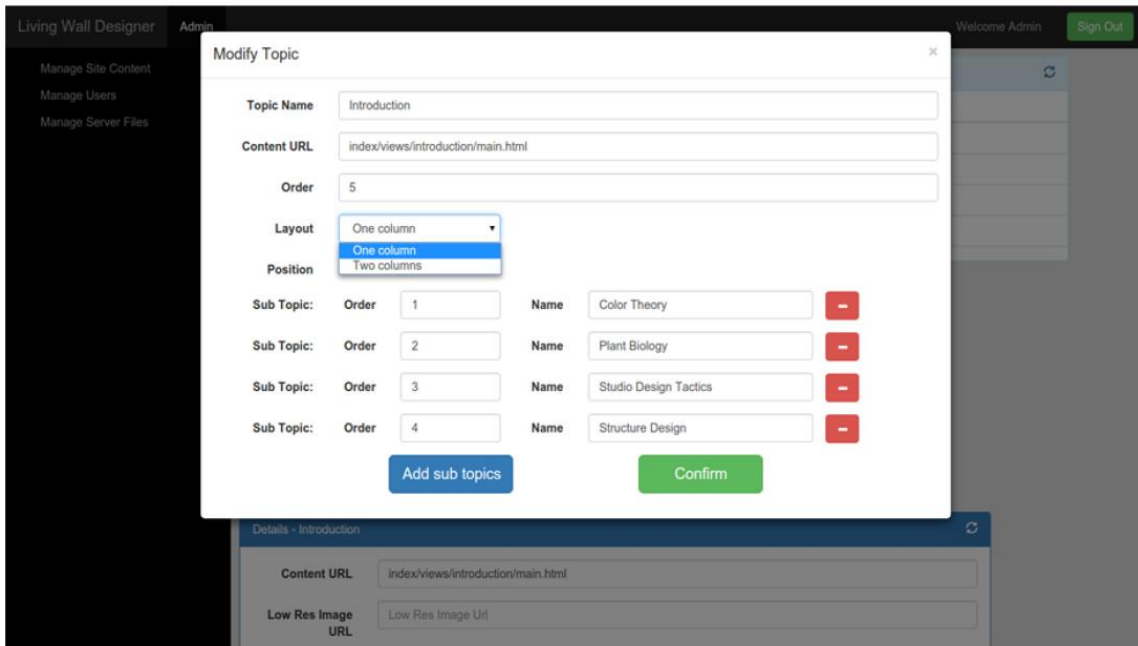
Figure 76: This is an example of the user interface if they wanted to upload files to the site. During the early parts we thought it could be a file sharing site similar to flickr or youtube. This is also something that one of the Computer Science students wanted to learn so it was included in the site design. This also required a log-in portal which was difficult to manage and later removed.
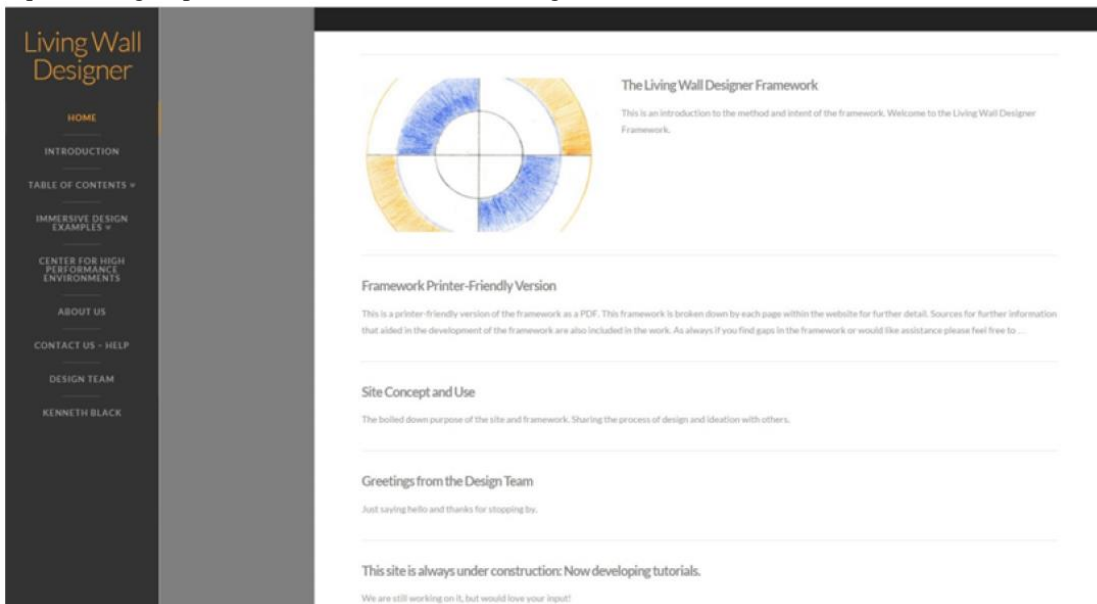
Figure 77: This is the first round of the website when it was moved to the WordPress site. Almost immediately the site was updated to the version below. This migration process solved many of the log-in and user issues as WordPress is a platform for individual blog sites and easily converted to a static website. This also started the process of reviewing the representation of the site as much of the content had been discussed and reviewed between myself and a student from Industrial Design.

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Figure 78: The next few iterations, versions 1.3-1.6, were different representation attempts to finding how the website should look, and the flow of the site architecture. This is an example of the front page of version 1.6 as compared to the two main previous iterations (versions 1-1.3).

This process of using and reviewing the site improved its flow and determined what was necessary to each page. The main difference between the two versions became removing the images of the appendix paper method of the framework presented in the results chapter and adapting them as actual pages in the website. This was something that was not originally a part of the dissertation and was to be left as later research; however it

became apparent in the use of the framework by students that it simply needed to move beyond the process notation to become an actual web application.

The Second Version

The second version of the website was made available at livingwalldesigner-prototype.org (figure 79). This web application was to serve as the living document of the dissertation and serve as the permanent home for the decision support framework. This came from a conscious decision to make the information determined by the study available to the public for free. The results posted there are not intended to be a money-making venture. Since many of the users of the information would also be students, there was no real need to charge already overburdened target audience. The second version is explained below. Its main focus was creating a platform that would be easy to read on multiple platforms and be able to include videos and audio examples as well as photo examples of the plants and previously designed projects.
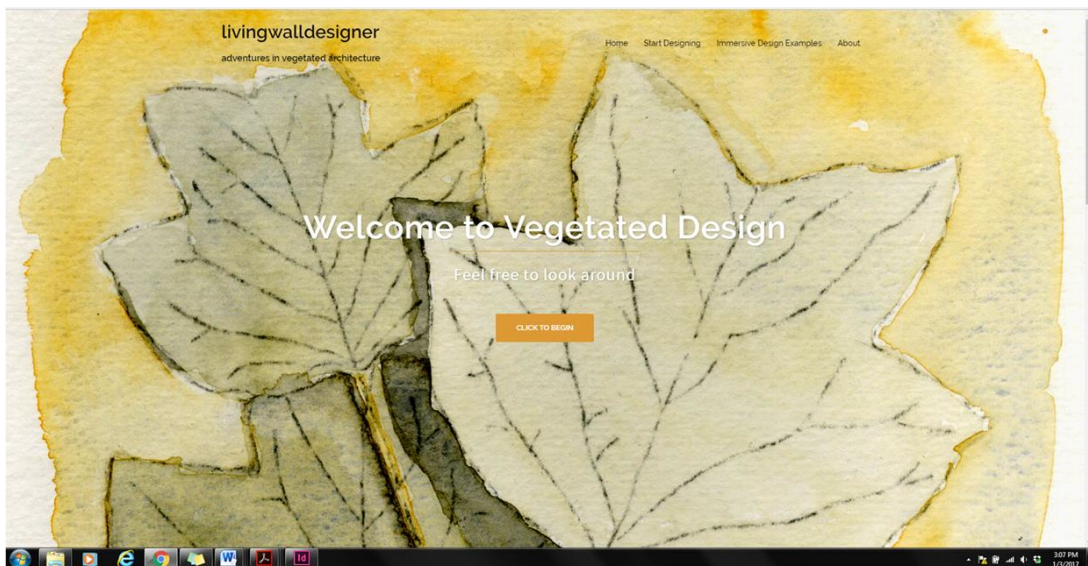
Figure 79: This is the home or splash page of the website. The next three images are different examples of the work that could appear on the front page. This is a watercolor study of some poplar leaves.

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Figure 80: This is another image of the home page set to a rotating timer. This project is an example of a full-scale project, the deck and planter system using pallets that was the impetus for all of the vegetated assembly research, completed in 2010 during my undergraduate studies with another classmate.
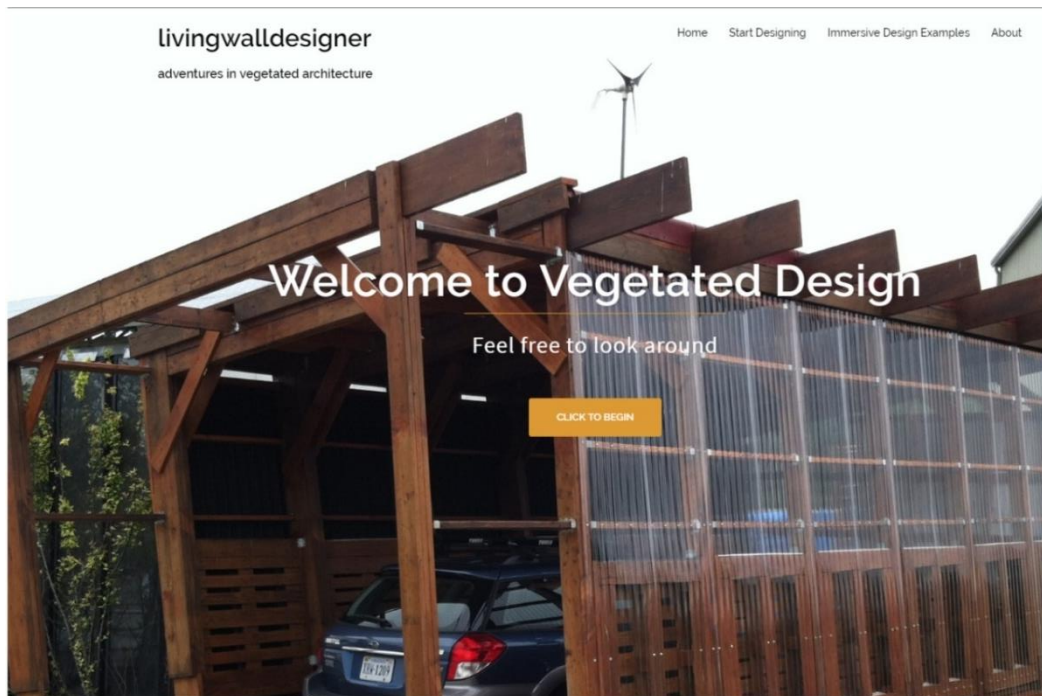
Figure 81: This is a photo of the Solar Garage case study. The "click to begin" button takes the user to the beginning of the website which serves as an introduction to all of the information on the site while introducing the overall framework.
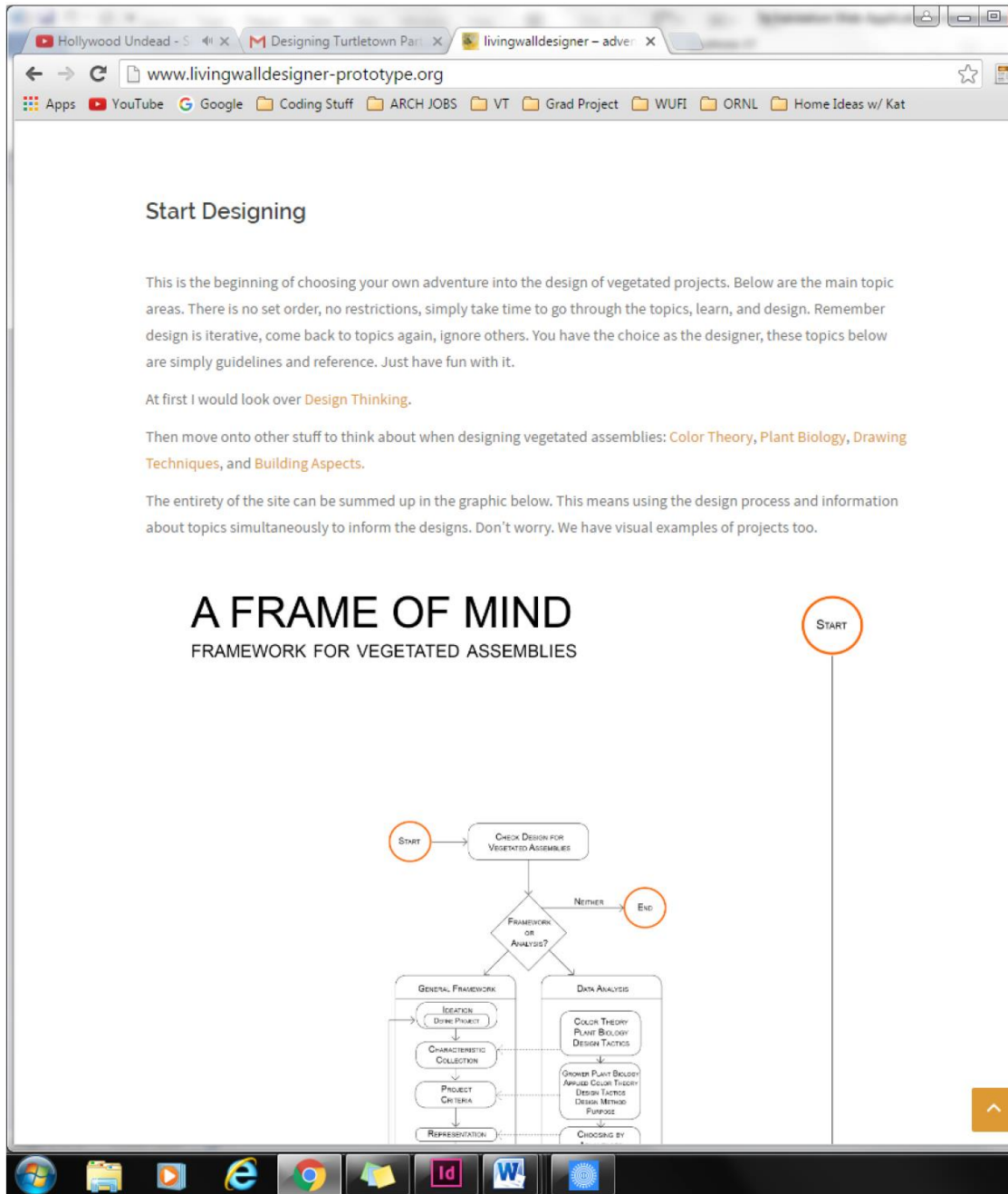
Figure 82: This is what the user sees after clicking on the start to begin button. The site scrolls down revealing the list of the main topic areas as well as a short explanation of the topical areas and a short introduction to iterative design. The graphic of the overall framework is then provided below the written explanation. Much of the written explanations are kept short and when the bottom of the page is near a back to the top arrow appears in the lower right corner. This feature is most helpful for mobile devices.
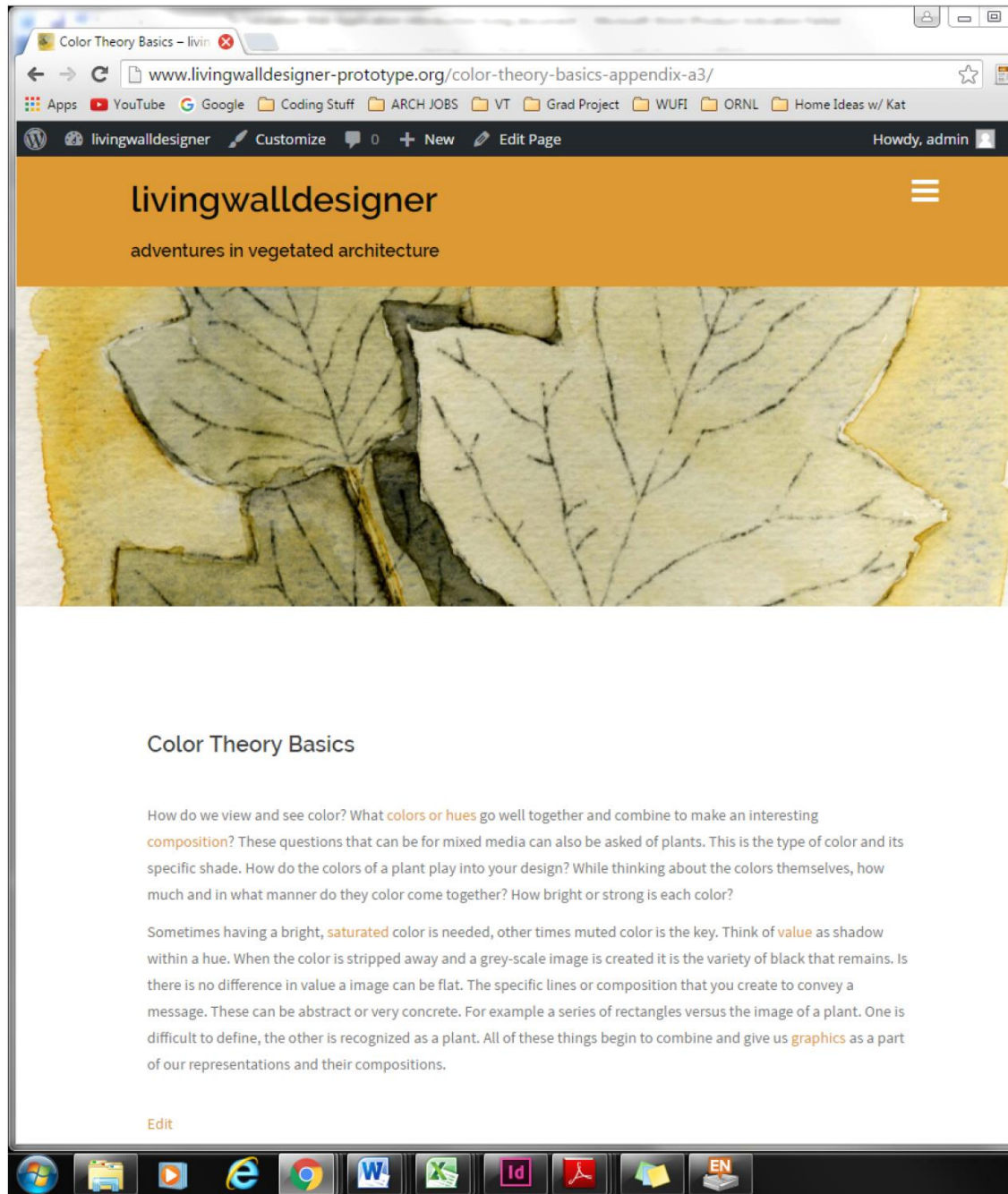
Figure 83: From the main topics on the home page, one option would be to click the link to Color Theory. The other main topics have pages like this as well, and then further divide with links to sub-topics. For example color theory divides into color/hue, composition, saturation, value, and graphics. The text that is visible on the page is all of the explanation of color theory for a fast, but complete summary of the topic area.
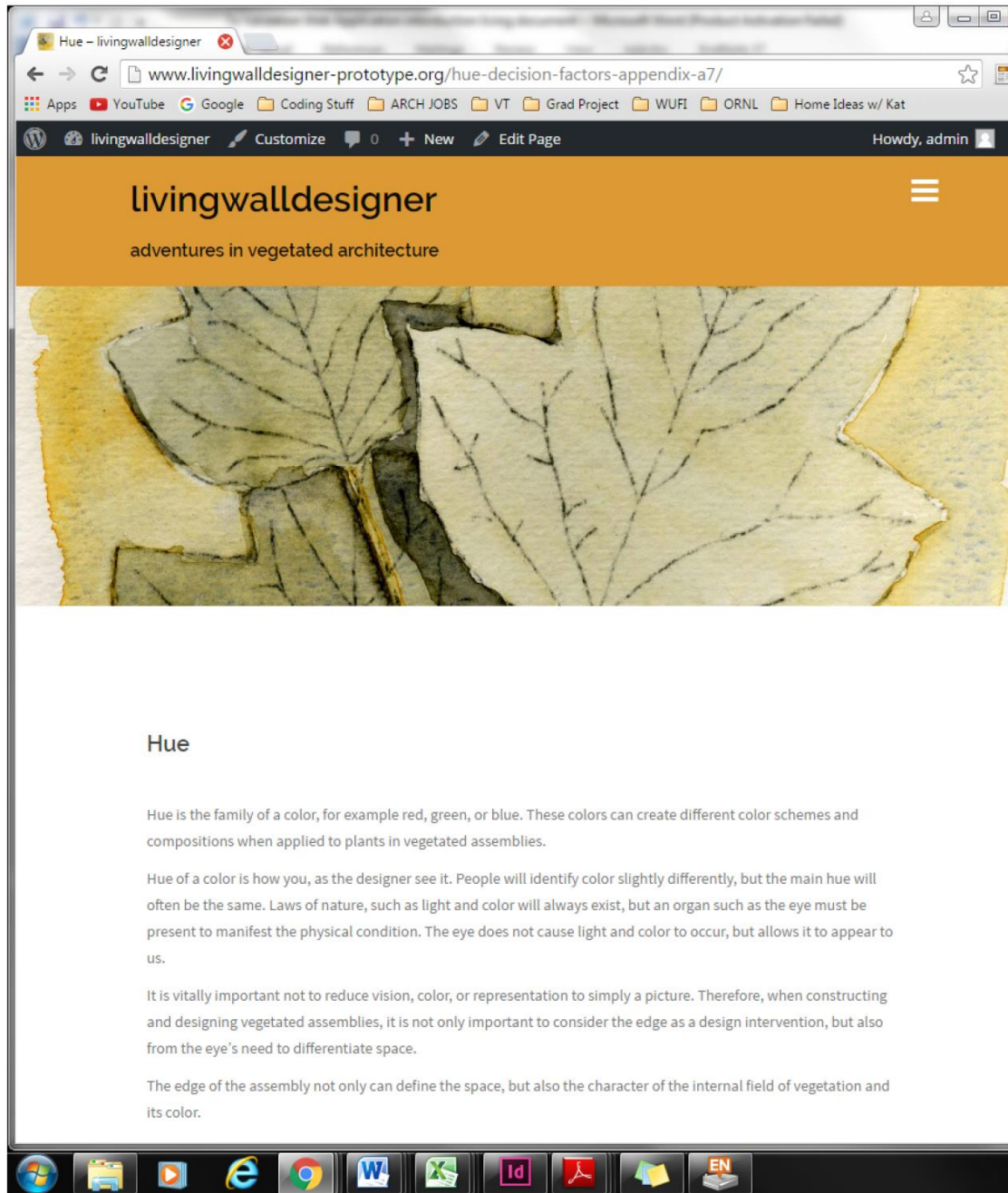
Figure 84: Hue is a sup-topic of color theory mainly concerned with the visible color, for example red, blue, or green. These pages have information, but also some help tips when using the information. These come from experiences I have had from projects or what I have learned from my own mentors.
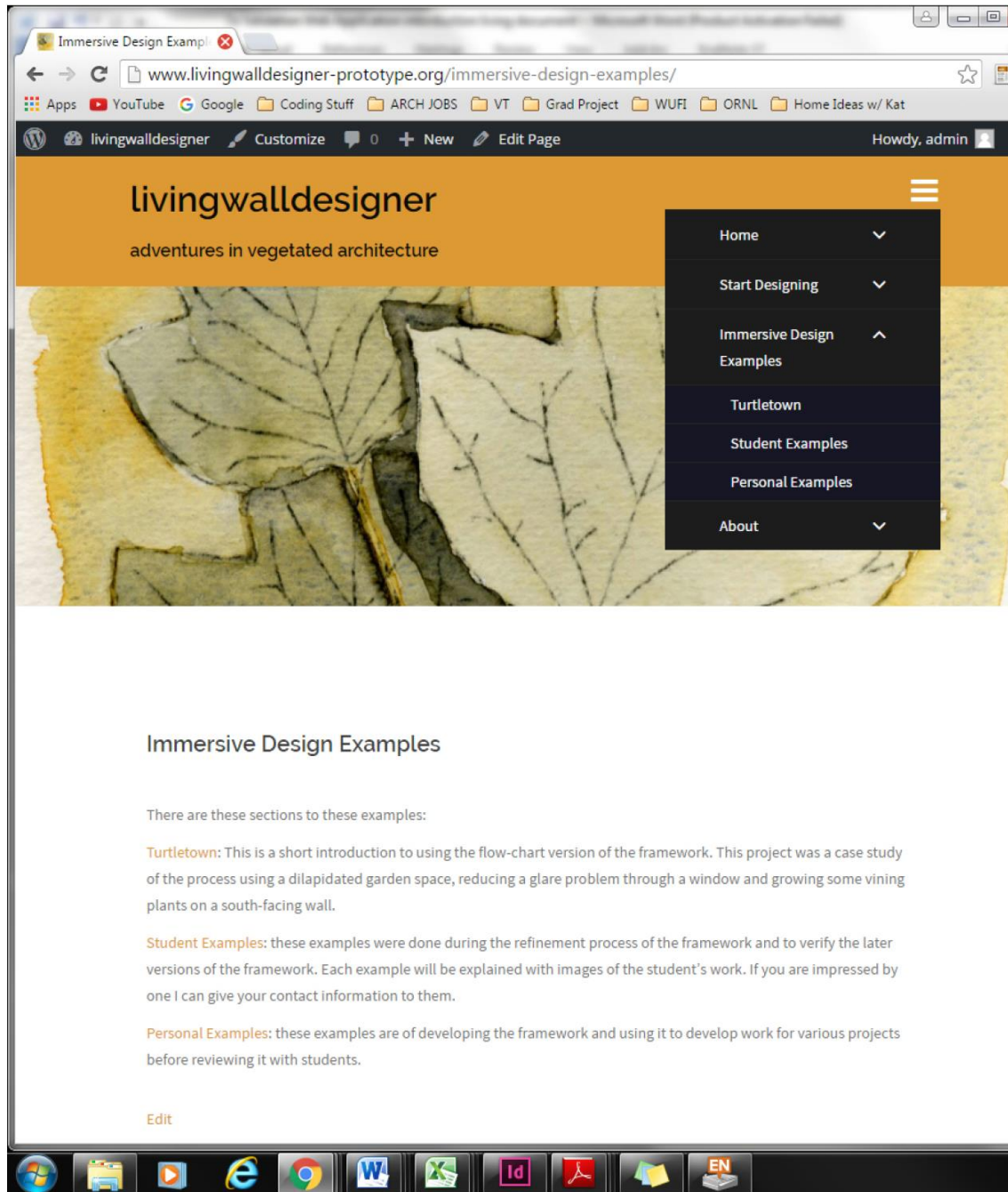
Figure 85: From the general topics and sub-topics, users can then move through the top menu. This is where the menu has been opened for one of the four main areas keeping the menu small and compact. The page shown is the immersive examples using the framework. The options in the menu are also available on the main page about what each kind of example.
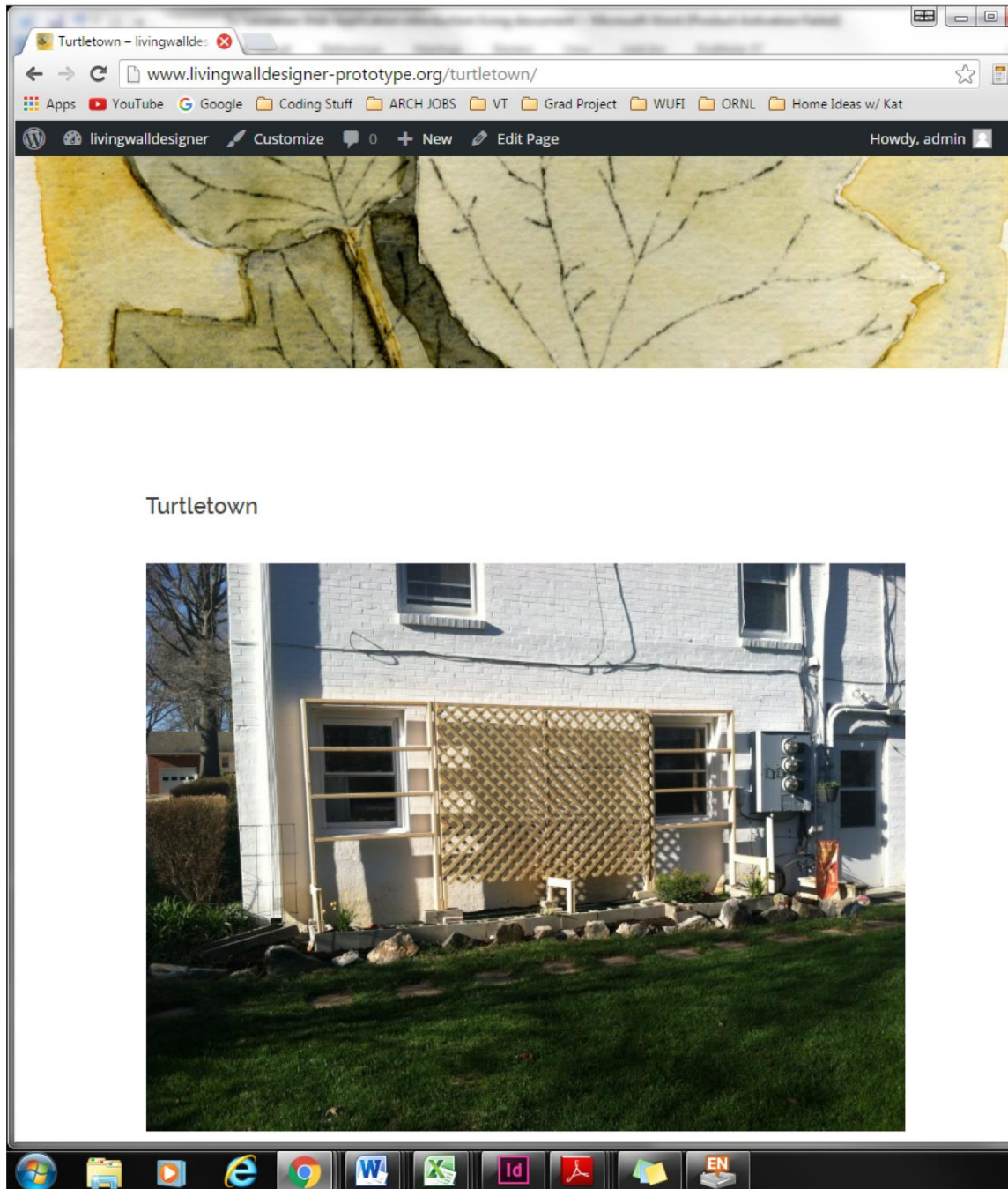
Figure 86: This is a personal example of using the framework. This project was called Turtletown. These examples not only have images of the project, but also give an explanation of using different parts of the framework and the thought process that was used. This specific example is of using the paper appendix version. This version is called the printer-friendly version on the website.
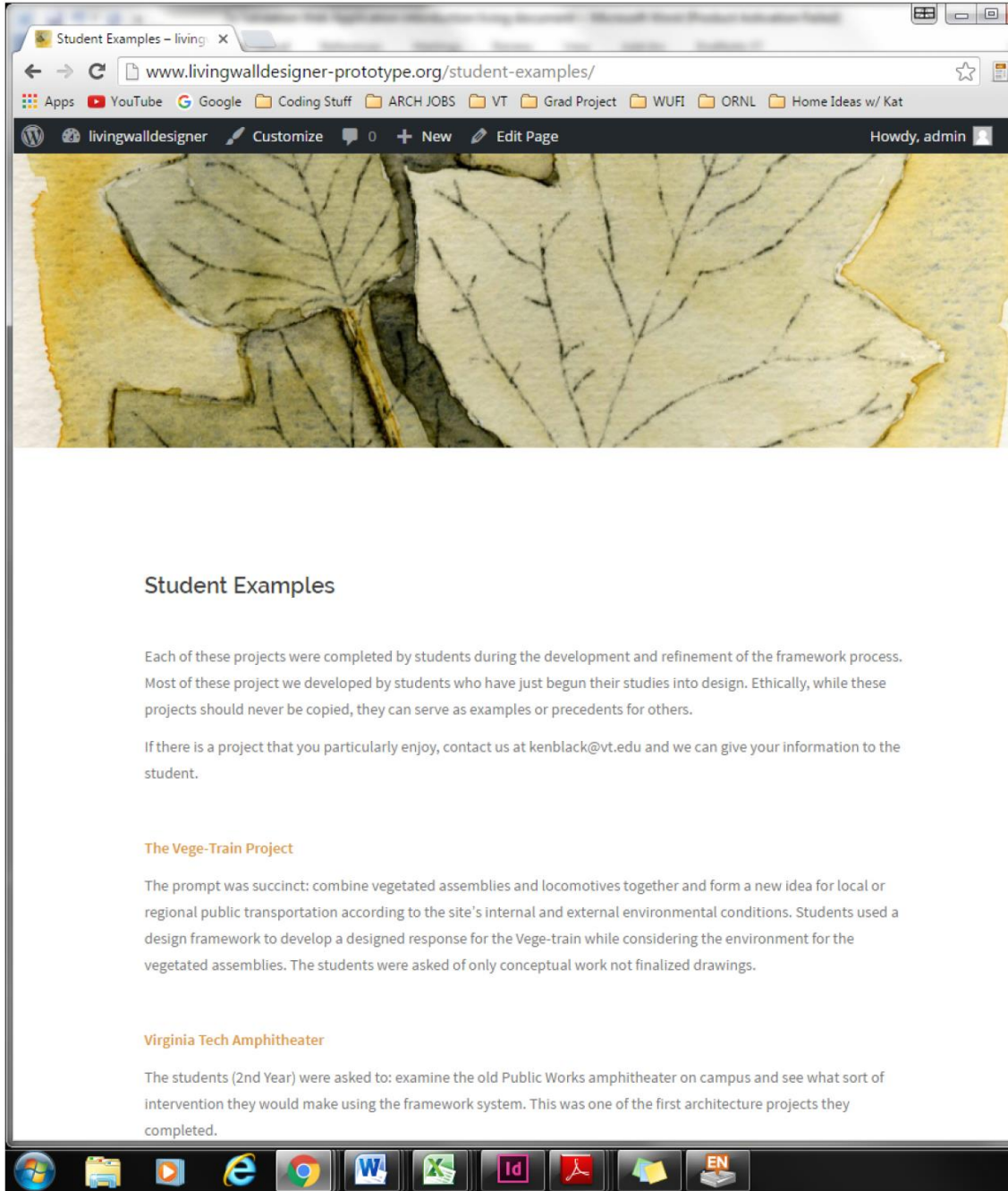
Figure 87: Both types of examples also have a list of all of the possible examples to choose from. This is part of the list showing student examples of using the framework. These student examples were developed through different class types including traditional studios, seminars (non-traditional studios), lecture classes, and questionnaire exercises.
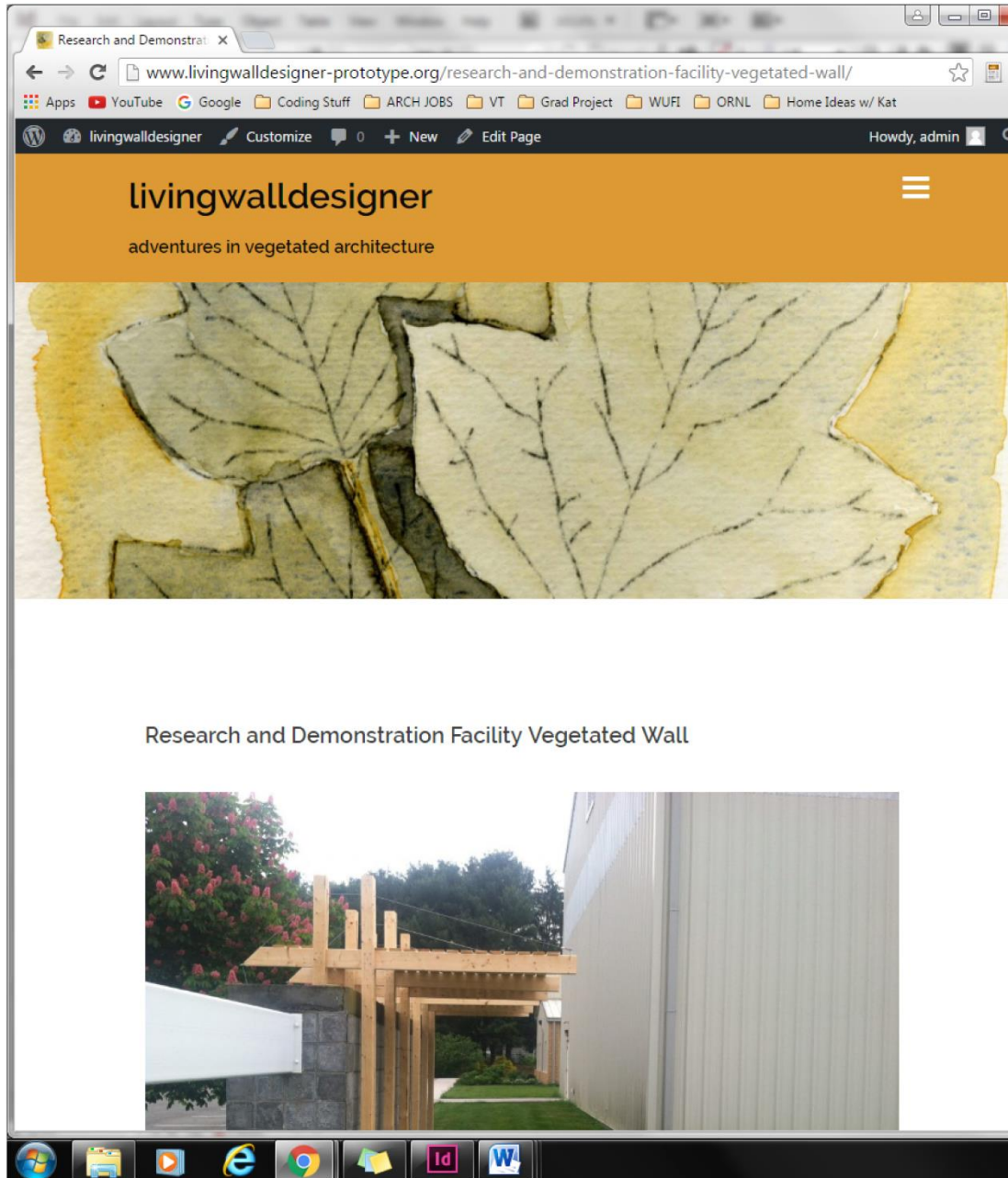
Figure 88: For example if the user clicked on the RDF Vegetated Wall, the full scale construction I did with two students would appear. The project was conceived by two students from some of the courses I taught testing the framework. We took the design project past that of a typical studio developing what would be later called the Solar Lounge. By developing into a case study for the dissertation the project secured funding and was completed in Spring 2016.
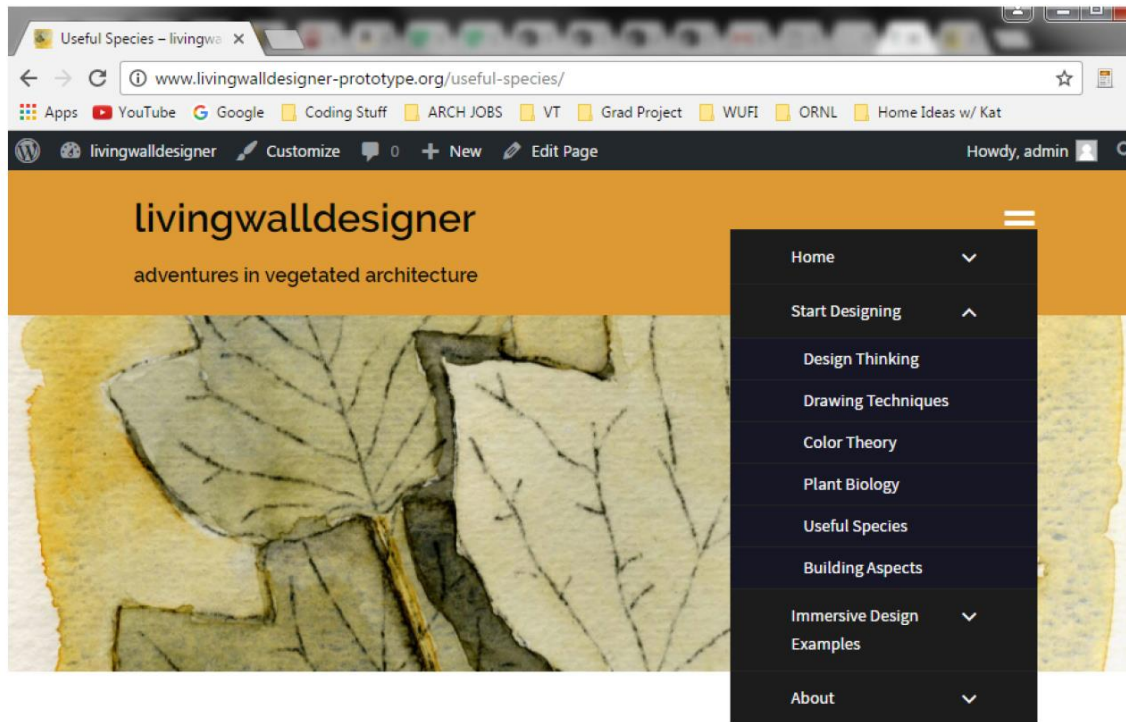
Figure 89: From the general topics and sub-topics, users can then move through the top menu. This is where the menu has been opened for one of the four main areas keeping the menu small and compact, specifically the different topical areas (color theory and plant biology, etc.) and the Useful Species List. The page shown is the beginning of that list while using the framework.
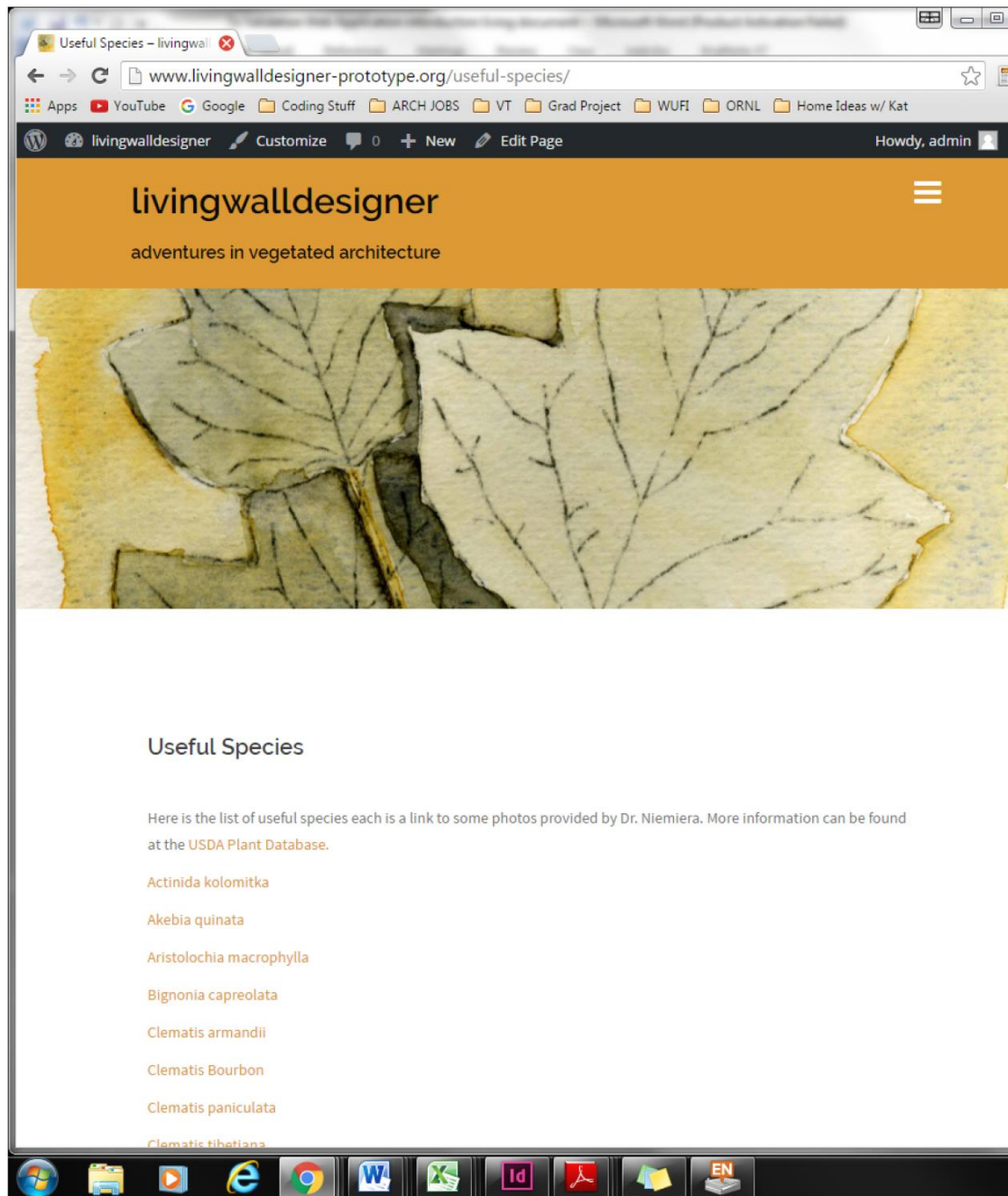
Figure 90: There is also a list of possible species of vining plants to use. The list and the images (after clicking the links) were graciously provided by Dr. Alexander Niemiera of the Horticulture Department at Virginia Tech.

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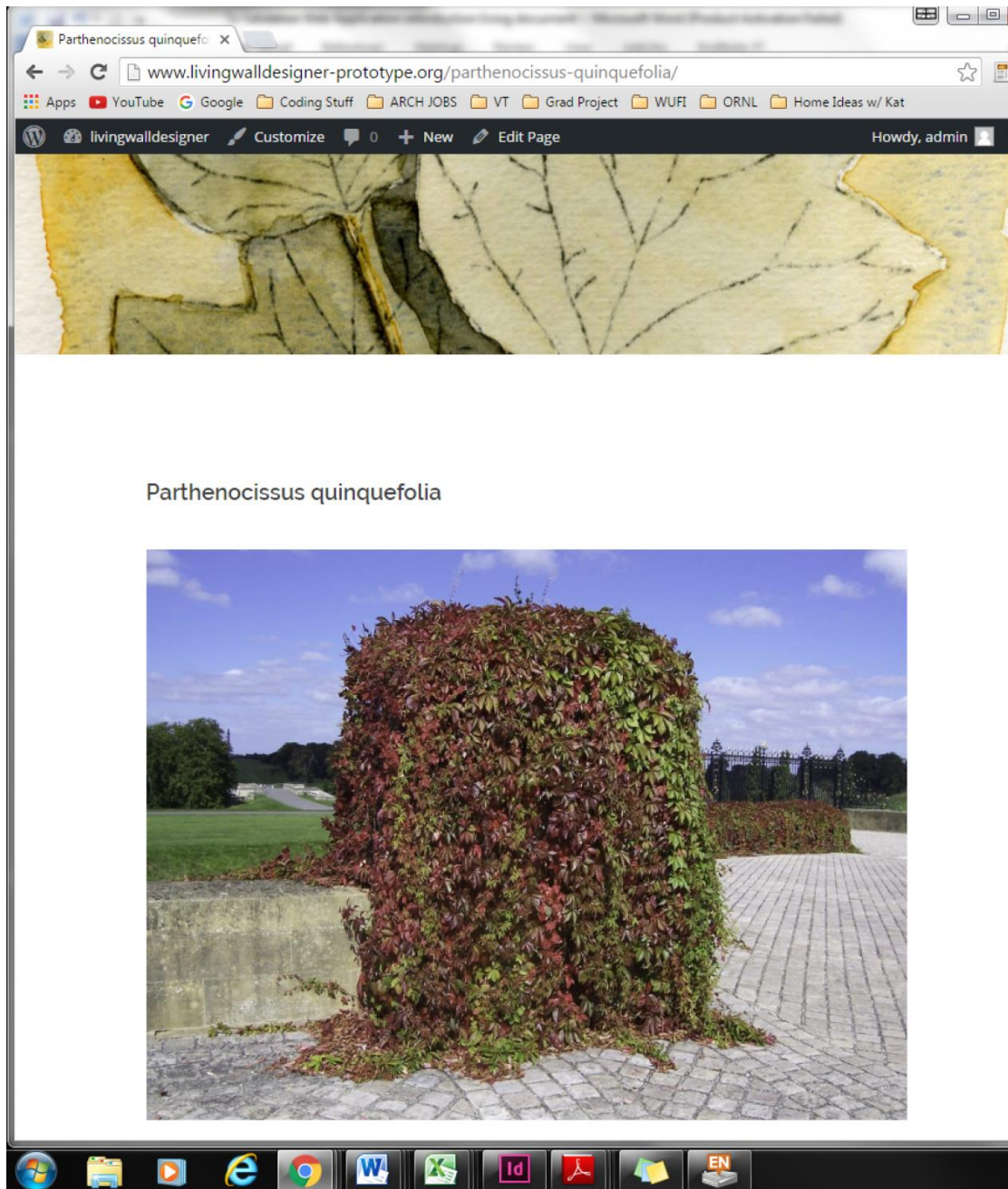
Figure 91: This is an example of one of the plants, Parthenocissus quinquefolia, also known as Virginia Creeper. There are multiple images of each plant from Dr. Niemiera's database of plant photos.

This concludes the short introduction to the website, the most current result of teaching

and researching the design process, vegetated assemblies, color theory, and how these

interact and combine when teaching. The website will have updates as time goes on, providing more information to others as topics and other methods are researched.

4.3 Significance: Web Application and Framework Results

The web application took a static page and became a dynamic platform that can be used anywhere with an internet connection on multiple platforms (computers, tablets, mobile devices). Computers are more prevalent than ever with tablets and other technology making their way into almost everything that we do. The work discussed here needs to be accessible to its intended audience and only providing a full book is not effective.

This web application combined the ability to access information with the ability to sketch and draw an idea and then present this idea to the world. Technically anyone in the world can gain access to the livingwalldesigner-prototype.org site and be able to use its information. This is a first step to a system of decision support frameworks and tools similar to that of Climate Consultant. It perhaps will not be that robust for some time, but it can serve as the beginning for a longer line of inquiry. This search for a series of qualities and designs leads the work towards developing a pattern language for vegetated assemblies and the methods that lead to their design.

There are almost an infinite number of topics that can be reviewed for vegetated assemblies and their combinations. These ideas are also those that students are already identifying as a part of their undergraduate studies. If we are careful to listen to what interests them, then the future research can be more useful and targeted. The inclusion of more topics might overwhelm the audience, but if we take care to organize the web

application carefully, more information can be included for students. The ideas that students bring forth are the direction that the project will need follow in the future as they are the future of the profession.

The significance of the web application was the final determination that the audience of the work would be students and those who needed a reference later. This is not a decision making tool and will not guarantee success, but it shows how something ought to be done and serves as a guideline or an introduction to broad topics both in design and its application. We, as designers then have the capability of interpreting these designs and have them inform our own works.

Chapter 5: Validation

5.1 Validation: Using the Framework in Studio Environments

Overview:

The framework is what was made, the thing or product of the dissertation. The information it contains then provided a base for work in validating possible applications of the framework. There were many steps to validating the process for developing a framework, reviewing, using and then revising the framework. From this process the framework was then adapted for both a paper appendix system and a website application. The results of the dissertation started with explaining the framework itself. The validation seeks to understand if the process of making such a framework was what it ought to be. Is it the normative or accepted process for starting out developing and finalizing a framework? A summary of the work and methodology thus far can be found at the end of the methodology in section 3.2 of Chapter 3.

Comparison to other classroom methods not in a traditional studio

The next section deals with the situation where the framework was **not used at all**, in a large lecture classroom. There are many approaches that educators or students could use to implement the framework. Within architectural education the design lab or studio is the primary work environment. Professionally the charrette is commonly used for collaborative design. For non-design majors, or for other architecture lecture classes, a studio-like course could be used to introduce issues of vegetated assemblies. The decision support system was used in three different types of teaching environments: the traditional studio, a studio-like course, and an independent study to see if the decision

support system was viable for use in these types of courses However, before this decision

for each type of course was made, an initial study of typical large-scale lecture methods

was conducted through a large lecture course to be able to compare the ability to use the

decision support framework in each type of learning environment.

The main goal of the decision support system or framework is to serve as a

knowledge sharing device and to assist designers in improving decision-making; that

improvement is determined by having more information and therefore a more informed

decision-making capacity after using the framework. Further, the framework is intended

to be used by students to aid in introducing them to an unusual building assembly

(vegetated assemblies) and a theory about design (color theory) to integrate the two in

architecture. However the process can be adapted to many topics. We teach topics so that

students can become more familiar with them and in turn are more likely to use them in

the future. This process can influence the profession and make certain methods, topics or

assemblies more prevalent in future practice. However the normative process for how this

ought to be needs confirmation. For the present research, this has been done through the

use of questionnaires, design exercises, and validation through immersive case studies

and publications.

Lecturing on Vegetated Assemblies

Often vegetated assemblies are introduced as a topic in a lecture class. The

purpose of this initial study was to see how such a lecture would change students'

understanding of a vegetated assembly, and if this change was insightful or meaningful to

a core idea that the students were currently pursuing. This is something that the

framework proposed in the dissertation is specifically designed to do. If students do this inherently, then it might disprove the need for a framework in the first place.

This study was conducted in a 3rd year Environmental Building Systems course lecture. This is a large lecture course of approximately 100 students on average. The Environmental Building Systems course serves as an introductory course to active and passive building techniques. The students are mostly from the 3rd year of the undergraduate program and they are taking the class in sequence after the first half of the year-long sequence in Environmental Building Systems. They know a majority of the structures sequence as well and some of building materials, however most of these courses are occurring at the same time. Thus these courses are first-time exposure to systems, structure and material characteristics. The course that the vegetated assemblies lecture is in focuses on passive and active strategies for design including heat-loss, heat-gain, stormwater and plumbing. The first half focuses on other topics such as acoustics.

Procedure of the Large lecture Study

The study was carried out as a standard lecture in Hancock Hall (figure 92) while the primary course professor was away at a conference. There were two main questions to the study: first, what were the sketches students would give before and after a lecture on vegetated assemblies; second, would they integrate a design idea identified as important to them in architecture.

There were five steps to the study's exercise. First, the topic of vegetated assemblies was introduced. Second, students were asked to "draw what they thought a vegetated assembly such as a green roof or wall was to them" currently from this initial

introduction in 15 minutes. Third, the full lecture was given on vegetated assemblies

similarly to how most lectures had been given during the semester by the primary

professor with generalized examples. The lecture was taught on the general

characteristics of vegetated assemblies and what they might be used for in design, for

example shading, connection to nature, stormwater runoff reduction. It also taught the

major characteristics of the parts of each system focusing on vegetated roofs and walls.

These components were put into context with images from local and Europe Travel so

that these were not diagrams that were removed from the building envelope. Fourth,

students were asked to "design a vegetated assembly such as a green roof or wall again"

with the information provided in the lecture also within a 15 minutes time span. Fifth,

once this sketch was completed, the students were asked to give a topic in architecture

that was meaningful to them. This order was done to prevent prompting them of the topic

while designing the primary or secondary vegetated assembly.

Figure 92: Hancock Hall, a large lecture auditorium where Environmental Building Systems study lecture was performed.

Purpose and Results of the Lecture

The purpose of the lecture was for the students is to be exposed to the topics so that when in the profession they are not unknown to them; however this is not enough exposure to assume any expertise, but only understanding. The purpose of the lecture for me was to convey the information, but also to see if a lecture homogenizes the thought process on a topic, such as vegetated assemblies. This was done in a two-part activity of all of the students present in the course on the day of the vegetated assemblies lecture (using the previous procedure in the last few paragraphs). Five things were directly reviewed by doing the activity: (1) are the responses homogenized?; (2) can students inherently analyze and make a new assembly for a project or is a vegetated assembly regurgitated without further thought?; (3) what might the vegetated assemblies be used for?; (4) what were their interests in architecture?; and (5) were any of the ideas they have about architecture put in this design of a vegetated assembly?

The answer to the first question was that overall responses were homogenized over the group of students (figure 93). This is due to the fact that most of the students have not seen the systems before, learn it for the first time, and believe that this is what a system can only be. Further, I, as the instructor did not explicitly ask for anything other than the component that was taught, so they might not know to make a unique system, but return the answer as though it were a test. Therefore to receive something as an educator I must ask for it, or identify possible options for the students. This is difficult because you want them to see what the assemblies could and ought to be without directly telling them, but perhaps many are not yet ready nor desire to know vegetated assemblies in such a way.
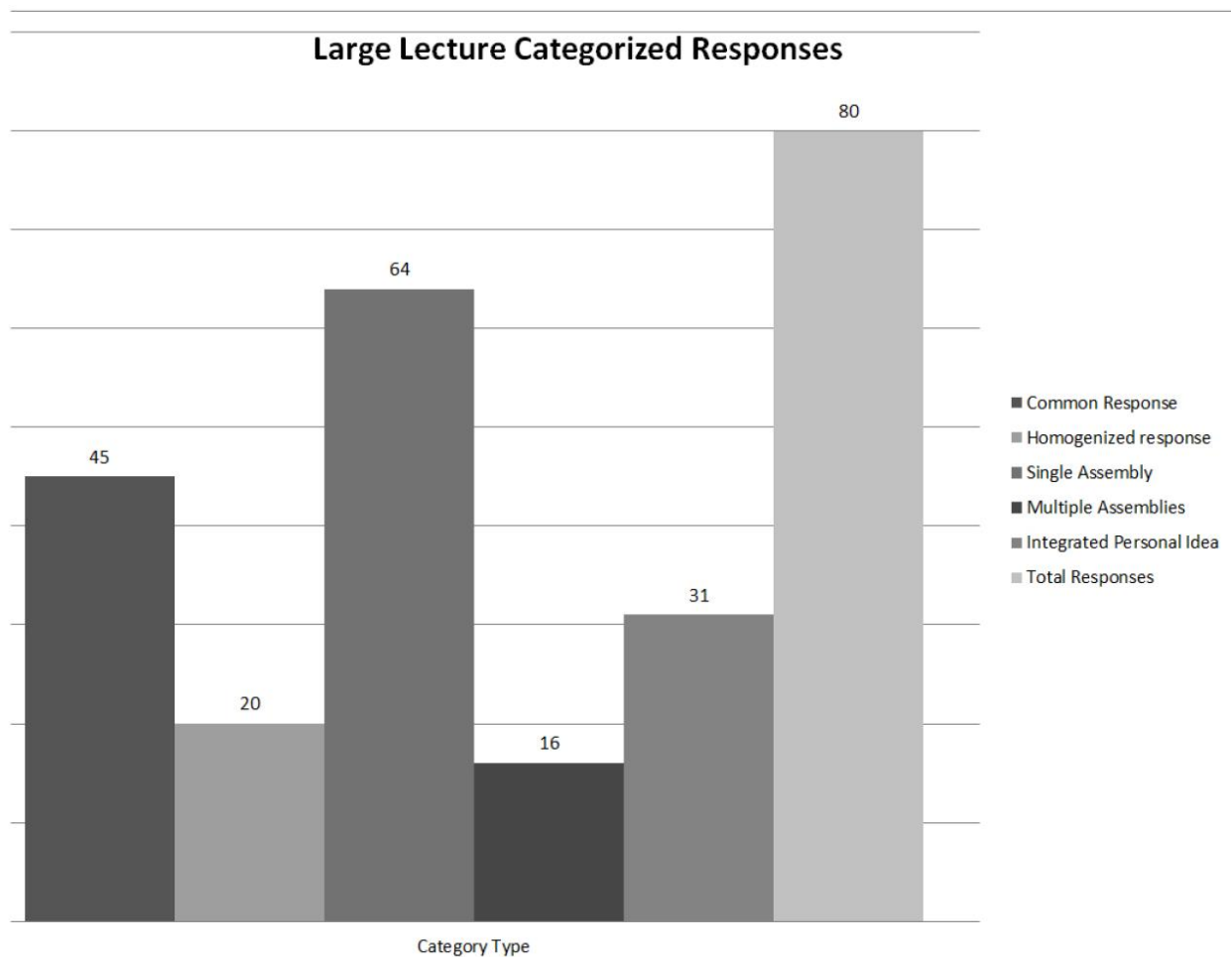
Figure 93: Categorized responses from the visual representations provided by the study from before and after the study. A common response (45) was one similar to figure 94, where a layering of materials was presented as a first response, then after the lecture a second response was one of the diagrams shown in the lecture. A homogenized response (20) was when a unique or different assembly or idea was introduced in the first response, but then for the second response an example of the lecture was used. Then the total responses (80) were divided into having either one (64) or multiple assemblies (16) drawn on either response. For integrating a personal idea into the responses, only 31 of 80 had an idea other than simply identifying the vegetated assemblies presented in the drawings.

Figure 94 is a representative example of what most students developed in two 15 minutes periods. From this we can also answer the second and fifth questions that while the students could be analyzing the vegetated system, outside topics were more often not

included in the designs provided by the large lecture class. Overall, the design exercise in

the large lecture was viewed as more of a test question than design. This is most likely

due to the nature of the course, and that they were not instructed to integrate an idea. This

lack of instruction was on purpose to see if students would integrate an idea without

direction.
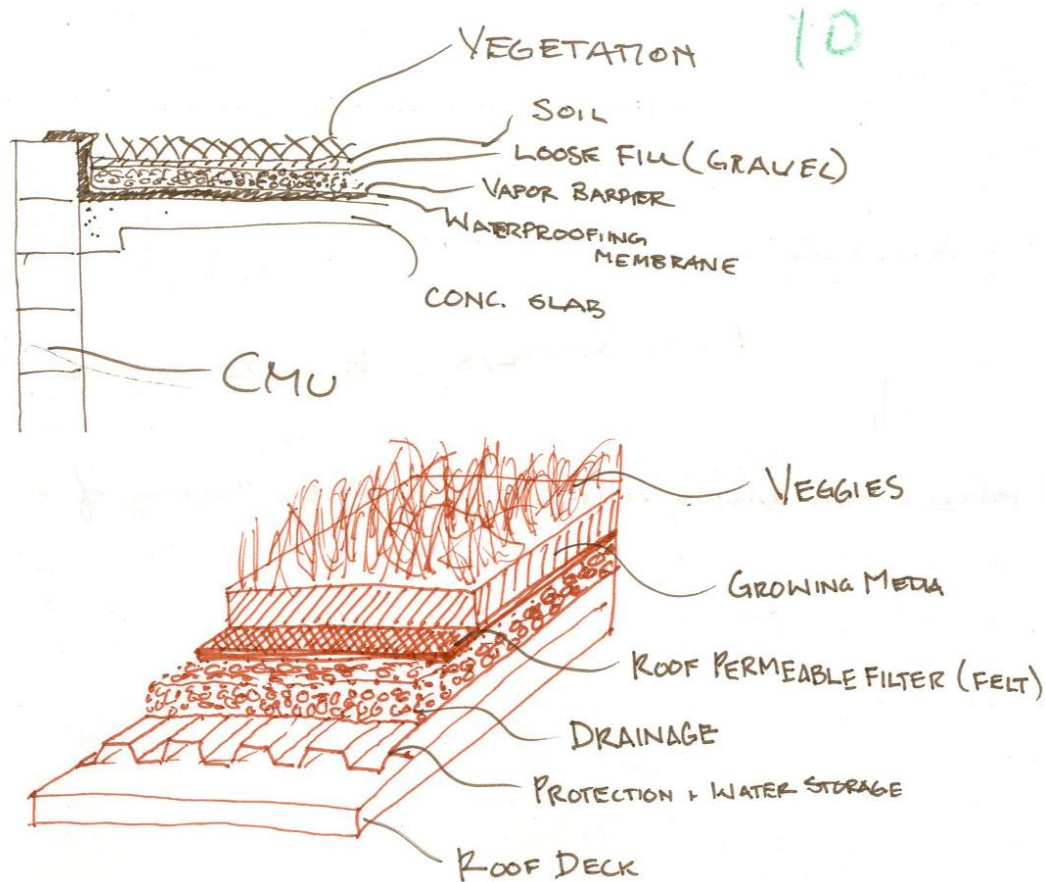
Figure 94: An example done in the EBS large lecture class by a student we will call Jerry. This shows a common example of a layered roof condition (top) in the first response followed by a second response showing the volumetric example used in the lecture (bottom).

This is a combination of what features were found in most of the examples. The top

image is from before the lecture where the student included a component-style diagram

of a vegetated roof on a concrete structure. After the lecture, a three-dimensional updated

roof system was introduced, but no longer in relation to a wall. This was the most

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common progression from before and after the lecture. In the beginning a detail would be drawn about plants and a soil layer. This student had more detail including a fill layer and different moisture and vapor barriers. One of the most prominent images in the lecture was similar to the second volumetric drawing shown here. Most of the students when prompted for a vegetated assembly drew this or a similar image (45 out of 80, 56%). They focused on the layers of the roof assembly and did not integrate it into a full envelope. What was troubling was those who had unique ideas, but then changed to a more common response afterward. This resulted in there being 20 additional common responses totaling 65 out of 80 responses (81%) shown in figure 93.

To review question 3, the students had an idea for what vegetated assemblies might be used for, but most saw them as a component, rather than an integrated system. This is most likely due to the fact that the class itself is mostly a performative-based survey course of systems with beginning context for instruction. Once again the context that we give students is a large factor in what they learn and what they believe something is and ought to be for. Further, the ideas that were the goals of the students were not infused into what they thought a vegetated assembly could or ought to be. However, while topics were on the whole not included, the topics themselves show the wide breadth of topics that would need to be reviewed in the future for inclusion in a larger decision support framework series. The topics included: passive solar, aesthetics, ventilation, water collection, connection ot the earth, urban nature, green spaces, human health, drainage, absorption, rooftop gardens, sustainability, insulation, outdoor spaces, wildlife health, energy costs, wind chill, color, privacy, protection from the elements, urban heat island reduction, noise reduction, dynamic wall systems, living architecture,

views, usable roof space, aromas, and veneer. Not all of these were mentioned in the same frequency and figure 95 shows each topic with the number of responses that had each topic.

Number of Responses	Topics over 80 Responses
51	passive solar: shading, solar winter, passive cooling summer, plants need sunlight, thermal comfort
44	aesthetics (appearance)
39	ventilating areas, CO2, polution control, improved air quality
34	water collection/ runoff - 1 greywater uses
21	vegetated assemlbies bring earth to structure much like we put structures on earth/ giving back to the earth
17	urban nature (green spaces)
16	human health
14	drainage/absorbtion
13	rooftop gardens/ food harvesting
10	sustainability/LEED
9	insulation
8	outdoor spaces, welcoming
8	wildlife health: bugs, birds,
6	save on energy costs
5	internal temperature
5	wind chill
4	color
4	privacy
4	protect roofs eg driving rain,UV
2	urban heat island reduction
2	blend boundary roof and ground
2	less noise
1	dynamic wall systems
1	desired programs
1	living architecture: makes it more alive
1	hiding unwanted views
1	fewer toxic chemicals
1	usable space on roof
1	aromas
1	veneer

Figure 95: The topics students believed vegetated assemblies are useful for in design. These topics are all related to vegetated assemblies, with the main reasons for using these systems at the top. Some of the topics are parts of other topics listed such as passive solar or indoor air quality as parts of sustainability and LEED. This chart is mainly to show what students are thinking of when they hear vegetated assemblies, regardless of whether the system is intended to do these things.

This finally comes to question 4, the ideas that the students are interested in architecture. After the initial and final sketching of a vegetated assembly and asking for what they thought vegetated assemblies were used for, the student were asked one question: what topic interests you in architecture as a line of inquiry? The concept of a line of inquiry

was clarified to mean: what interests you in architecture, what is your architectural idea that goes beyond one project? The students' responses are shown as a list in figure 96.

topic	how volumes interact
environmental lifecycle cost/analysis	form
environmental/sustainability	form: organic forms
site evaluation and use	form: building exteriors
light: whole concept	space
light: initeraction with materials	space: division of
light: regularity and repetition	monumentality
daylighting and its interacction with space	threshold
arch lighting conditions	public vs private
light: light and shadow	screen as sturcture and reverse
passive solar in luxury buildings	wonder
light: vegetated assemblies	non-conventional concrete
light: volumetric spaces	metaphysics
acoustics	flatness
cultural and enterainment spaces	use of space in residence
interior and exterior transformative spaces	residential architecture
industrial design elements	human activity
unique places	time in architecture: its portayal and reception through t
layers	building systems
additive or subtractive mass	materiality
material usage	mass
sense of place (rooted buildings) conneciton to landscape	mass-void
new life to history	mass-geometry
historic preservation	mass: thickness, thinness, and reveal
flow through building	intersection of aesthetic and function
spatial qulaities	vegetated assemblies aesthetic and function, to context
traffic flow - arhcitecutral movement	vegetated assemblies relaxing, occupied spaces
community	extraordinary spaces
modularity	structural: detail/expression
structure: exposed	stairs
atmospheres and senses	tower vs halls
minimal architecture: blends into surroundings	inside vs outside
Kengo Kuma	nature
improving qualiy of life	contemplative space
Grand Spaces	outdoor and gardens
Emotional responses to space	symmetry
care for detail	
follies	
elevate nature and its experience	
design as art	
scale: range	
scale: part to whole	

Figure 96: The ideas that the students present for the lecture exercise were interested in. These ideas are presented in no particular order, but are grouped by similar topics.

This exercise of the large lecture provides a basis for comparison between a traditional lecture and other methods of instruction including the implementation of the framework. Later in the validation, examples like these will be discussed and compared to the other design exercises, traditional studios, and the studio-like Metaphysical Room lecture class. Since the time given for the design exercises using 2nd year students from a studio course and this large lecture course were the same, and that neither group was familiar with the decision support framework (not used in the lecture at all), I believe that some conclusions can be made across the different class types. Between the two sketching exercises and the 30 minutes that was given to lecturing on vegetated assemblies, about an hour of time was devoted to the large lecture activity. This exercise should be directly comparable to the students in the 2nd year studio design exercise as these students had an hour to teach themselves the framework and vegetated assemblies while integrating a topic for their design.

The main difference was that students were shown in the framework how a topic might be integrated, while in the lecture activity no direct instruction for integrating designs was given. Next was to review the work of students in a traditional studio and how the framework might begin to be implemented in the future.

Initial Summary: Studying Multiple Environments

The work from studio served as the basis for understanding the as-is state of studio and how the framework might help in a student's design process. *Fusion of teaching and research: design support tools and vegetated walls* (Black, et al. 2015) supported two other papers that reviewed the initial framework design and studio-like

courses or learning environments. The following is a summary of that paper, written with the support of Dr. James Jones, Dr. Elizabeth Grant, and Mario Cortes.

Design is inherently a decision-making process, and the making of new ideas (ideation) and representation are at its foundation. Designers typically move from ideation to representation and then to multiple versions of a design (iteration). At Virginia Tech, students were given a two-week project in the second-year studio and asked to use vegetated assemblies. Their work was reviewed for what types of representation and methods supported their design decision making. These methods serve as an extension of the representational process and allow designers to test proposals, understand implications and allow clients to visualize work. (Black, et al. 2015)

The purpose of this study was to see how students design and interact with vegetated assemblies and perhaps the tools or technologies that influence the representation of ideas and their process to make decisions. Initially this was performed to confirm targeted software programs might be used in a future prototype tool. Though this quote should be commonly assumed, the results from the survey statements showed that:

> a professor's knowledge base influenced the student's comprehension and, with exposure to topics, students were more likely to include topics in future work and develop distinctive representational styles and methods. This study also confirmed the mindset that the envisioned tool will help to inform designers, but not make decisions for them. (Black, et al. 2015)

This initial research refined assumptions in the prototype tool, and actually allowed the students to request a supporting tool. This served as a stepping stone for a larger study

aimed at reviewing the normative process for designing vegetated assemblies, at the time by creating a prototype tool for the representation of vegetated walls focusing on color theory. (Black, et al. 2015)

However this is only the beginning to understanding the As-Is process. Where do we go from here? This first paper sets the foundation for the following studies. Many of the ideas presented here are similar to those now central to the dissertation. Old verbiage was changed based on the study and in the changing times of the dissertation: a tool then became a decision support framework. Key concepts were identified for future work such as: the lists of growers, precedent studies, and color theory representations among others.

We later know that more examples were desired from surveys, not just a few. The need for case studies is not simply that right now case study books are popular and have lots examples of little depth. However students wanted examples of using the framework and its information, and this needed to be combined with a depth of inquiry. Therefore, is there a way to combine these with a line of inquiry? This desire for case studies looks at taking case studies for their ideas and showing how ideas can be translated to designs. This would change the focus from purely representing the vegetated assemblies and instead reviewing the normative process for how students ought to design using a decision support system and have the ability for other ideas to be explored.

The work presented by the students reconfirmed that representation is important and the need for a longer look into representation and its methods. This prompted another project, as an independent study with a more experienced student to determine if the information provided in the framework should target a specific year since it already looks

at the beginning parts of design in pre-design, schematic, but not intended for construction documents.

This work coincided with another student's desire to do a study with the on the Solar Garage and the adjacent Solar Decathlon House out at the Research and Demonstration Facility at Virginia Tech in Blacksburg. This would also start to review the As-Is process via researching and designing for automobiles, a vegetated system, and reclaimed materials and for a longer term study of the design process of a single individual and see where the framework might be useful.

The next publication, *Student-driven design in architecture: interacting with reclaimed materials and passive solar techniques,* (Black & Doorn, 2015) introduces how the process of design can be done in a group setting as a pair between designers (the proposed Solar House renovations from the paper) and as a sole designer with larger group of volunteers including designers and non-designers (the Solar Garage). This also would become important in understanding how lines of inquiry form and associated works begin as part of the adjacent possible mindset, contributing to the development of a studio-like learning environment which would become the Metaphysical Room lecture course.

From this dual project, lessons such as needing information on a generalized design process were added to a prototype version of the vegetated assembly framework, so that it had two sides to the design process. This dual-track version of the framework is what would later become the overview version of the whole framework, or page A1 of the entire Appendix framework version.

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The last paper, *Learning by Doing: Applying Vegetated Assemblies in Architecture Studio* looked at the initial stages of implementing a paper appendix version of the framework in a design exercise with students from a 2nd-year studio I assisted teaching. These students were given only the overview pages of the appendix framework, essentially pages A1-A6 of the paper appendix.

From this process, a number of lessons were learned in what information should be presented, in what manner, and to understand that not everyone will need the framework nor desire it. Rather, the framework will become a decision support system for those who seek advice on the topic, not as a mandated method or process. At this point the framework graduated from a "tool" to a "decision support framework", and as a framework that students would graduate from with enough experience and use a reference in the future.

From observing the As-Is to Implementing A Design Framework

These publications begin to weave a story through the dissertation of systematically approaching the project both as a means of inquiry, but also as a series of works that should be published to show how a dissertation can be validated through publication. I have been very fortunate that the larger academic community has reviewed this work, and has deemed it appropriate for dissemination with the community. There is a large risk in validation through publication; however it has worked to the advantage of the dissertation simultaneously validating it and in many cases pushing the body of work forward. Everyone starts from a beginning and uses experience to create a foundation for design, which in turn helps us to form our decisions and ideas. The decision-support

framework, proposed and tested in an academic architecture studio, is a visual graphic for the learning process students could have when working with green (vegetated) roofs or walls. It is the beginning for gaining experience that students can use to bolster their design processes using vegetated assemblies (such as roofs and walls), and color theory (colors and how they interact).

Reviewing the Traditional Studio in an As-Is Process Survey

The large lecture class is good at what it is designed to do: convey large amounts of information to a large audience in a time-efficient manner. Due to the tradition this style of learning has, it provides neither the prompting nor suggestion of analysis nor the active learning environment that a traditional studio or laboratory inherently possesses.

This next study started over the course of a three-week period, and centered on understanding the as-is conditions in a traditional studio before implementing the design exercises later in the year (see figure 54, Spring 2015). Usually this 2nd year studio was taught by Mario Cortes, a tenured faculty at Virginia Tech, however during the three week period he was away, I ran the studio while he was on the travel program (see figure 54, Fall 2014). We worked on developing the prompt for the project and I was given the opportunity to teach it during this period. Before getting to the results of the As-Is Process Survey, where does this work fall in the process of the dissertation? From these results in the Second Year Studio 1 survey, the method for exploring the new prototype tool (at the time) was diagrammed from ideation to the tool.
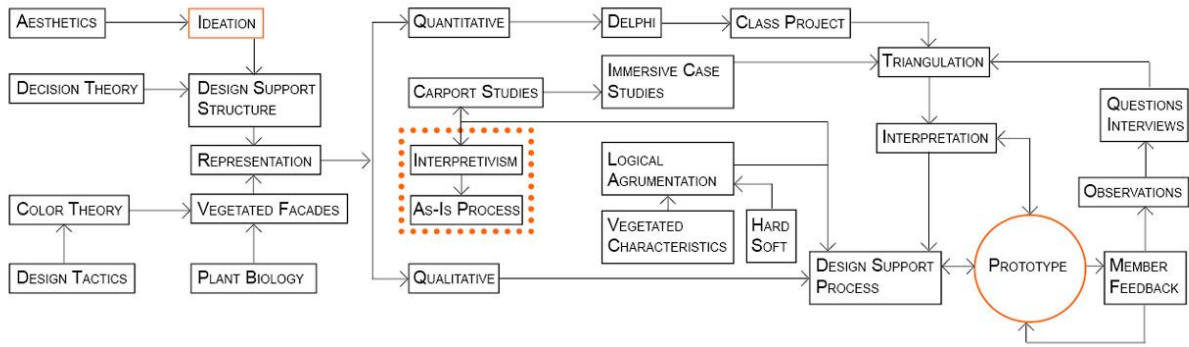
Figure 97: Theory Map for the prototype tool methodology; the dotted rectangle shows the work of this study.

From this grounding of the study and dissertation, we can begin to look at how the background of the students involved might begin to influence the results or at least be able to understand the abilities and knowledge of the students in the study. Much of the work shown here comes from the analysis done for the paper: *Fusion of teaching and research: design support tools and vegetated walls* (Black, et. al., 2015).

> As shown in figure 98, addressing experience, many in the studio did not have prior experience with vegetated walls and other assemblies. Of the 12 students who responded, 7 self-identified as working in both analog and digital techniques, often switching between techniques to explore designs. Students who worked with hand-drawn techniques worked with media such as charcoal on brown paper, pencils, pens (mainly HB lead and micron pens) colored pencils, and Prisma markers. Students who worked with computers used programs such as Rhinoceros, Photoshop, Illustrator, Google SketchUp and InDesign. (Black, et. al., 2015)

Experience and Method	Digital/ Computer Design	Analog / Hand-Drawn	Both Digital and Hand-Drawn
No Previous Experience with Vegetated Assemblies	2	2	6
Previous Experience with Vegetated Assemblies	1	0	1

Figure 98: (Black, et. al., 2015) Number of Students in relation to Experience and Method Used in Vegetated Assemblies

This confirms what was suspected: there was a range of personal preference when using techniques to explore designs, in this instance, over half (7 of 12) of the students used both methods. It was also found from the responses gathered that the list of assumed computer programs used by students should be expanded. Having confirmed what kinds of methods would be useful for interfacing with the prototype tool, the next step was to confirm that the students are interested in using such a tool. Before the project half (6 of 12) agreed that a prototype tool would have been helpful, after the project, 83% agreed (10 of 12). (Black, et. al., 2015)

From this initial understanding in the Spring 2015 called 2nd Year Studio 1 (see figure 54) of the previous amount of experience each student might have, further questions in the same survey was given to the same students. This survey happened after the three-week project and before the two rounds of design exercises using the decision support system. These later questions focused on the students' perception of their knowledge and changes in how they viewed vegetated assemblies before and after the

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project period. There was no use of the decision support system in this project as it had

not been developed at the time, nor was anything done differently than a typical studio.

For this reason, a "post-then-pre assessment was used to not influence the base ability for

the students to engage vegetated assemblies differently than another other new topic in a

studio setting.

The students made a number of interesting responses to the survey. From a larger

set of questions and statements, six will be reviewed here in more depth:

07: I understand the considerations involved in designing vegetated assemblies.

11: I understand how I can design vegetated assemblies in studio.

13: I understand the risks and complication to design when including vegetated

assemblies.

14a: I have familiarized myself with other projects that used vegetated assemblies for

the project.

18: I understand the difference between the various types of vegetated assemblies.

19: I understand the major obstacles to implementing vegetated assemblies.

A "post-then-pre assessment" was used to compare students' opinions after completing

the project to their opinions before beginning it. For each of these six statements, students

were asked to rate on a Likert scale of strongly disagree to strongly agree, their level of

agreement with the statement after the project was completed, and to also estimate their

agreement with the same statement before beginning the project. Results are shown in the

following figure out of 12 student responses per statement. (Black, et. al., 2015)

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Responses to Questions Before and After Studio Project
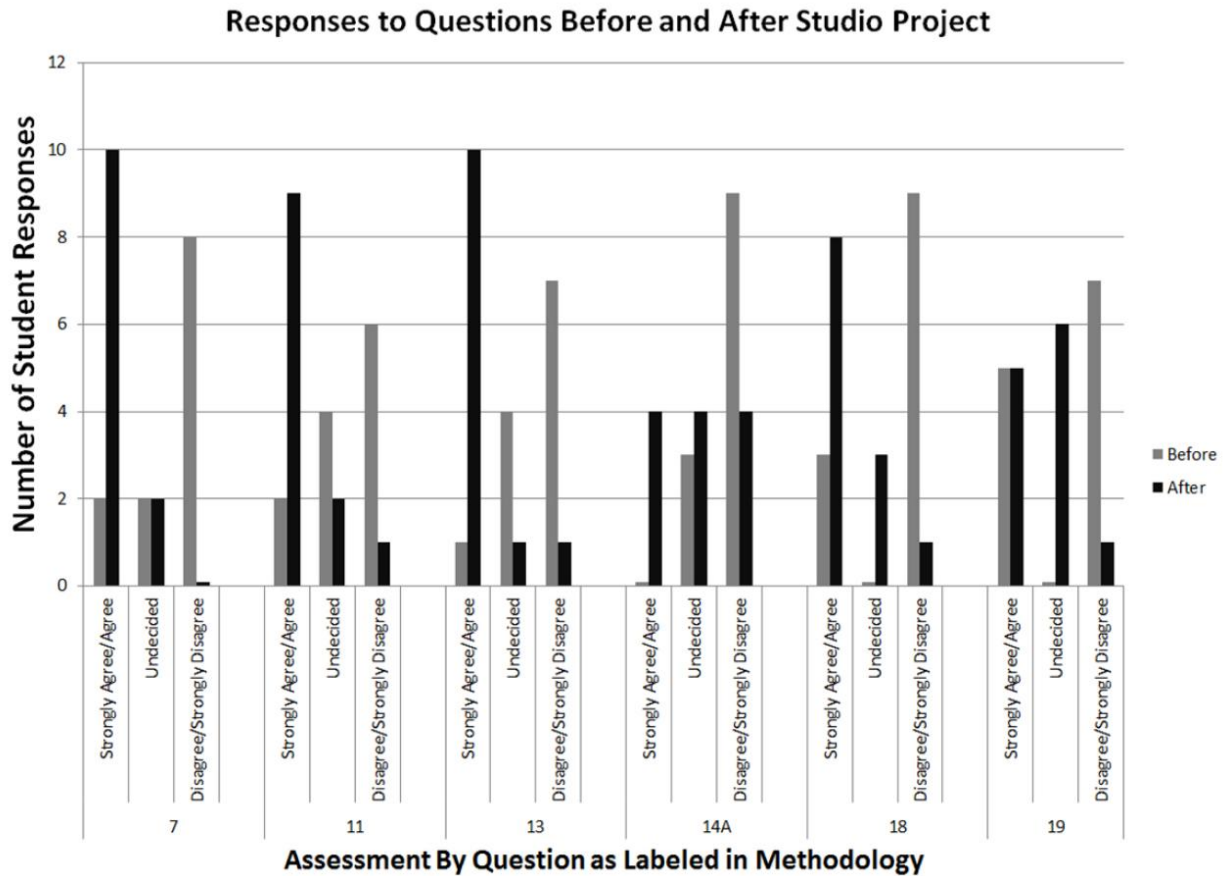
Figure 99: (Black, et. al., 2015) Selected Responses to Questions Before and After Studio Project

In statement 7, the students responded that they had a greater understanding of the considerations involved in designing vegetated assemblies after the project. In statement 11, they expressed a greater understanding after the project as to how to design vegetated assemblies. In statement 13, they showed that after designing a vegetated wall, they now understood the risks and complications involved with the design when including vegetated assemblies. What was most interesting was the response to statement 14a: "I have familiarized myself with other projects that used vegetated assemblies for the project". The students were not familiar with vegetated

projects before the studio, but not all of them indicated that they had looked at precedents even after the two-week studio project. While vegetated assemblies were discussed as a building system by the teaching assistant leading the project, specific projects were not used as examples, in an effort to see whether students would search for precedents on their own. Knowing that not all students have the inclination or means to discover precedents on their own will be critical to developing the future prototype tool. In responses to statement 18, they understood the differences between the different types of vegetated assemblies after the studio project. In statement 19, the same number of people agreed with understanding obstacles to implementing vegetated assemblies both before and after the project, but many were undecided, which suggests that this was another place to target in the prototype tool. (Black, et. al., 2015)

Figure 100 shows the remaining responses which were for the following questions:

08: A design tool for vegetated assemblies would be helpful in your design process.

09: Architects provide valuable insight to vegetated assembly design.

10: I understand the benefits and qualities of installing vegetated assemblies.

12: Building users provide valuable insight into the design of vegetated assemblies.

15: I know the general types of vegetation that will thrive on a vegetated wall.

16: I know the general types of vegetation that will thrive on a vegetated roof.

17: I know the general types of vegetation that will thrive on a vegetated facade.

20: Vegetated assembly suppliers provide valuable insight into vegetated assembly design.

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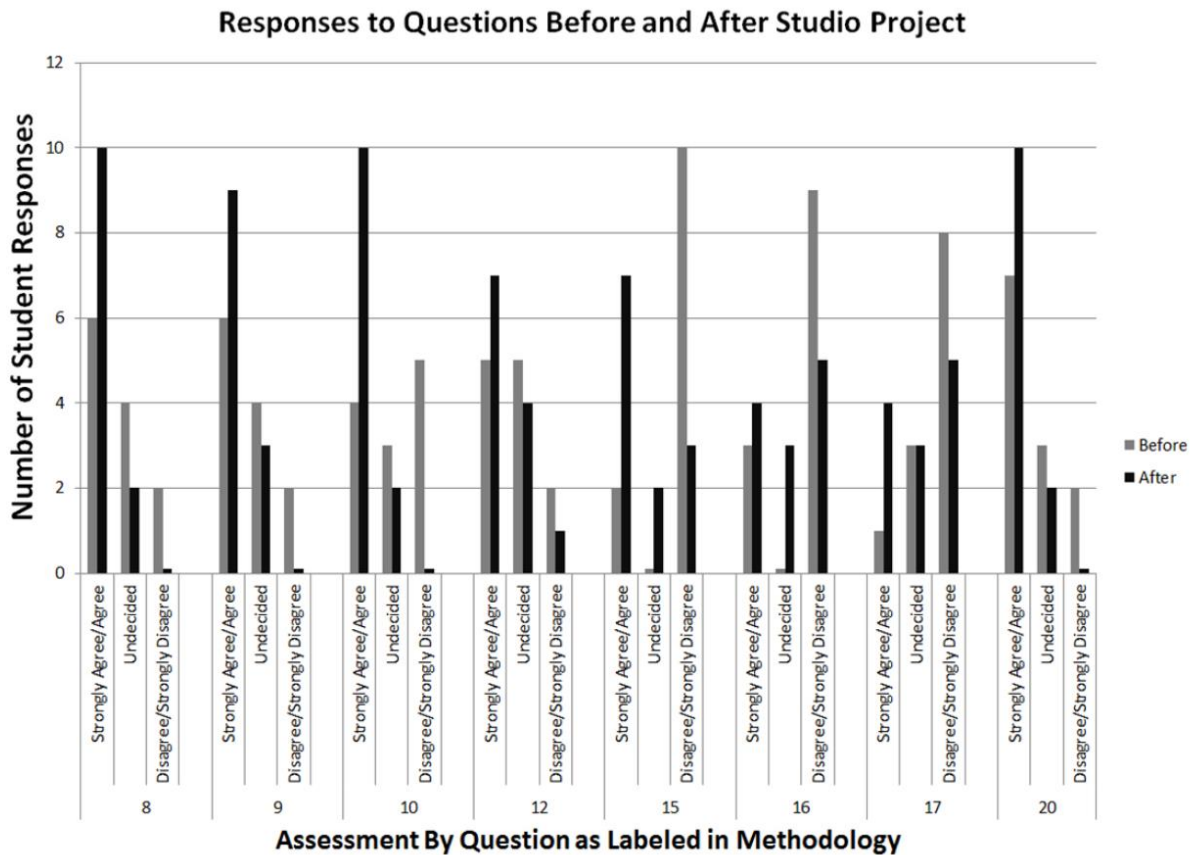
Figure 100: (Black, et. al., 2015) Remaining Responses to Questions Before and After Studio Project

In summary, from (Black, et. al., 2015) there were four topics that grounded further inquiry into the dissertation and framework: the project brief was beneficial to the students; the survey revealed a greater understanding, but lack of overall understanding of vegetated assemblies after the project period; the framework needed plant biology and its interaction with color, species and grower lists and implementation issues, precedent studies, and color theory representations among other items; and the tool perhaps becomes a decision support system or framework as suggestions with a designer's choice rather than a list of design mandates or a sole outcome

Reviewing the Traditional Studio in an As-Is Process Independent Study

While the survey of the lecture exercise and traditional studio exercise were two versions of how to instruct vegetated assemblies, the previous project spread by Tim was the results of hands-on experience with architecture and design, and thinking. The paper: *Student-Driven Design in Architecture: Interacting with Reclaimed Materials and Passive Solar Techniques,* (Black & Doorn, 2015) focused on how the two projects (the Solar Garage and the Solar House renovations) intertwined, the dissertation reviews Tim's contribution to the project and what it might mean for the decision support framework. Tim was a 5th year thesis student at the time and had prior interest in the Decathlon houses, and a need for an independent study. From my choice to sit in studio rather than sit secluded in the PHD room, he asked me what he might do. I told him about the ongoing Solar Garage project and asked if he might be willing to perform a study for the next step after the completion of that case study. Granted, the complete renovation of the 2002 Decathlon house was out of scope, but it was sorely needed.

With a little bit of time a proposal for an independent study was ready and approved by Dr. Elizabeth Grant. She gave us considerable latitude on the project and useful guidance for Tim on how to develop his work during the semester while simultaneously working on his 5th year thesis. His work primarily focused on the development of a deck and arcade system for the exterior of the 2002 Solar House and the inclusion of a vegetated system. His description of the project is as follows with drawing following:

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 Tim, with guidance from Ph. D. student Kenneth Black and Virginia Tech professor Elizabeth Grant, began with a revitalization of the exterior. 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. (Black & Doorn, 2015)

The work completed by Tim and watching his process of designing using vegetated assemblies allows insight into the difficulties even an experienced student might have with such vegetated assemblies. He had previous experience with the assemblies and was able to very quickly iterate ideas for the Solar House project, however it was in the development of which species to use and how they might be implemented in a system or on a facade where things became difficult. This showed that while a large amount of the framework would be less necessary as he had a developed generalized design process, examples of selecting species or a list of species and growers would still be useful for a more experienced student. Further the independent study showed that a method or suggestion, of how to combine ideas or how to select such topics might be useful. This

resulted in further developing the right side of the framework in figure 101 regarding

"Data Analysis". This name does not limit information to only data, but also other

information and context in regards to color theory, plant biology or design tactics that

would influence the resulting designs.
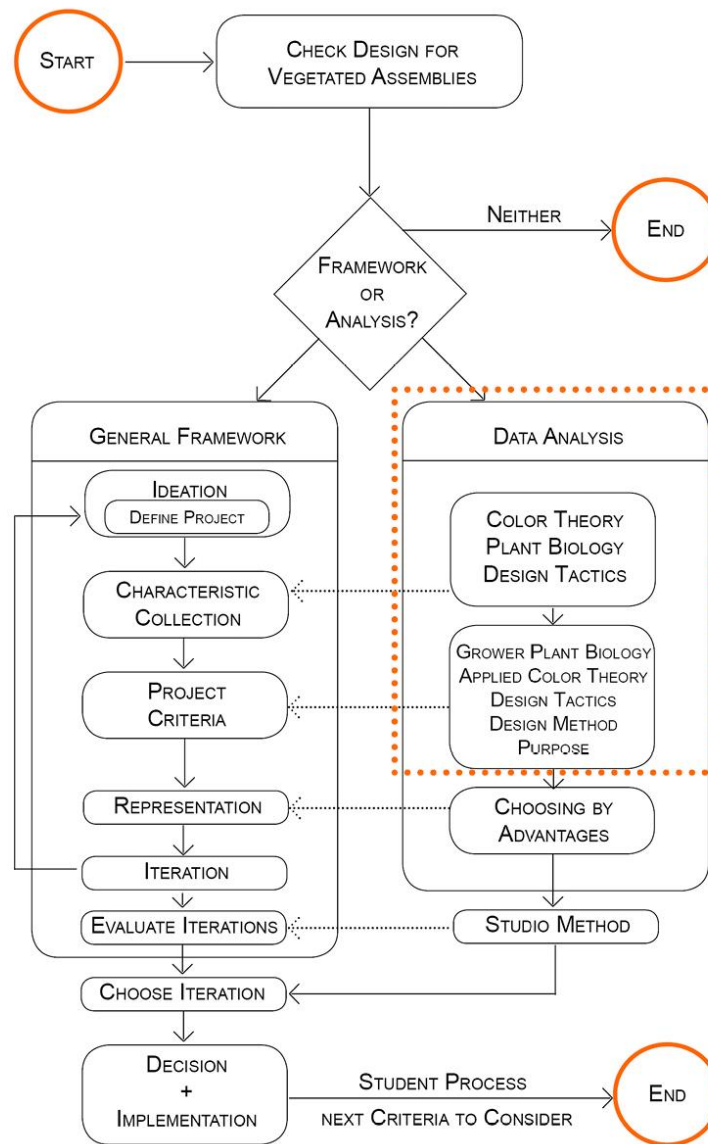
Figure 101: Tim's work confirmed and influenced the diagramming notation of the framework itself going from an undisciplined flow chart to a thought-process organization using Business Process modeling

Notation. This allowed the framework to be read more easily and revealed new information to be included in the dotted portion of the diagram. These changes are further described in the results.

Some of Tim's work is reproduced in figure 102. His design for a renovation to the Solar Decathlon House included many of the standard drawing including plans, sections and elevations, as well as the first instance of directly representing vegetated assemblies in a project shown in the combined hand and computer collage. His uncertainty about plant species selection led to more detail being added to the framework in these areas.

His representation in the collage shows plants depicted as a green surface, photoshopped from another image. This process of defaulting to a green surface for a vegetated assembly is common and resulted in further information being added on selecting plants for colors over the course of a year (as colors change), as well as how to select different combinations of colors.
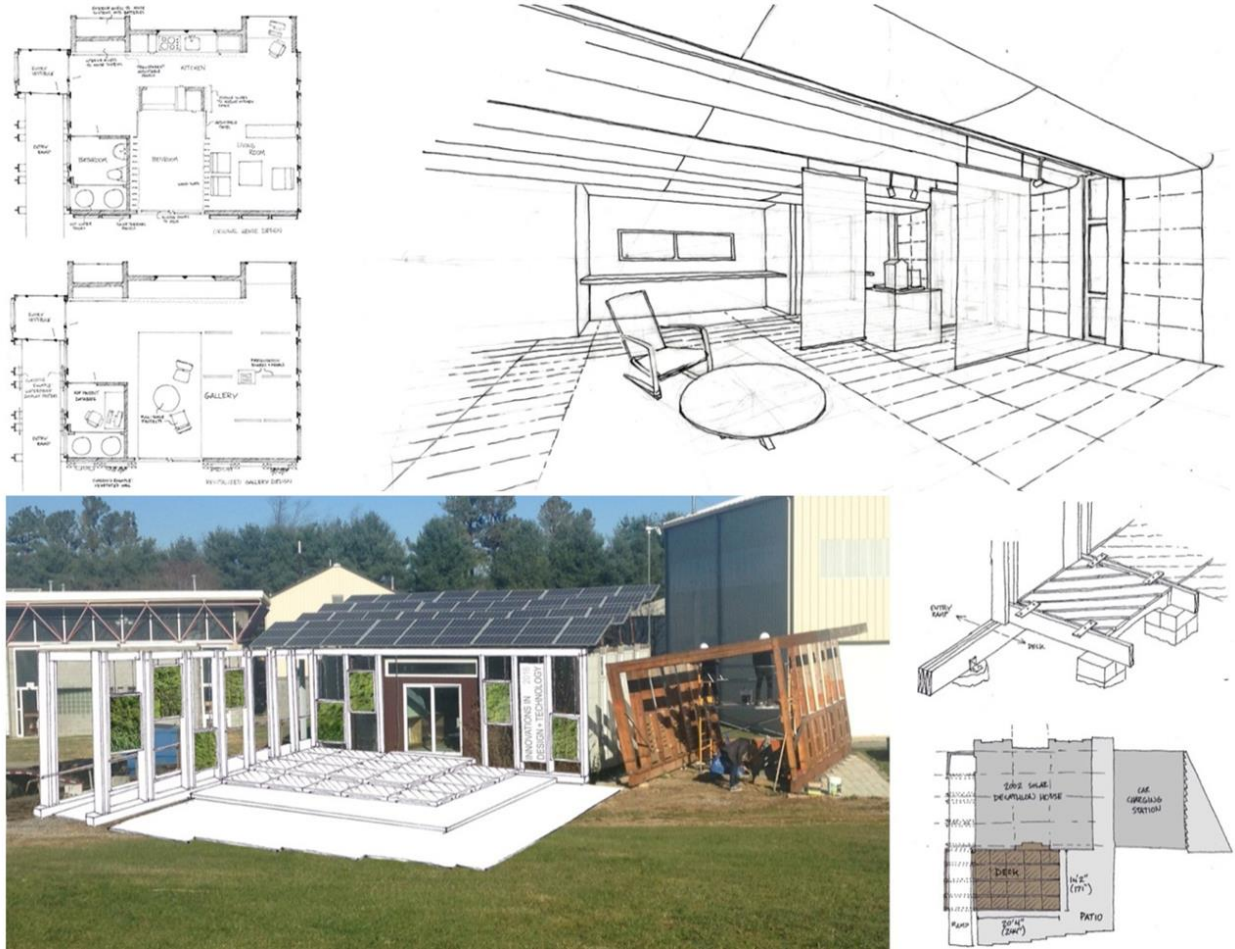
Figure 102: The work of Tim in his Independent study. This work was used to further the understanding of how the framework would be improved or useful to a more experienced student. The framework gained more clarity in the general design process to help less-experienced students, as well as gaining more detail in color theory, plant biology, and design tactics. This is also shown in figure 101 and 103. Figure 103 goes into detail specifically combining the framework as showing it in his work.

The Framework: students using the framework - Tim

Below is my interpretation of Tim's work as it would relate to the framework that he had access to. This is the Business Process modeling Notation version from Tim's review and where the work is informed by and informs the framework.
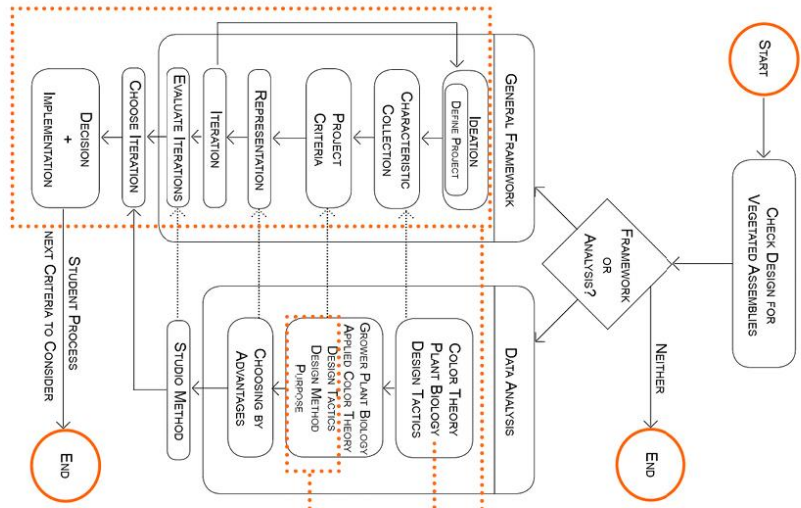
Figure 100: This shows the relationship between the framework and the work completed for Tim's independent study on the renovation of the 2002 Solar Decathlon House. Tim used the whole general framework side and areas of data analysis.
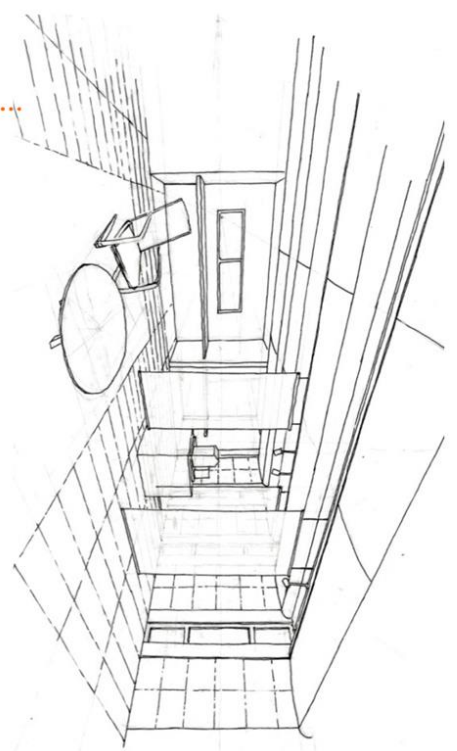
Tim's work shows the general framework of exploring through representation. While color theory was not a main consideration for Tim, the spatial qualities of a future gallery were, and by using perspective drawings could show a potential space.

Plant biology and the use of pallets were design tactics and methods that were chosen for implementation, specific to the project.
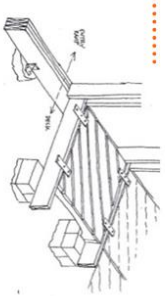
Figure 103: This shows the relationship between the framework and the work completed for Tim's independent study on the renovation of the 2002 Solar Decathlon House. Tim used the whole general framework side and allowed for the development of other areas of data analysis.

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The Framework: students using the framework - Tim

Figure 103 is my interpretation of Tim's work as it would relate to the framework that he had access to. This is the Business Process modeling Notation version from Tim's review and where the work is informed by and informs the framework. This shows the relationship between the framework and the work completed for Tim's independent study on the renovation of the 2002 Solar Decathlon House. Tim used the whole general framework side and allowed for the development of other areas of data analysis. Tim's work shows the general framework of exploring through representation. While color theory was not a main consideration for Tim, the spatial qualities of a future gallery were, and by using perspective drawings could show a potential space. In figure 103 Tim's use of plant biology and the use of pallets were design tactics and methods that were chosen for implementation, specific to the project.

Peer Review of the Framework: The Results of a Multi-Year Design Exercise

The next paper represents a fundamental shift from testing the As-Is process in lecture and studio to implementing the dissertation research with a shortened version of the framework to see how students interact with it in a design exercise situation. In short, a design exercise is a process for introducing a possible idea, process, or tool to a group that is representative of the target population for the object being reviewed. In this case the work produced and reviewed of these design exercises was students from the studios I helped to teach over two years.

This was a group of students, specifically some of my 2nd year students who helped to validate the framework. This design exercise work done after the earlier

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questionnaire provided insight into the next direction of the framework's development. The initial questionnaire in the three-week studio period was also done to see what the framework would accomplish and how the framework could augment the design process for students. Finally by implementing the framework in a limited manner next steps in its development could be determined and then acted upon.

The future goals from previous work were implemented in part to further the research; however things do not always go to plan. While you might believe that you have caught it all, there is always room for improvement. This next section talks about the lessons learned from both years of the design exercise and its associated article, "Learning by doing: applying vegetated assemblies in architecture studio" and then the future goals with student review of the working with the framework. The results from the design exercise were also used in developing the next three steps of the framework and associated dissertation works: the Honors Colloquium Class: *The Metaphysical Room*, differently scaled immersive case studies, and a review of one of these case studies using a newer building standard called the Living Building Challenge. These works were also reviewed later to identified ways to strengthen the framework and possible examples.

This was then used to complement the already-developed side of data analysis from new information added from reviewing Tim's independent study work and information gathering as shown in the following Appendix A1, figure 104, from the *Learning by doing: applying vegetated assemblies in architecture studio*, (Black, 2015).

Now there is the switch from understanding what is the current As-Is method to beginning to use the framework to assist designers as a decision support system. Using the experience from Tim's independent study, the general design and data analysis

framework sides of the decision support system were established as shown in Appendix A1 (figure 104). The next sequence of images are a few examples of students using the framework and are taken in further detail to show how and where the framework influenced their process and design decisions. After these diagrammatic examples, results from the survey are presented to show the reported usefulness of the framework, and then in the second year its usefulness over two platforms: the paper framework and the website application.
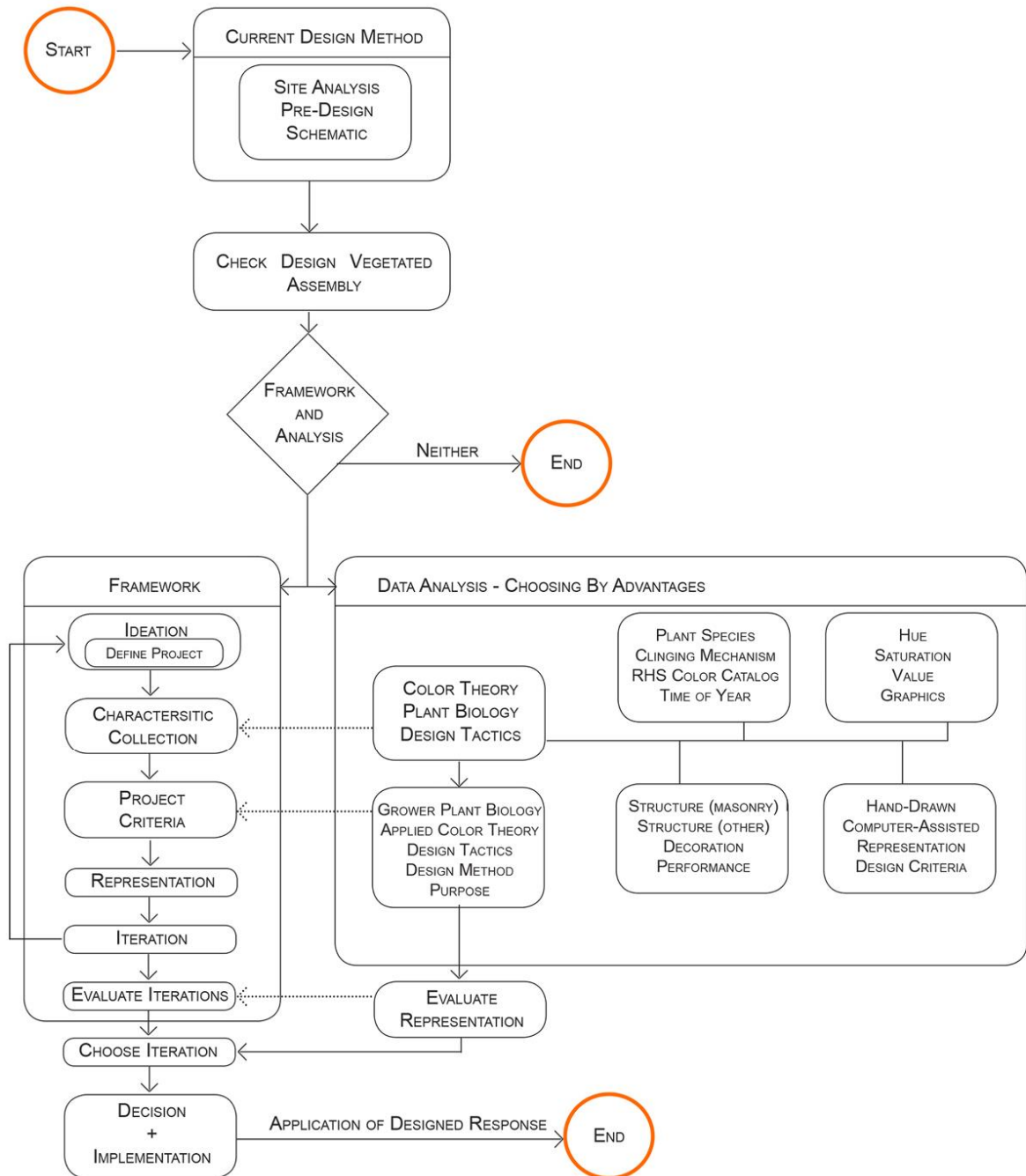
Figure 104: Appendix A1 developed from the As-Is process studies with the large lecture class, the review of a traditional studio, and the independent study by Tim. The left hand side under "Framework" was developed by observing Tim's design process, and the right "Data Analysis" side was developed from missing information while designing.

The Results of the Student Questionnaire and Design Exercise

The questionnaire and design exercises were conducted in 2nd Year Studio 1 and 2 shown in figure 54. Each exercise was a one hour introduction to and use of the decision support framework each year. The purpose again, was to have students engage the framework and review it for improvement. The figure 105 was adapted from a presentation made at ARCC 2015, (Black et al., 2015).
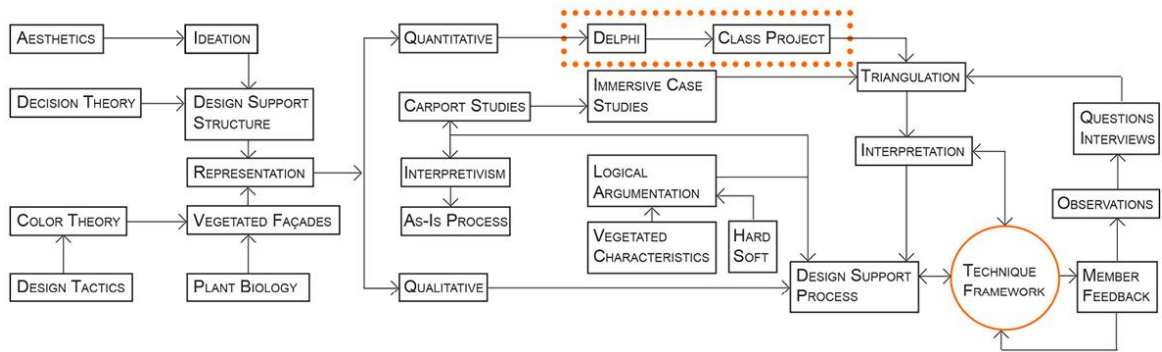
Figure 105: Theory map for the research and studio methodology; the dotted rectangle shows the work of this study. At the time it was termed a Delphi, however due to a lack of expertise in the topical information, it was changed to be a questionnaire. This was also due to the fact that no consensus was made on the framework and what level of information should be included, however it provided vital critique on the development of the secondary detailed pages of the framework and the development of a digital website.

This design exercise stage was only for schematic designs, and took place over an hour on a single day. The prompt was: "Design a retreat space for community members at the nearby amphitheater using vegetated assemblies using an aspect of color theory and the framework." These following examples were done with the framework after the initial questionnaire as a design exercise. The framework was introduced and then, I the researcher played a minimal role in the students' use of the framework to see how it functioned not only as a decision-support system, but also what its capability as a knowledge sharing method might be. The hope was that some form of representation of

the framework can be used to help students while the educator is not present or after a lesson in the topic has been completed, or as a reference in the future. In the first year there was only the analog or paper appendix version and in the second year both a paper version and the first digital website version were available. Following are some example works over the two years, explained and reviewed in further detail.

The Framework: students using the framework - Jerry's Design Exercise

This shows one of the design exercise responses to the use of the framework in the first year. Joe's work focuses in the detail of color theory and he denotes what parts were interesting to him and how this influences the designed space. He reviewed saturation and value, and selected a loose sketching style of the green grass for the covered walkway (figure 106). He moves from a series of sketches that work out some of the relationships that he wants in the project and then presents the space in a perspective sketch. While it is not on this part of the framework, representation is a fundamental part of the overall process of designing and allows us insight into his process. Some of his comments include considering the "differential of greens in grass and surroundings" and "What value of grey should the concrete be to reflect the surroundings". He also considers having ivy to climb the walls, but unfortunately did not specify the species. This shows the use of a secondary level of the paper appendix version of the framework (as the digital version was not made at the time) which show greater concern directed at color theory.
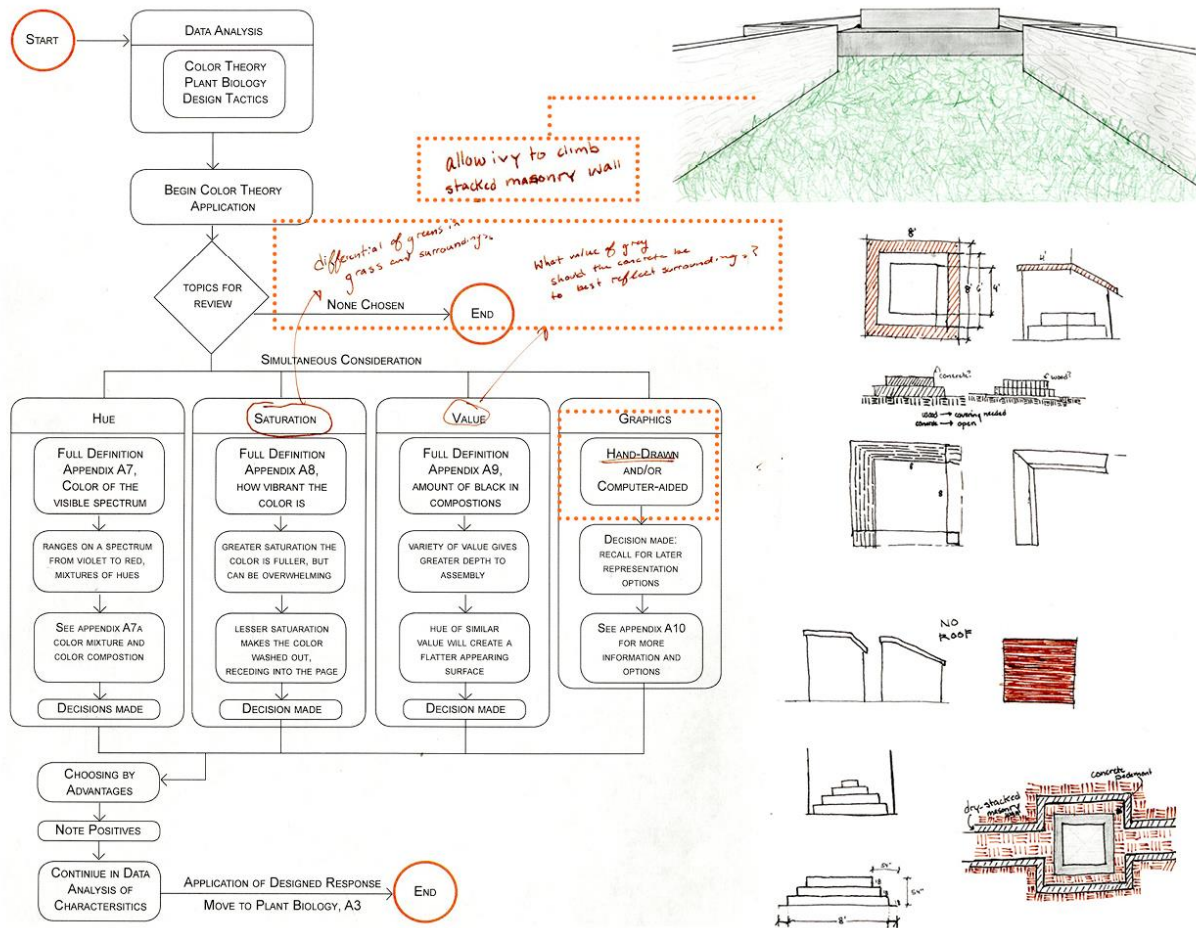
Figure 106: (Year 1) This is one example of the student work from a student we will call Jerry—a raised platform with a raised vegetated walkway. He begins to use the secondary level of the framework to answer questions of color theory and how it might relate to plants; however more information was necessary to select a viable species. The thought process of the retreat was a calming walk through the space with a central gathering place.

The design is the beginning of an idea of how the vegetated assembly could be a place for gathering. This same student is also the example from the large lecture class (figure 94). It shows that the atmosphere and the intent instilled in the students were just as important as the content delivered. If I ask for a vegetated assembly I get a technicalesque drawing. If I ask for a place of retreat using the framework with vegetated assemblies and color, something else, a thesis or an idea about architecture might emerge.

The Framework: students using the framework - Jake's Design Exercise

This work by Jake was done in the second year of the framework design exercise (figure 107). While the digital version of the framework was available, it was also done using the paper appendix version (only the initial 6 pages for the exercise). Jake also has shown which parts of color theory that was important to his designs. He directly labels saturation, value and graphics, however the variation of hues in the representation of the plants suggests that this is also informing has work. The beginning of a structure for the vegetated assembly suggests that some aspects of design methods were also considered from the main condensed framework.
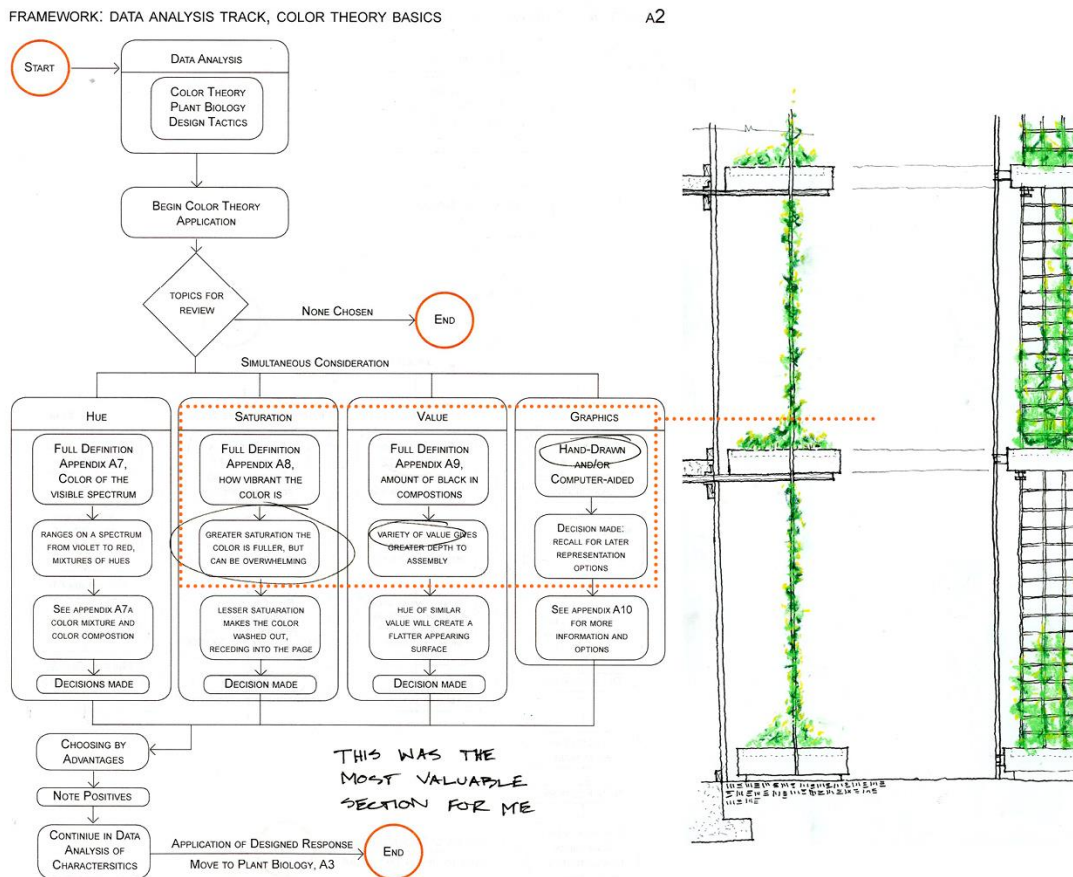
Figure 107: Jake's work looks at color as did Jerry's the year prior. Where is differs is in the type of structure designed, but also what media used to represent color. Jerry used colored pens while Jake used oil pastels after penning a drawing. Jake began to think in more of a section, elevation manner while Jerry worked in a series of sketches.

This project looked at a secondary lattice structure and included an idea for a foundation assembly for a selected twining vine. This suggests that the framework helped to make decisions for a design based on potential plant biology and necessary structural requirements for a secondary facade system as well.

The Framework: students using the framework - Terrance's Design Exercise

Terrance's work is an example of how the paper framework was not going to be the only version of the decision support system would be implemented. Terrance was able to take an idea that was not part of the framework, integrate it into the design while considering different parts of color theory, plants biology, and design methods. He also used oil pastels, which were not a common media choice in the short design exercises over both of the years. He mentioned that while it was a helpful tool, "the part of the framework that confused me was the ordering. Maybe I just think differently." The BPMN notation was unfamiliar to him (and all of the other students) and he wondered "is the process necessarily linear?" He also brings up that the framework should be connected to other ideas of architecture. Terrance's example (figure 108) looked more deeply into the volume of spaces, how walls can be developed from strict geometry and what the perception of the space is with the color of the vegetated assemblies contrasting the red and blue of the structure.

All of these considerations from Terrance show that the framework needed more detail and flexibility past that of the initial six appendix pages (A1-A6) and when asked, he mentioned that a digital version that was more flexible could have helped.

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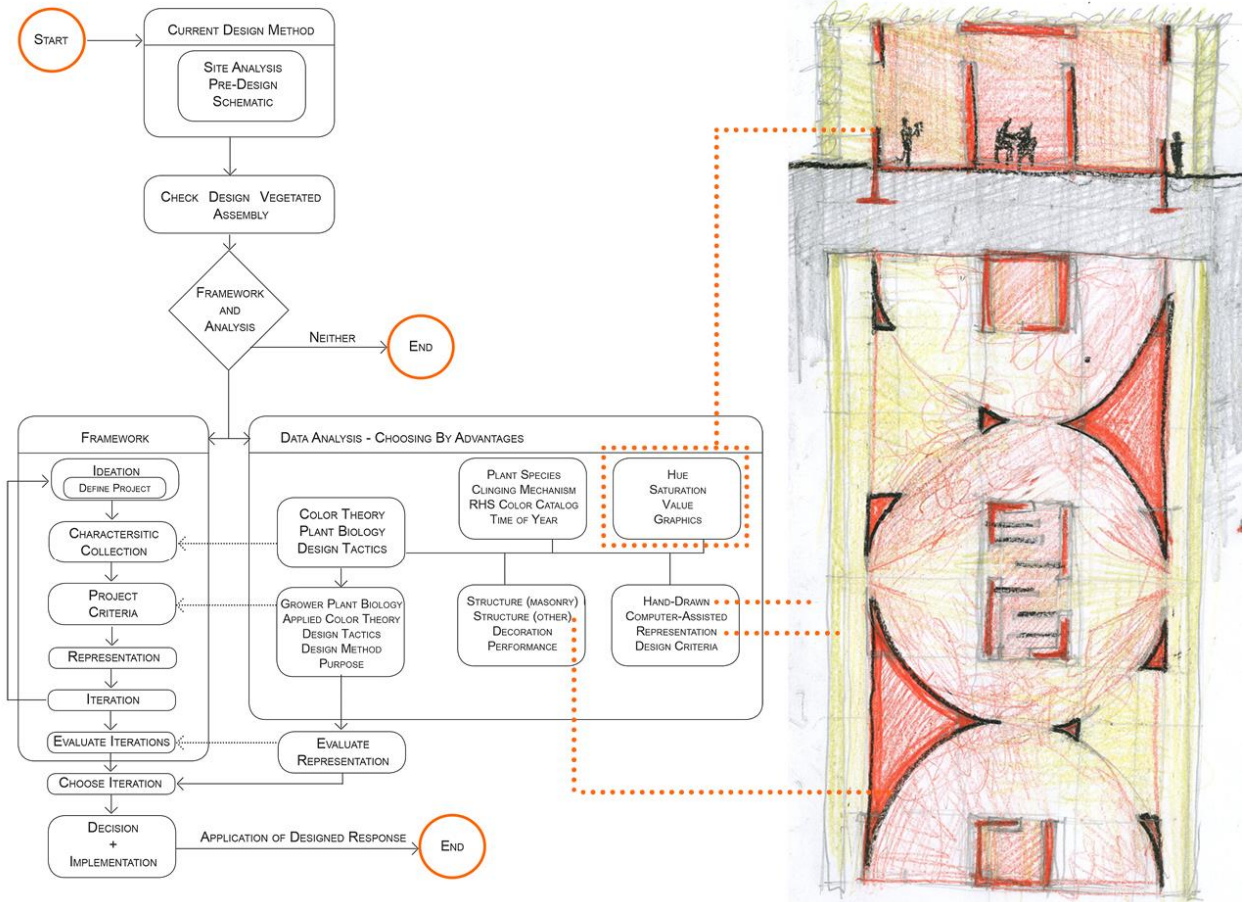
Figure 108: The interpretation of Terrance's work during the second year of the design exercises and initial questionnaire. His work showed how a unique idea such as the geometry of space could be added to the information of color theory and vegetated assemblies provided in the framework.

The Framework: My own use of the framework – Ken's Design Exercise

The next project is my own tensile repeating frame structure with vegetated walls and roof comprised of twining vines over metal mesh developed in 10 minutes rather than the whole hour given, during the first design exercise. The project was described as a having edible plants such as vining grapes that would travel the suspension system and between the frames. This example is to show that over time familiarity with a topic or a decision support method can decrease the time needed to make decisions.

FRAMEWORK FOR VEGETATED ASSEMBLIES:
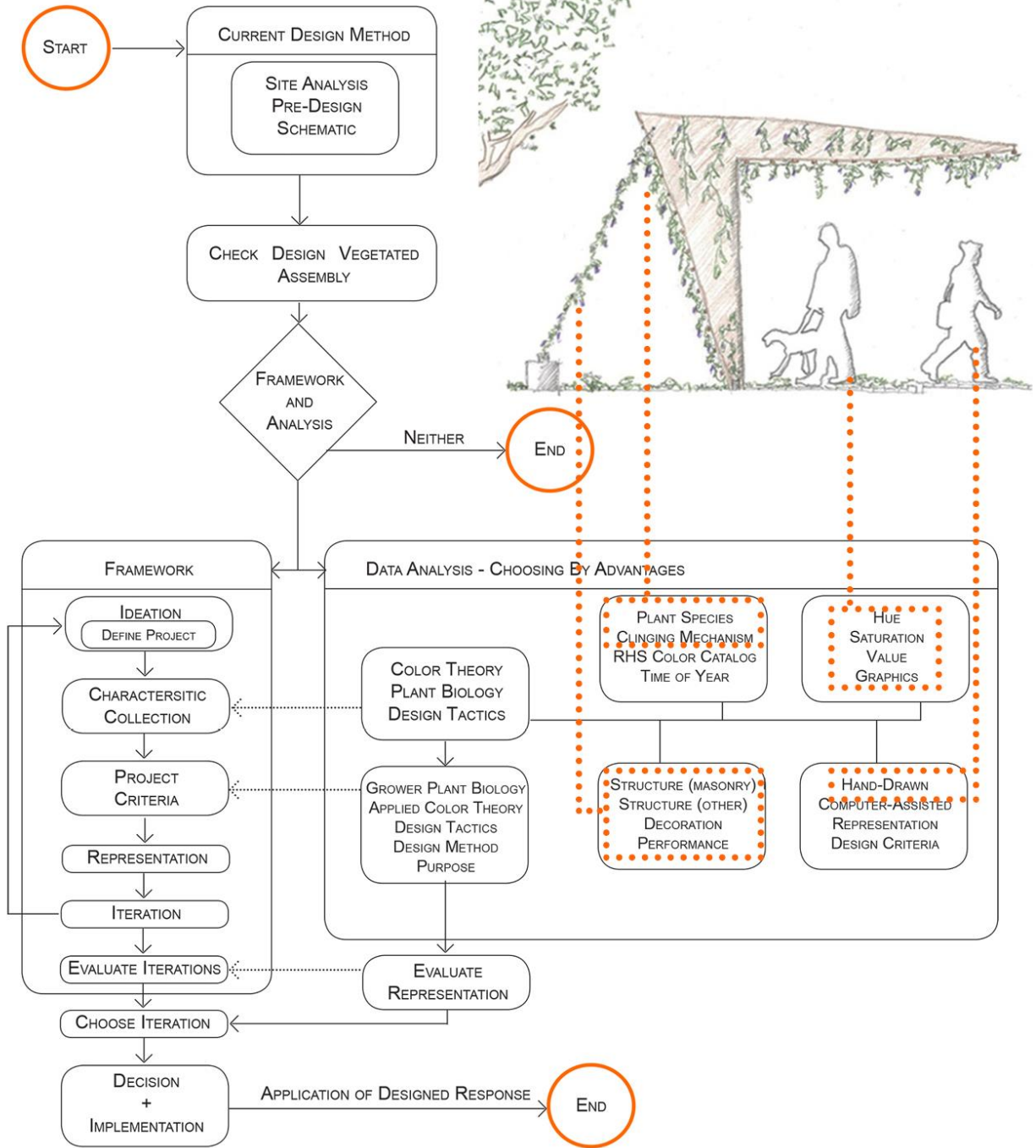
Figure 109: An example of a more experienced designer (the researcher) using the framework after becoming familiar with the process and the information provided by the decision support system. Over time the framework goes from being a system that provides information to make decisions, to a reference used to confirm initial expectations or design intents.

The Design Exercise and its Results

The design exercise was used to see if the process was overwhelming and not informative, or informative, if the framework was confusing, or if there were holes in the development of the framework. It also tried to assess the current understanding of each student in vegetated assemblies, types of wall sections, current projects.

By interpreting the responses from the design exercises, a series of questions were developed to see if the framework was perhaps useful and if the work developed during the exercise was as intended. From these questions the following responses were received and then developed into average responses. These simple analyses targeted general responses, and perhaps only show that consistent development of a design framework is needed. The main take-aways were that more examples of projects and plants that could be used were needed, this combined with reviewing the representation of the framework itself to others which prompted the creation of a web application.

Looking over the design exercise results the weakest point of the first year of the design exercise was the review and detail of the framework regarding the species of vegetation to include and the amount of detail that should be used in the framework. As a result more examples of not only plants species, but also project examples were added. Further review of the work and the amount of time students took to simply understand BPMN notation suggested that this was not the form of representation most suitable for design processes. Thus, after the two years of the design exercise, the paper framework was then updated to a web as most students now a familiar with the use of the internet and other online sites and is more receptive by the students since its representational method would be more familiar.

Going over the process of using the framework during the exercise, it was obvious that students simply needed visual examples to start their design process. This makes sense as architecture is a visually dominated profession. Further, since students are not familiar with different types of plants and associated species of plants, direct examples of vegetation for use in vegetated structures was also needed. This is coupled with the need for images of these plants at different times of year to show how they change with the seasons and how this might influence designs.

From this design exercise, the paper appendix version was completed and then more development was given to the online web application of the decision support framework. Multiple versions of this web application were developed and the most recent version is available online and under continuous development at livingwalldesigner-prototype.org.

Summary of the Initial Questionnaire and later Design Exercises

In summary from (Black, 2015), the framework helped students to: consider vegetated assemblies early in the design process; collect technical information and not ignore it; choose an option for implementation in the design process; combine the two tracks during the brainstorming and troubleshooting, moving between the framework (the general design process) and the data analysis (reference materials).

The design exercise also revealed that perhaps solely the raw framework using Business Process Modeling Notation was not the best method for representing the information present and that a more developed website was needed to aid students in understanding the process without being confused by a series of annotation (especially

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the shapes and other embedded meanings of the notation) they had not encountered before. Finally, many of the students suggested a digital framework to represent the ideas presented in the current paper appendix system. They cited in (Black, 2015) and were addressed in the second year: another platform should be used in conjunction with the appendices; multiple methods for showing and explaining information to others or the users; and with the paper appendix system, switching between pages was confusing to most of the first-time users.

Troubleshooting and using the Lessons Learned between years

By talking with the students after the troubleshooting design exercise, these main lessons emerged from the discussion about how to improve the framework to assist students in the future and were addressed in the second year of the design exercises and initial questionnaire:

It needs a small introduction for first time users

It needs only one more layer of detail explaining each topic, not too much

Use it early in the design process, and be familiar with its capabilities

Familiarity increases its effectiveness

Vegetated assemblies are a feature that was integral, but do not dominate designed
works

More topics aside from color theory might be added in the future

More performance-based topics detailing vegetated assemblies by location, not only
Blacksburg, Virginia could be included

The students in both years of the design exercises found that working in a group to design these systems would be beneficial and useful for entering the industry and receiving technical information. The framework might: support design and project communication; help the designer and consultant to bridge gaps in design communication; and find and effectively use information together to help designers and consultants. The results from the design exercises and initial questionnaires show that the concerns were justified and when addressed, improved the usefulness of the framework.

Response to Improve the Framework: Case studies

The first task after the survey responses was to design and implement examples of using the framework. These four Immersive Case Studies were done at two scales, two smaller, one larger. They were: Turtletown, the RDF Wall (the Solar Lounge), the Solar Garage and then its re-design with the Living Building Challenge. These projects show the continuing desire to construct and test at full-scale. Further discussion on the continuation of the selection of plants and design is shown in the continuation in figures 142-146. The first case study was Turtletown. It was done to show the power of combining ideas that were near to the problem at hand, no matter how odd, or seemingly unrelated they might be. This also served as a visual and written example of how to begin using the framework in the results chapter (figures 65-73).

The second case study to begin was the Solar Garage. This full-scale project was the largest of the four case studies and proved to be the most difficult to implement. The work was completed at the request of the Electrical and Computer Engineering Department at Virginia Tech. With a materials grant of $5000 a fully functional garage

was completed for the electric corvette that would be charged by the solar panel atop the adjacent 2002 Solar Decathlon house.

The third case study was a development of the studio-like course: Metaphysical Room class for the honors colloquium series. Three students and I were involved, and two of the 2nd year students were able to help in depth with its design and construction. This project aimed to revitalize the concrete block wall in the front of the research and demonstration facility at Virginia Tech. This project showed what students can do when they are inspired to move beyond common expectations.

The fourth case study is the redesign of the Solar Garage using the tenets of the Living Building Challenge. This challenge looks at the performance and aesthetics of buildings to a higher standard of performance than code requires. While the Solar Garage simply was not a project designed for the implementation of such a standard, portions of the challenge did apply and provided insight into the further development of the individual project and the decision support framework as a whole.

Finally from these case studies it was discovered that core ideas can not only inform the profession, but also inspire students. This is a difficult task. If we lean too heavily on the current frameworks we run the risk of students becoming dependent on them as they have not developed their own process. However such frameworks can be used to introduce ideas and define a developing personal process. In this case of the initial framework and then the website version of the same framework, teaching and exposure to new ideas in the process are invaluable to future success. The use of the frameworks does not need to be complete or entirely refined, but familiarity with topics

can give the confidence to students for when they become new professionals in these other techniques to achieve their design or architecture.

Solar Garage Case Study

The Solar Garage is a study in full-scale construction that stems from a project of a deck and planter in 2009. The lessons learned with a classmate, have served me greatly. The Solar Garage was developed initially as a group of four forming a group called DWF (Design with Friends). The group had since done two projects before splintering before the Solar Garage's completion upon graduation in 2013. Tim joined the group in 2014 and worked on the potential additions to the 2002 Solar house adjacent to the Garage. Many students have come and gone, helping with the project allowing it to live up to the design group's name: Design with Friends. The project itself was an extension of my undergraduate thesis and helped to form the framework and my understanding of vegetation.

Built for and funded by the Electrical and Computer Engineering Department at Virginia Tech, the Solar Garage will house an electric maroon corvette, providing a beautiful space for future research for the client, Dr. Lai. The original site was a bowl filled with stagnant water and other leftover materials from the construction of the 2002 Solar House. The mindset of the case study allowed me to not only understand the framework and its possibilities more fully, but to also hold stewardship over a place, leaving it better than I had found it, while providing a scaffold for future projects and research.

Figure 110: These are process picture of the Solar Garage case study for validating the framework from August 2013 through March 2015. The project relied on work from the design group Design with Friends who were mainly student volunteers, formed by the researcher and classmates in 2010.

Figure 111: Progress at March 2016 after a year hiatus on the Solar Garage case study. The project was largely completed by the researcher and volunteer assistance due to the tight budget.

Figure 112: This is the Electric Corvette under work next to its current storage shed, the Solar Garage will serves both as a case study for the dissertation and as a much needed upgrade in facilities for Dr. Lai of the Electrical and Computer Engineering Department at Virginia Tech.
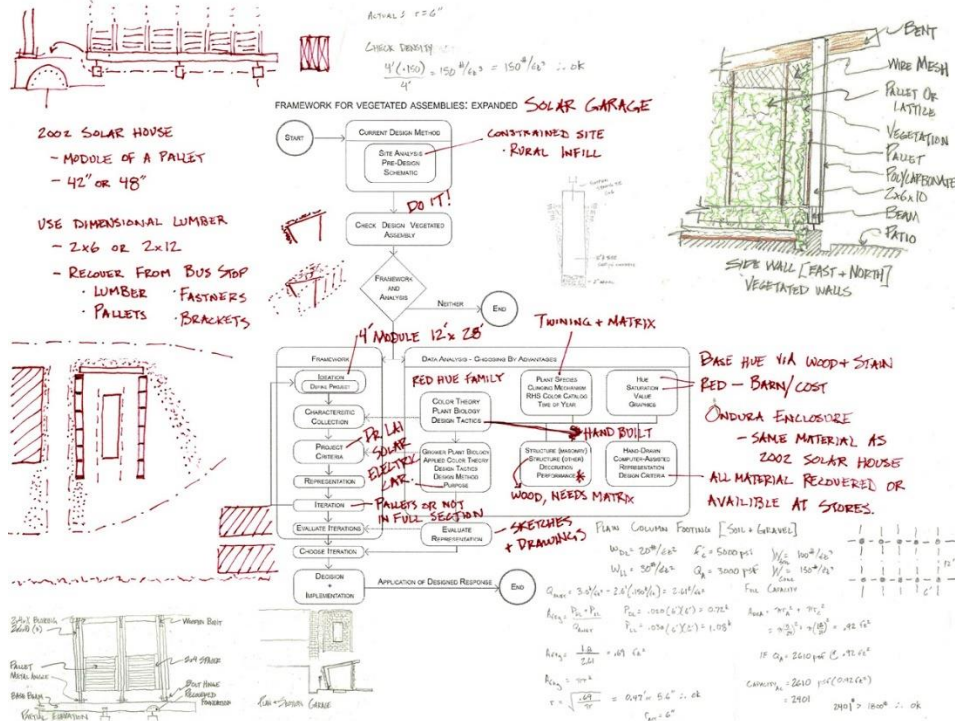
Figure 113: A collage of some of the work done in planning the Solar Garage and how it fits into the decision support system. The case study was conducted over a number of years and developed alongside of the framework, both influencing the other over the years. Diagrams for structure, color, planning, and the development of vegetated assemblies are shown above.

The Solar Garage focuses on qualities of light as its main programmatic element is for a solar-powered electric vehicle. Light is the progenitor for color, life, and daylighting. These three core ideas have been individually pursued through different projects and the Solar Garage is the first time all three were considered in the same project. Color is the refraction and reflection of light from a surface to our eyes. Flora reach and strive for light as vegetation is dependent on light for survival. Its growth is driven by the correct mixture of light, nutrients and water. Daylighting is an experience, not simply a happenstance. Its cultivation and control is nuanced and is a designed response.

Plants not only use light to photosynthesize sugars for survival, but also seek the light and grow, while producing vibrant colors of leaves and flowers. All plants have different physiology which create different values, sizes and depth, where smaller and darker plants recede while lighter and larger plants come to the foreground. Depending on how you want the wall to appear, plants can be chosen to: make a wall visually and literally have more depth though different hues and shading patterns through the characteristics of the plants or appear flat with different expressions of similar criteria but choosing only one species or a finer or shallower plant species. Your eye perceives depth though the differences or hues and in the shadow found at the edges of different adjacent plants.

From this plant biology, there come three main types of vegetated assemblies. The simplest is ivy or other plants growing up the side of a building directly on the surface. Intermediate engineered trellis system with plants rooted in the ground, climbing up a separate structure and allows more variety and options. Complex these include all four

elements: growing media, structural support, integrated irrigation and drainage system. There are a wide variety of considerations from plant biology that inform what kind of wall to use and how light will interact with each plant. Some are: the aesthetic color over the seasons, climbing mechanism, growth rate, light (full sun, full shade and other combinations, soil and plant and wall maintenance.

Since this design focuses on light and walls, climbing mechanisms of plants come to the forefront. There are three main types. Rootlets are aggressive and dig into and physically attach to a surface. They appear as little hairs on a main trunk. Holdfasts function through chemical adhesion to a surface. They do not go into under the surface, but while the vine might be removed the holdfast will remain. Twining vines will travel and follow a path by wrapping around another structure rather than a surface.

Plants are particular to the site in which they live. Each kind of plant has a particular niche that allows them to be most successful. When given the correct conditions plants are fast growing and tenacious, especially vines and crawlers. But the conditions that we attempt to mimic and create must match the species of plants designers want to implement. Each type of climbing mechanism must be used to maintain the survivability of the plant and the structure or surface of the building.

Designers cannot mix up types of climbing mechanisms and attachment structures while not providing water, adequate amount of sunlight and space. This sounds like common sense but each plant is particular to its species' needs and the conditions given by the built environment. The designer needs to look at the site and habitat diversity and determine how man interacts with nature, building in the possibility for flexible designs in the future.

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Considering color as a part of light, a scheme can be abstracted from the plants based on analogous or complimentary colors, referenced against the Royal Horticulture Society's manual. It is up to the designer to choose what sort of composition to start from. For example a plant displays a light yellow green, middle, lighter green, and then full green. This would be an example of analogous color. If you took the red from the petals of its flower and then the full green from its leaves, it is a complementary color composition. In reverse, if an abstracted composition is created, plants that have similar color can be selected and then placed into a system of mosaic. A possible section sketch of the project is shown in figure 114.

Figure 114: Sketching is a process in design for working out ideas and discovering relationships between different aspects of the physical world. The work above looks at how the Solar Garage fits in the site and how its section would relate to other modules present in the design from reclaimed materials, the scale of a person, anticipated vegetated assemblies and the light of the space.

Figure 115: The current Solar Garage with my personal car testing clearance and for scale in Fall 2016 and the proof of the concept from another angle, testing the dropped floor design and concrete masonry unit distance and strength.. Due to the prolonged nature of the construction process with the Solar Garage and testing of the vegetated assembly system in the next case study: the Solar Lounge, vegetated assemblies have not yet been implemented on the structure.

Solar Lounge Case Study

This project served as a testing system for potential vegetated wall assemblies for the Solar Garage Project as well as increasing infrastructure for students to test other wall systems in the future. This is the RDF wall project before starting construction. The wall was built as a part of the Research and Demonstration Facility at Virginia Tech in Blacksburg Virginia. The wall is made of experimental concrete blocks, as is most of the facility. The original wall is approximately 24 inches deep and 22 feet long. The module that the concrete block creates informed the spacing and design of the resulting structure. The project was designed and built by two second-year students and myself as an extension of a project that had been assigned in the honors colloquium class I was the instructor for and is described later.

The front side of the project at the start (figure 116), facing towards the parking lot, is where the vegetated prototype walls will be tested. There are two test walls currently installed on either side of the pallet. The pallet is a theme across many of the projects that I personally do, in this case serving as an anti-racking panel of the entire system. This side also has a bench for resting while waiting either for classes at the VT Fire Foundry, the Vibrations Testing Lab, or the Research and Demonstration Facility. This side is the main support for the wall with the doubled columns running into the planter bed and a main support beam near the top lintel of the original wall. The total cost of the project was $500, funded by the Student Initiated Research Grant program run by the college.

The ground was a difficult thing to master as the project could not dig more than two inches into the ground (figure 117). The rise and fall of the ground meant that the

project would need to respond to it, rather than level the ground. Also, since grounds keeping would not be able to drive and mow between pillars, the project needed to be supported as close to the wall as possible. The cantilever that was designed would rely heavily on the wall for support of the structure and future plant growth. Starting from the base on the back side, concrete blocks filled with gravel protect the bottom 8 inches of the wooden supports from routine cutting of the grass with large riding mowers. The columns are spaced at 4 feet apart or every 6 blocks. The columns are doubled up 2x4s to support the main beam of each bent and provide a place for running the steel wire backup support system. The project consists of five bays, which break down into two modules on each side of an open center bay. The wire system is run through I-hooks and is tightened with a turnbuckle on the other side (figure 118).

Figure 116: This is the front of the concrete block wall before constructing the Solar Lounge. The project serves as a test of many systems that might be included in the Solar Garage case study.

Figure 117: View towards the Research and Demonstration Facility after from constructing the Solar Lounge. The repeating frames of dimensional lumber provide a space for resting at RDF.

The RDF Wall (Solar Lounge) was very important to understanding the materials that might be used in a simple matrix-based vegetated wall system. Using the framework a plant species, a hydrangea, was selected as it adheres to almost any surface and tolerates low-light conditions, and has nice blooms in the summer as a perennial. At this time it has not been implemented due to a lack of funds (figure 118). These characteristics are important as the planter is in a north-facing direction and will not receive a large amount of light, and as a perennial it will not need to be re-planted every year. The wire matrix that was first selected will be updated for use in the Solar Garage as the mesh used was weak and depending on the location would snap when fixed with

screws. From this knowledge, larger gauge wire would be used on the Solar Garage along with full-exposure tolerant vines.

Figure 118: The top image is the completed structure before adding in the designed vegetation. The Solar lounge serves as a testing system for potential vegetated assemblies to be included in the Solar Garage as a place for rest while out at the Research and Demonstration Facility.

The Solar Lounge focuses on the development and understanding of structure and the influence structure can place on the success of a vegetated assembly. The next image (figure 119) is the collage of the considerations that went into the Solar Lounge and the development of the temporary structure that could not directly anchor into the concrete wall. Further, the structure takes advantage of the natural aging process of wood to turn from a yellow to a grey color, matching the grey of the existing concrete block wall.
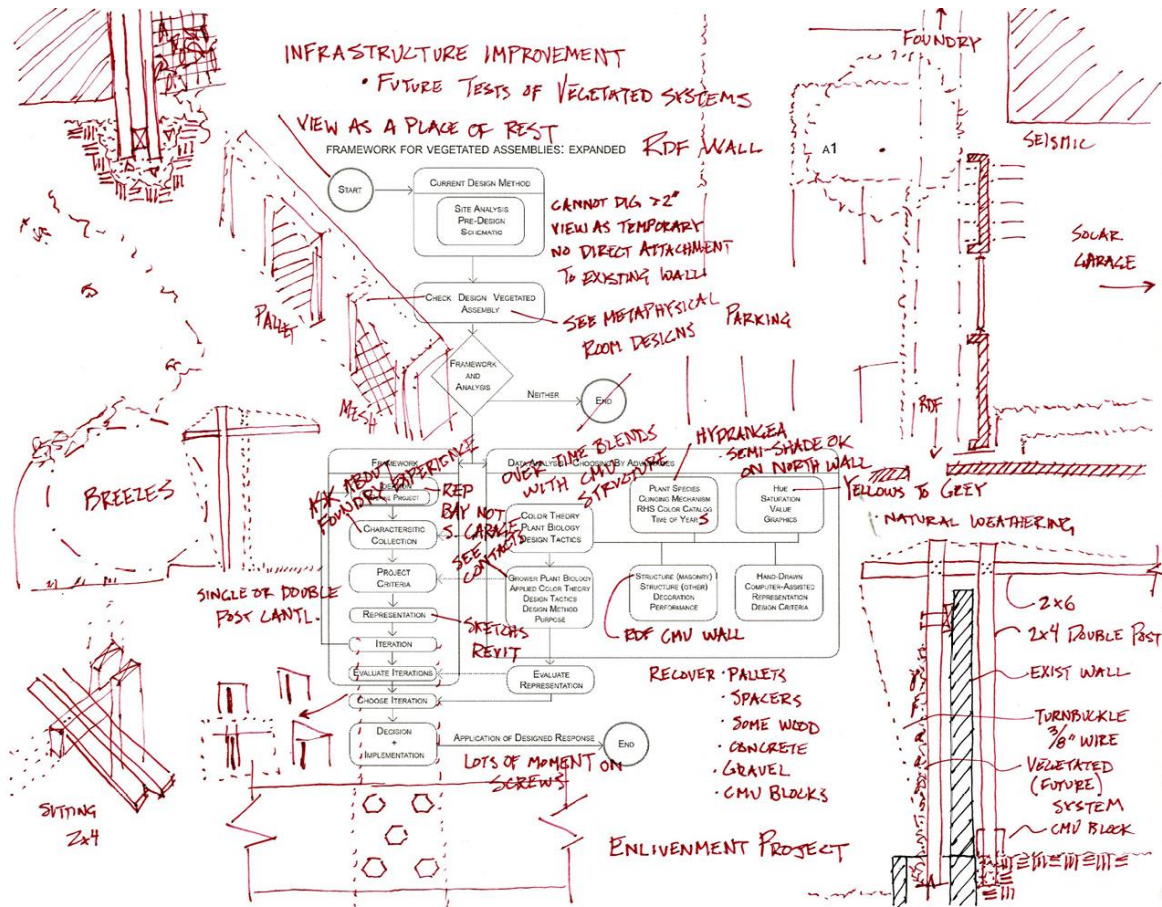
Figure 119: The collage for the RDF wall (Solar Lounge) case study. This case study reviewed how structure influences the selection of plants for vegetated assemblies and used the natural aging process of wood from yellow to grey as a part of nature and the environments over time changing color. It showed that time does have an influence not only on living natural processes, but also the passage of time on materials and how color can be designed for.

Revisiting the Solar Garage Case Study

The Solar Garage was a successful project. Its redesign was to see how a potential

building standard, such as the Living Building Challenge could be brought into the design

framework and its decision support structure. Below is the placement of the building

standard and its main tenets or design philosophy. It is placed in data analysis or

supporting information. This is important to note that while the standard is important and

informs the design process, it does not replace the fundamental process of designing

through ideation, representation and then iteration. In fact the process of including the

Living Building Challenge in the design framework shows its potential for adaptation

over the lifetime of the designer.
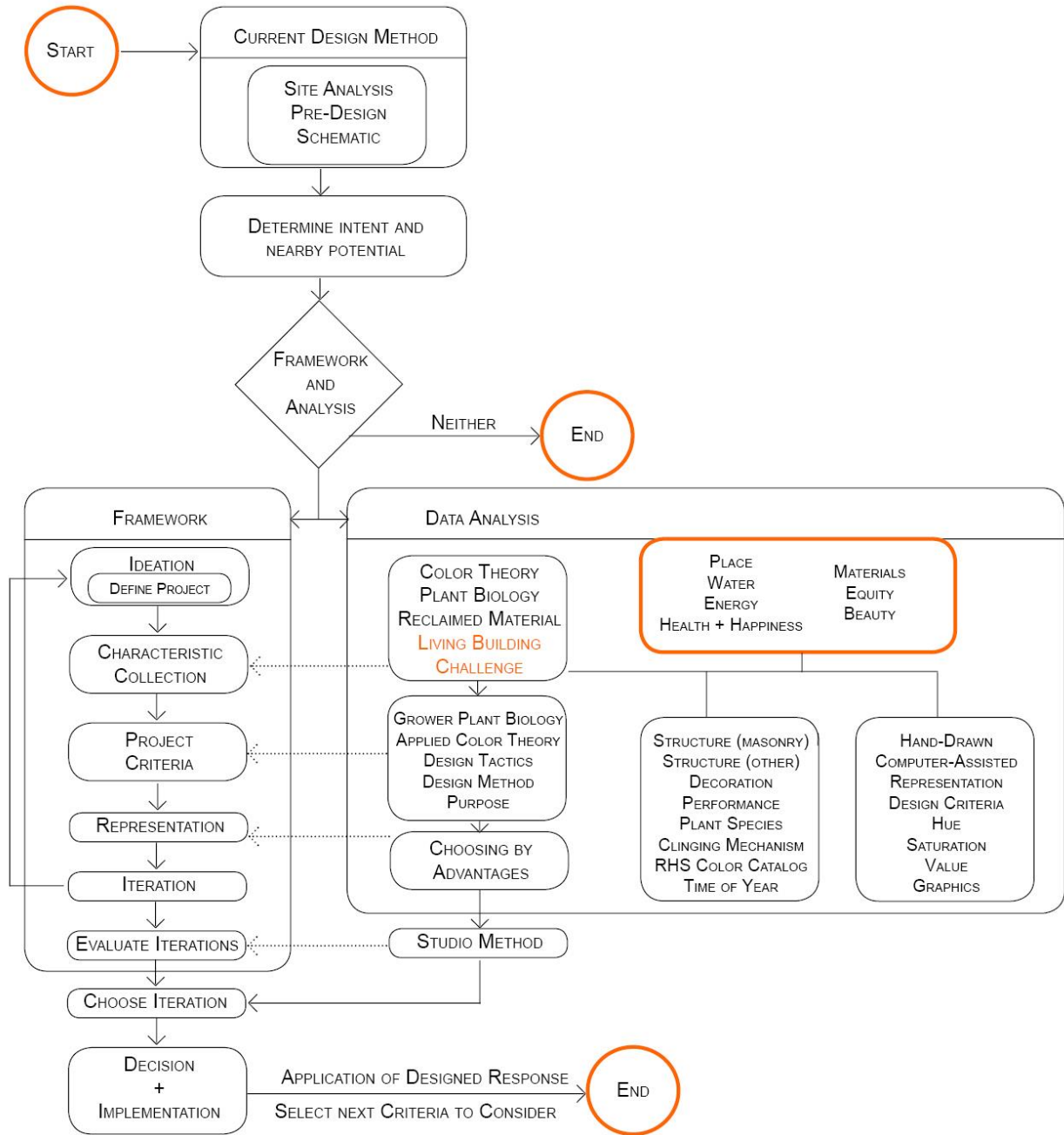
Figure 120: The expanded design framework with the Living Building Challenge added. This case study showed how other ideas might be integrated into the framework as later times, or by other designers using the framework in the future.

Living Building Challenge: Solar Garage Petal Areas
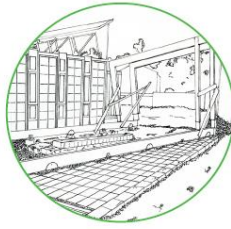
Water

The intent of this is net positive water. The program of the building calls for no plumbing or water usage, however the site historically was a drainage pond and used as a storage site. It was not specifically designed for this, instead water simply ponded under the pile of extra materials. Therefore, to limit the amount of flow of water under the Solar House and limit ponding water, a large French drain system was constructed to allow water to infiltrate rather than sit and fester. Future work and budget would allow us to construct a cistern system off of the Solar Garage for use in watering the vegetated assemblies.

Energy

The intent of this is net positive energy. The new Solar Garage will be tied into the adjacent Solar House's solar panel system to charge one vehicle, a maroon 1990 corvette. The concept of the project was to limit the overall use of energy the Solar Garage to a bare minimum. The program of the Solar Garage will be fully supplied by the Solar House. With more time and budget, the nighttime lighting will be from newly installed solar panels as well.
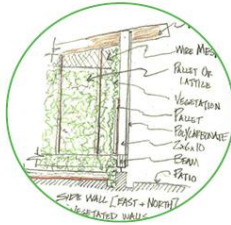
Health

The intent of this is a civilized environment. But what does this mean? It meant that this project relies on a true connection to the outside, not simply the visual. The project is not climate controlled and relies on natural ventilation using cross ventilation off of the nearby cornfield. There is vented space low on the walls and a vented space high for air to flow upwards as it get heated. It is our innate connection with nature and the restorative properties that a Biophilic environment has that the project is centered upon using vegetated walls and natural daylighting. This is explained in more detail in the Beauty section.
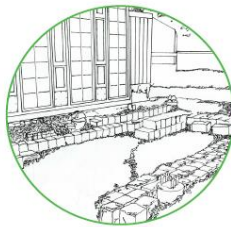
Material

The intent of this is net positive waste. First, all new wood was Forest Stewardship Council certified and aside from cladding most other materials were salvaged from an adjacent site of old construction materials and removed projects. Second, salvaged materials made up more than half of the budget. Another quarter specifically came from older projects recycled into the experimental envelope. Soil (about 4 tons), gravel and sand (4 tons) was recovered from an adjacent project and used for the Solar Garage. All excess materials are currently being designed for and will be used to make other products such as the phone chargers.

Beauty

The intent of this project is to connect back to nature. The ability to touch and interact with a vegetated matrix as a tactile, not only a visual experience is incredibly important to reminding people why the environment matters. Not only because we should, but because there is beauty in its order and process. The benefit for humanity of the vegetated wall is that it serves as a habitat for insects that become prey for native birds. The color and song creates an enlivening atmosphere. The Solar Garage and its walls develop with time, marking the passage of its own existence through a yearly cycle life, death, and nutrient return that continues with or without our presence.

Figure 121: Different aspect or "petals" to the Living Building Challenge that might be included in the redesign of the Solar Garage in the future. This process was used to see how different ideas might be integrated into the framework in the future.
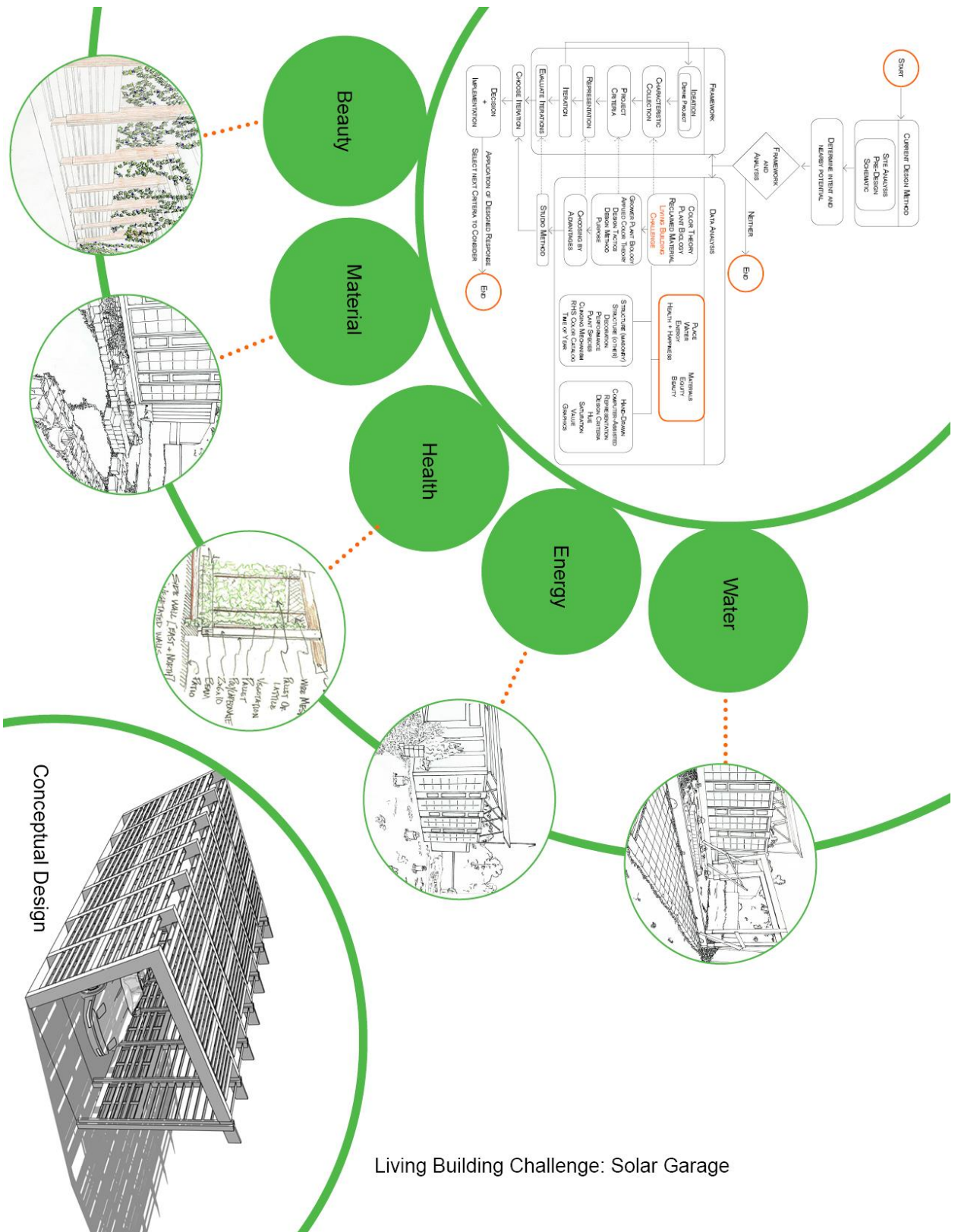
Figure 122: The complete graphic of the redesign of the Solar Garage and its representation and additions to the expanded version of the decision support framework

5.2 Significance: Revising the Representation of the Framework

The Framework has been vetted by the academy at a number of steps allowing for some degree of certainty in its methods, results, and conclusions. The more important concept is why does this matter? It matters because so many of the methods used in the dissertation were rather unique and specific to my dissertation, were utilized at Virginia Tech, or did not entirely have established precedents or standards for verifying the application of knowledge in a studio setting with a semi-professional educator.

This extends to the information that could be present in a framework and how students might respond to it. The product of the dissertation could have been a textbook on how to utilize frameworks in design and have been thick and cumbersome, but that was not the purpose of the dissertation, at least in my mind. Instead what was borne out of the process was the concept of a free and open website for the information. It would become a living document for the work.

This living document will hopefully provide the foundation for many projects and design works in the future. I believe it to be an impetus as a knowledge sharing device for students to have a more informed decision-making capacity, and for me to begin a longer line of inquiry into vegetated assemblies, frameworks and other material topics and light as it relates to color. If the website and the framework allow students to begin a longer line of inquiry, it will have achieved its goals. As of now, from discussion in passing during the year, 7 of the 12 students from the first studio have used vegetated assemblies in subsequent projects. This was either as studio projects or as studio projects shown in environmental building systems assignments suggesting a potential line of inquiry and not as a one-off project from their 2nd year studies.

From this validation, the framework outlined here underwent digital development as a website to gain some more layers of depth and support for student designers; allow students to make informed decisions about the building envelope; develop students as the future of the profession; more informed students become a more informed professional; have students gain comfort with vegetated assembly systems to use them as professionals; and incorporate more varied topics into the framework, broadening its possible uses. The framework then is the foundation for the website, and the website is the foundation for the dispersal of knowledge to an audience that needs or could benefit from it. It is a knowledge-sharing device for when I, the expert, am not available to students. The framework may not drastically change a student's process but it can assist them. That is what the website inherits from the framework as a decision support structure.

The framework was confusing when students used the initial framework as represented in Business Process Modeling Notation. The representation of the work was foreign to them and clouded their ability to learn. What students are familiar with are the internet, connectivity, and the free exchange of knowledge across a computer interface. There will always be a paper copy for people. The information that was present in the original paper appendix version is all included; the difference is in how it is represented.

Finally, the significance of the validation lies in the improvements that were made to the framework and website based on student feedback. As a living document, the website will undergo changes as it is able. Currently it is gaining more examples of designed projects using the framework the whole time, projects that will be revised using

the framework, and photographs of plants that are useful in the design of vegetated assemblies.

These different representations and new topics will serve to a make a pattern language for vegetated assemblies as I see and interpret them. From trying to learn their processes, the students are teaching me something— what they desire and what moves them. If this process can improve the graphical representation and flow of the website, all the better.

This is significant because what they ought to know must combine with what they desire to know. If we can meld the capacity to learn with the desire to do so, it could make the ultimate decision-support structure and learning environment. In the end what they ought to know is what they desire to know. This desire to come to know something is what spurred on the case studies and how I might gain insight for helping others to design in the future.

As an instructor you have to let students think for themselves otherwise how will they think when you are not there to guide them? This is what the framework works on, the time after the lecture and during the design process to assist students in bringing the topic to the design. Looking at the results from the questionnaire and later design exercises over the last two years and the responses given to the Environmental Building Systems lecture design activity in the large-scale course, you would not believe that the less colorful and more component driven designs are from more experienced 3rd year students. The difference is in how the information is presented and in the method of the course design. In the large scale lecture course, the students are presented information, but not necessarily asked to design with it, only to understand what is presented. The

Design exercise from the 2nd Year studio is based on actively designing and integrating ideas in a traditional studio setting. Personally, this integration is what I want the framework to do: combine a topic with a system to show that vegetated assemblies are not a component added to the building envelope, but an integral part of it.

The design exercises in figure 106-109 look at how students can use the framework individually. However, we already know that, on average, people work together to achieve results rather than the designer working alone in isolation; this process of working together can inform our work; and finally there are topics or projects that are near, and sometimes dear, to us and we can use these to inform our work further and provide limitations to strengthen our design.

This idea was first explored in one of the publications coming from the dissertation and forms the foundation of the discussion chapter (Chapter 6) of the framework. That paper, *Educators as a Filtering Information Node: Design Frameworks* (Black, 2016) presented at Passive and Low Energy Architecture in Los Angeles, looks at this concept of making sure that students are informed by the framework, but do not rely too heavily on it. This is also found in the distinction of decision-support rather than a decision-making framework.

This course was developed from the Second Year Studio 1 (see figure 54) and became the studio-like course: the Metaphysical Room that is taught through honors (also see figure 54) The project discussed in the paper was a Vegetated Train and this loose prompt was intentional as it is important to see how much information is needed to be given to a student in order to have a designed response. Too much information and the students were overwhelmed. Too little and the student is overwhelmed by needing to

make all of the decisions. The main outcome was how the framework should be used in studio-like environment that is not a one-time design activity or exercise method in a single afternoon. This process of learning what each type of course has to offer and how the framework might be useful is presented in the discussion of the dissertation in chapter 6.

Chapter 6: Discussion

6.1 Discussion of the Framework

Overview:

How do students respond when vegetated assemblies are introduced only as a singular assembly? What happens when the students begin to use the framework? We have looked at how the framework supports decision-making, if it is useful, revised it and posted it online to the world, but how can it or the knowledge it conveys be integrated into a studio? That is the focus of this discussion. How does the framework become the basis for an understanding of an assembly in the greater context of architecture?

Now the goal of the work, from the different methods, is to see which methods of teaching or instruction are the most appropriate for the framework and for use in what manner. For example the different methods of a large lecture course, and independent study, a traditional studio project of an amphitheater, two different years of the framework design exercise and the classroom method of the Metaphysical Room Colloquium will be examined. Are there general findings about each type of course? What were the differences in implementing the framework in each type of course? What were the benefits of each type of course, their drawbacks and improvements? How did the results compare across the two specific courses from the same students? Is there a difference of usefulness across different levels of student experience from the same course? Do these differences effect decision making and the improved decision-making capacity developed by the framework? These will become evident via the interpretation of the researcher (me) and by looking at some of the work from a selected group of the students, and their reflections on the course.

Specifically we will look at the work of two students: who I will call Jake and Ron, and reference the work of two others who I will call Tim and James, aside from my own observations. These first two students were in multiple courses and in the same course of The Metaphysical Room but at different stages of their architectural educations and some conclusions can be drawn from the courses I have instructed.

Most effective learning environment for the framework: general findings

The framework has been used in a variety of courses. We have looked at the results of these different course types and have found that the concept of a framework is a useful method for knowledge sharing. However the usefulness of the framework is varied across different designers as each approaches the discipline in their own unique manner and as they see themselves in the world based on previous experiences.

Based on the results from the large lecture class citing the need for such a vegetated assembly framework, we know that supplementary information is needed in general for specific systems. This need arises since introductory courses of a large scale are exactly that: non-personal and not comprehensive into the considerations of more specific topics such as vegetated assemblies. The need is found in the gap of knowledge that the student has and in the gap of time that perhaps the educator has during the length of studio, not available in a large lecture course. A student can have a question now, however there is only one professor and so the lecture continues, no questions asked. The framework can provide a supplement to the professor and as a knowledge transfer method or knowledge-sharing device. This suggests the framework is not unique to the class type to be a supplementary resource. The difference lies in the types of results

required: of the individual, the individual course, the expected outcomes of the course, and the schedule of the course.

What were the differences in implementing the framework in each type of course?

For example in the large lecture course such as the Environmental Building Systems lecture, a student is asked to retain information in large quantities, in a quick manner and be able to respond with that information in a timely manner, usually in tests. This creates an atmosphere of regurgitating information even among some of the most inquisitive and creative students. Here the framework is a pure supplement of information.

In the traditional studio the framework becomes a reference material for the studio and for the individuals who are interested in the topic. This situation shows that the framework is limited in scope, to vegetated assemblies and color theory. Over time a series of frameworks might be developed for different topics to serve as a repertoire of works for students to discover the interaction between one building assembly and many other associated topics. This can develop further into a language of how such systems are developed in the future.

In non-traditional studios or discussion courses, the framework becomes a scaffold for the students to implement their own lines of inquiry, or to use it as a reference directly depending on the topic of the course, as the main focus of the course might be a topic of the framework. This might also extend to special studies courses to then develop a permanent course in the future around such frameworks or associated knowledge domains. The independent study is perhaps the most visually direct example

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of how the framework can directly impact a line of inquiry. Using the framework in an independent study is as though a student from a traditional studio was taken aside and directly asked to interface with the framework. This method could expand to having a student evaluate and determine their own framework in the future.

The point is that the framework is not more or less useful in different classroom environments, only that it has a different function in each based on the needs of the individual students and the needs of the course. As the research becomes even more familiar with the limitations of the framework and the ever-changing methods and needs of the students, the framework will become a more vital part of a personal design process.

What were the benefits of each type of course, drawbacks, and improvements?

In the large lecture course the largest number of students can be reached very quickly about a topic, however the framework is not easily brought into the lecture. Information from the framework can be presented as topics; however the process of how the designer would engage the framework is not readily present without taking time out of the lecture to either instruct on the framework or to have the class use it for an exercise. This is not, I believe, appropriate to do in this type of course. The framework serves well as a supplement to the course as a resource. The large lecture is designed for the largest number of people to be instructed in the least amount of time and limits the depth in which a topic can be covered.

I found that the large lecture format is the most common means of transferring information outside of the discipline of architecture, so there needs to be a better way of utilizing its potential. I believe that this can be done by incorporating projects into the

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course rather than relying on a lecture then test approach. This mindset is currently being used in the specific Environmental Building Systems course in Hancock hall (figure 123) for more generalized projects, but perhaps a project involving a deep-dive into one topic could be done. The flip-side of this is to not overstep the bounds or needs of the course; to not over-specialize the course. Perhaps a special study or topical studies course would be implemented on desired topics. Currently there is a need for such course, especially at the graduate level where a more varied course offering is needed.

Figure 123: Hancock Hall, a large lecture auditorium where the Environmental Building Systems study lecture was performed and formed the basis for comparing the framework among different class teaching methods.

The traditional studio (figure 124) has distinct advantages to the large lecture course that are steeped in pedagogical tradition. While the large lecture course can have

from 45 to more than a multiple hundreds of students, a traditional studio has from a dozen to two dozen students at most. The first result of this is a more personalized interaction with each student and more directed critique of work. This relationship with each student develops over the year to a point where some students will go back to previous professors for advice. Not only does this speak volumes to the trust and rapport that the relationship has but it begins to develop a mentoring role rather than being a teacher for a single moment. This mentorship allows the student to grow and develop as a scholar, not simply to be a repository for information.

Figure 124: One of the studios I was able to co-teach. This was a Second Year studio space in the foreground. This learning environment is much different from the large lecture hall method seen in figure 123.

This difference between the "sage-on-the-stage" lecture model and the traditional studio model is this mentor relationship. This allows you to begin to learn what interests the student on a fundamental level and begin to engage them while maintaining their agency to decide what is their line of inquiry. This ability to choose is not only what the framework is predicated on as a decision support system, but is also one of the foundations for design. The ability to choose and deliberate on a work is the core of the design process and this translates to the process of representation and iteration. The iterative loop finds its way into the framework and is a critical part of the typical design process and subsequently this specific framework aimed at vegetated assemblies and color theory. The framework was designed for use in a studio environment as a supplement to the already-developing architectural design process that each student forms, maintains and curates over the course of their life as an architect.

The traditional studio also has the physical space and time needed to begin to work on a line of inquiry into the profession. The second year studio has a minimum of 12 hours a week in studio with the professor, with other hours that are scheduled for student working time. There is also a supporting lecture series to introduce designers or other ideas to students every week for the whole school. The time and commitment to studio is what makes it so strong as a teaching model combined with the physical space and mentoring method. The downfall of the framework in studio originally was that its visual or graphic representation was unknown to the students. This was alleviated by the development of the website and the continued critique of the framework in the studio design exercises.

The point is that while a large lecture course can choose to cover a topic such as vegetated assemblies, it does not cover it in any real depth nor shows how to implement it in a personal design process. There is a disconnect between lecture courses and the process of augmenting recent examples for use in studio. As a result many topics are, in large part, copied. A studio, especially at the second year level, is not designed to introduce one specific topical area, but to develop a personalized design process. Studio is a place for exploration and each topic needs to be supported. This means that over time other areas and topics need to be considered, in some depth. The idea of incorporating all ideas into one place is simply not feasible and would take a lifetime to incorporate. This is why the decision support structure is a support system to a student, not the only interaction the student has with the topic. While there are other sources, the key aspect is that the professor is present to assist with questions and the development of the line of inquiry for the student as a mentor. I will reiterate that the framework was never intended to replace the presence of a mentor-professor, but assist in their temporary absence.

A non-traditional studio presents a unique set of issues. There are two main ones: first, the non-traditional studio does not have a physical space usually that the students can come to for working; second, the non-traditional studio does not only have design majors, but majors from many disciplines. Usually non-traditional studios only attempt to tackle one of these two potential issues that make them different from a traditional studio at once. Having both non-design majors and no consistent physical place for the studio were the biggest issue and the biggest strength of the specific non-traditional studio that was conducted. The class was specifically the Metaphysical Room course for the Honors Program. More in depth review of the work is later in the discussion; however it is

important to note that within the different levels of design majors and then between the different disciplines peer-mentoring occurred. More experienced students were able to show others new techniques and were able to work together to achieve a goal.

This strength of being able to work together on a project is different from the usual situation in studio. Commonly, students work on individual projects together in the same space and help each other as needed. This informal peer-mentoring allows critique which is helpful during the design process. However, this is inherently different from working together in a group setting. The groups were made of at least one designer and one non-designer allowing for different perspectives on the design at hand. These different perspectives also allowed students to build from each other's experiences and then influence the design. This will be specifically reviewed in the amphitheater and expanded RDF Wall (Solar Lounge) projects. While the combination of different majors and experience levels turned out to be a blessing in disguise, the lack of a physical space for the students was a irreversible drawback. Halfway through the semester the course was moved to a common space in Cowgill to give students space and access to resources that the design students were used to having, and introduced the non-design students to the place of design, a studio.

The Metaphysical Room course has shifted since then to become a more preliminary design course and an introduction to forming lines of inquiry and basic design-thinking in the context of phenomenology. This allows for students to be introduced to designing and then use them to design a project, but not be immediately required to design on their own. The group-focused projects will remain and be centered on something that the student can literally see and interact with. The more abstract a

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project becomes the more difficult it was for non-experienced students to engage. The course also adapts to the number of design students present. Currently the course has fewer design students and will respond to this in the number of groups and the size of the groups.

Figure 125: The Metaphysical Room studio-like course moved to this table in Cowgill for the second half of the semester to provide a space for the students to work together in groups. This also introduced non-design students to a type of studio and the studio environment.

The course will be improved with time. More feedback is necessary to the development of this unique course and to be able to provide the support that each student needs. One way to solidify the course would be to either make it a different example of non-traditional studios such as vertical studios (multiple years of design students) and integrated studios (multiple disciplines in one studio). These would allow the combined issues of no physical space and different levels of experience to not confound each other. Finally, the framework works best again for support and reference in the course and not as a decision-making tool. This distinction is critical to understand as taking the decision away from the designer by implementing a decision-making tool is neither the desire nor function of the decision-support system and the dissertation.

Aside from thesis year, the independent study is the most useful course for distinctly setting up consistent individual interactions with a student. In the independent study that was conducted with the 2002 Solar Decathlon House, the use of the framework was directly studied in reference to one individual in depth. The in depth application of the framework by someone other than the researcher was enlightening, and independent studies with others may prove to be an interesting mechanism for future guided, but collaborative, research. This collaboration is a more structured version of the mentoring process that takes place in studio and can be used outside of the discipline of architecture for other faculty and students to utilize research, perform, or follow lines of inquiry above that of a classroom or studio, but not at a full research project or thesis scope.

Figure 126: The site out at the Research and Demonstration Facility for the Independent Study after the completion of the Solar Garage project. This image is of the 2002 Solar house next the Solar Garage project. Due to a lack of maintenance and pruning, parts of the façade of the Solar House are spontaneously self-vegetated.

This depth allows for the fundamental assumptions of the decision support system to be challenged, and either confirmed or refuted. Thankfully, much of the framework was confirmed and deficiencies were addressed. These deficiencies included other examples of vegetated assemblies by the researcher or from peers. This also resulted in the development his independent study work (figures 101-103) and the development of the general framework side of the framework as shown in Appendix A1 or figures 101-103, and 127 (this process of developing the whole framework is show in figure 49-52). This general framework was mentioned by Tim as something he did not necessarily need as a thesis student, but could be useful for others with less experience or who were from outside the discipline. This limitation needed to be corrected and further research was conducted into the design process and "choosing by advantages" to understand their relationship. In these examples and in the case studies no true process of choosing by

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advantages is used. This process was instead identified as the next area to be developed in the framework.

The independent study's greatest strength was also its weakness. The course was limited to one individual, which meant that only one student was exposed to this in-depth approach to the framework and its use. An independent study is also meant for the student to gain specialized knowledge in an area of interest and should not only be used to feature or further a research agenda. While Tim was amicable to using the framework with the work, he was not required to do so. If so, the whole point of having choice would have been undermined. This starts a larger conversation of how research is brought into the classroom and used to the students' advantage rather than for the researcher's sole gain. Further, this concept of using the framework in courses might be better served by a topical studies course or a special studies course where the focus is to use such frameworks or evaluate them. This special studies course would then be reviewed to see if a permanent course should be established.
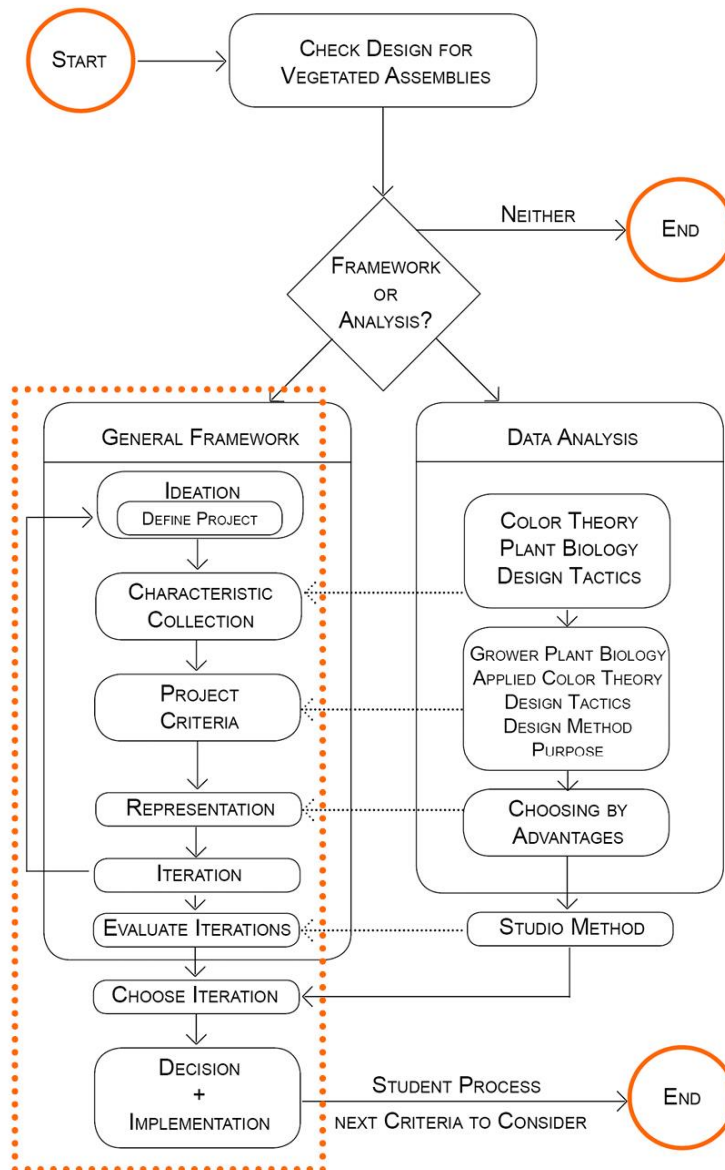
Figure 127: Tim's work confirmed and influenced the diagramming notation of the framework itself going from an undisciplined flow chart to a thought-process organization using Business Process Modeling Notation (also see figures 49-52 and 101-103, for how this was developed and the work completed with the independent study). The portion in the dotted box shows the areas he used for designing the independent study, while the data analysis side was developed from the complete work and missing elements during the process.

How did the results compare across the courses from the same students?

A second year student, Jake, happened to be enrolled in the Metaphysical Room

course (UH 3004) and the first half of the second year studio sequence (ARCH 2015) at

the same time (Fall 2015). Jake worked on many of the projects that have been given as examples of case studies and the second year design exercise. Because of this, his work begins to show the development throughout the year as well, while becoming more aware of the framework, but more importantly, the lines of inquiry that interest him in architecture. His work is on the following spreads.

The first series of works is from both the Metaphysical Room and second year studio courses. The particular project was about an Amphitheater. This amphitheater was introduced as a project for my first year back in 2009 and I have found it an interesting place to pose the same questions that were asked of me back then.

"Looking at the site, propose an architectural intervention to improve the space."

In this one sentence we have a number of considerations that immediately arise. The first is that of a site. What is a site? Where does the site boundary end? What is its context? The second is that of an intervention. What is an intervention? Does something need to only be added to the site or also taken away? What is its scale? What is the purpose? The third is that of improvement. What does it mean to improve? How would I go about this? The last is of space. How do we define space? Why design space? There are many other questions that can be asked and then applied to the simple question of posing an intervention. However it begins a process of design and exploration that becomes critical to the foundation of developing a personalized method for architecture. Personally, I also believe that being out in nature and being able to visit a site makes any project more of that place, as you have experienced it, not simply looked at it from the internet.

So when we review the work, what is it that we really desire to find? Is it that the framework directly resulted in a visible change? Does it mean that a process was influenced? Do we try to attribute something directly to the framework or do we look also to the mentorship that is required to begin to bring someone into the profession? I would have to say that between the two courses (the Metaphysical Room studio-like course and the traditional studio) there is a change, but it is not that a design process was radically changed by the framework. Rather it was the development of a line of exploration and interest in doing more than the minimum that began to develop.

Now, I would say that this sort of drive was developed long before the framework and that the framework did not cause it, rather the framework supported new ideas and topics that then were explored for the first time. Looking at the two boards, and after learning more about Jake's methods, we can see in the first board (figure 128) that his method is to sketch out a composition in pen and then place sections and plans in relation to the perspective. This method of placing images in relation to each other is common for architects and allows us to begin to understand a space.

While the drawings are well composed, plants and spaces are not all in only black and white. In the Metaphysical Room course I introduced Jake to the framework and asked if he would try other than his normal or usual techniques. This would allow him to explore, but more importantly be able to focus on a new technique instead of redesigning the amphitheater project for each course. After using the framework and my suggestions he introduced color using Prisma color pencils, and drew a constructed axonometric. The axonometric is a drawing that is volumetric to get some sense of the place, however unlike a perspective none of the distances are altered as a person would see the space, and

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instead every line is measured out at length. This makes the drawing to scale and measurable, but makes a spatially altered image. I later learned that he was not as familiar to Prisma color pencils in the same way as pen. This was important to me, in terms of the framework, as it reminded him of a media type he had not really used before and he went with it.

This willingness to try something new is probably the biggest aspect between the two drawings (figure 128). Yes, the drawings are different and show a changing perspective of how the amphitheater was designed, however it is so much more important that the framework be able to introduce ideas and methods to others. As mentioned before the fact that the new media type was unfamiliar is an added bonus. To take a risk in design and learn a new skill is what studio is based upon, named a "Laboratory", specifically with the intent to test and explore. This ability to choose and then learn from working is what studio and the framework is all about.

This can be attributed to a variety of factors, but no actual causal link could be made, nor is it necessary to find the exact cause of this change. Fundamentally, it is the student's willingness to explore and think about design that will influence their work. As shown between the two courses, introducing the framework and its potential ideas gives students a sense of a less risky endeavor. In the studio sometimes there can be an extra need to perform that is not present in the non-traditional studio. This is not the main cause for the difference in methods, I believe, as the studio is a place for exploration, but rather this sense of trying to avoid failure that handcuffs students into not trying new techniques or methods.

In the long run, this risk-averse method produces consistent, but unimaginative work. It is a large part of the educator task or responsibility to cultivate a sense of allowing and even supporting risky explorations that might result in failure. The way that I have been taught this and the way I will continue to teach is: "What will you produce or design that will drive the profession forward and will this be compelling to the discipline". I believe that the framework has something to offer the profession through influencing students to seek methods that are different from their norm, and to test and explore and continue to do so once in the profession. This is best found in the studio lab, where iteration of representation, such as the two boards, allows for growth and the development of systematic design processes.

The Framework: Studio and a Non-Traditional studio - Jake

Figure 128 is my interpretation of Jake's work as it would relate to the framework that he had access to during his work between the two courses. Jake moved from working in black and white in pen as a perspective to in color in color pencil as an axonometric. He used the framework to simultaneously explore color theory, media type and design tactics. These three combine to address a fundamental exploration into technique in representation. These techniques were later described by Jake to be as being "unfamiliar" to him and served as true exploration into what could happen.
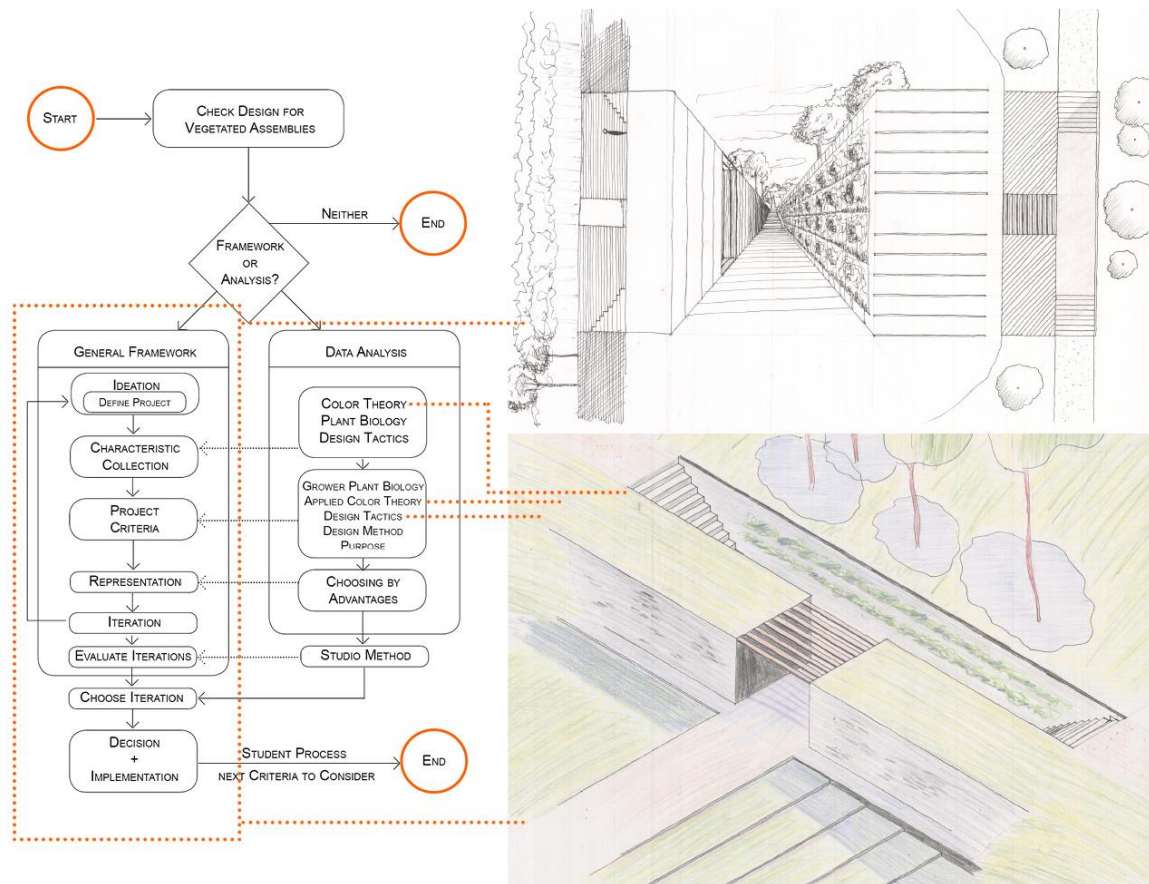
Figure 128: This shows the relationship between the framework and Jake's work completed between the 2nd year traditional studio (ARCH 2015) and the studio-like Metaphysical Room course. The upper right image is Jake's work for the second year studio for the amphitheater project. The lower right image is Jake's work for the Metaphysical Room course, the same amphitheater design moving into a volumetric drawing and using color theory and applied it to a loose representation of a possible vegetated assembly in the sunken walkway entrance.

Is there a difference of usefulness across different levels of student experience?

There is perhaps a difference in effectiveness that is based on familiarity with the decision support system itself as shown with the two iterations of Jake's amphitheater designs. Different levels of student experience are also tied to experience within the profession, so exposure to concepts in either studio or its support courses would impact the effectiveness with the framework. Quite simply, if students have seen it or a topic before students probably will have an easier time doing or understanding it. I do not

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believe that there is a profound difference, however the difference is found more in the design experience of the students rather than the framework itself. If someone is familiar with something it is better utilized, this is true for the framework as well. The work of Jake and now Ron together will help to illustrate this concept. Ron's work for the amphitheater project will be presented on the next spreads.

Jake is a 2nd year architecture student. Ron is a 5th year architecture thesis student. This three year difference in terms of curriculum and experience in the profession is significant, especially in the beginning of starting into the profession. This difference includes the fact that a 5th year thesis student has taken full building structures sequence, the environmental buildings systems sequence, art of building, building assemblies, building analysis, building cities, multiple history and theory courses, as well as the year sequences of studio. Further, Ron had the opportunity to study abroad including a residency studio in Ireland.

These courses are intended to build a technical and theoretical background into the profession and become a well that professionals draw upon to, well, draw. These previous experiences serve as the base for making decisions and influence our design processes. Building Structures focuses on the requirements for stabilizing a building against all forces, learning how materials each have their strengths and weaknesses and how these relate to size and use.

Building Assemblies looks at a combination of the theoretical stances on how materials have been used, and how they are used with each other. Though this course speaks to the common methods of assembly it also shows many unique examples of how common assemblies are used in extraordinary ways. Environmental Building Systems

looks at the passive and active ways of maintaining comfort in a space as well as understanding methods to improve performance. The Art of Building is a class that has evolved during my time here to become a course that introduces materials and asks how these materials are made and how you make with them yourself, with your own hands.

Building Analysis is an interesting course. This asks the student to take a building in the world and try to understanding of it from a series of drawing or images, how does it work?; why was the building constructed in the that manner?; what was the design intent?; among many other questions. Personally, I and my group reviewed the Reagan National Airport. The analysis of the vaulted, compression-ring module has greatly influenced my work.

Building Cities looks at cities through time to see how they have evolved, what the scale of a city means, and how to take the considerations of the city into account when designing. While I was in undergraduate studies we had the history of architecture from pre-history to the present, however a new course in theory was added in the 4th year to better introduce the theory of different movements in architecture. While I did not receive this course formally, I believe it to be an added benefit to students now.

What does this list of courses mean for Jake and Ron? It shows the wealth of knowledge that Ron has available might influence or ground his work differently than Jake's. The experience and knowledge also allows Ron to formulate an idea very rapidly and iterate just as quickly. I have watched Ron generate multiple ideas and draw them out in a similar manner to the work presented in short order.

Frankly the overriding factor of comparing two designers directly to each other is somewhat difficult. Jake takes a method that starts in his sketchbook and then becomes a

more constructed drawing as a final drawing. Ron has a method that retains fluidity and appears rougher. Both students have drawings in relation to each other and from this we can conceptualize their designs. My interpretation of the two works is that Jake viewed these images as more final, a culmination to the project thus far. Having watched Ron go through his thesis parallel to this side project, you can see the same method of questioning the design and always allowing it to evolve as new ideas presented themselves and in some cases are drawn over each other.

Each designer is different in design processes and media methods. To decide the method of expression or technique used to design handcuffs designers and does not allow their full potential, but as shown with Jake, if you do not do this they have the opportunity to discover new techniques. In my future work and teaching, balancing this approach will become essential to student learning. The purpose of the framework is to present information so that a more complete decision is made when utilizing vegetated assemblies. For me comparing designers is less important than when they have the opportunity to work together towards a common project.

While Jake had not yet developed a completely formalized process, Ron's noticeable characteristics across different projects are evident even with the addition of the information provided in the framework. Ron was also in the Metaphysical Room studio-like course and in figure 129 is Ron's amphitheater project. Another project done in the Metaphysical Room course was the Vegetrain project which was one of two group or common projects in the course: the Vegetrain and the RDF Wall. The Vegetrain project was published in detail in *Educators as a filtering information node: design frameworks* in the 2016 Passive and Low Energy Architecture Conference. Ron's and

Jake's RDF Wall project (which would later become the Solar Lounge project) are shown in figure 130.

The Framework: Studio and a Non-Traditional studio - Ron

Below is my interpretation of Ron's work over two iterations of the amphitheater project for the Metaphysical room course. While Ron used color in the representation to denote importance of design interventions (orange) as compared to existing conditions (black), he did not look at color intentionally. The difference between Ron and Jake lies in Ron's increased speed and process that developed over more years of experience. His ability to iterate, evaluate and then choose between ideas quickly cannot be overlooked.
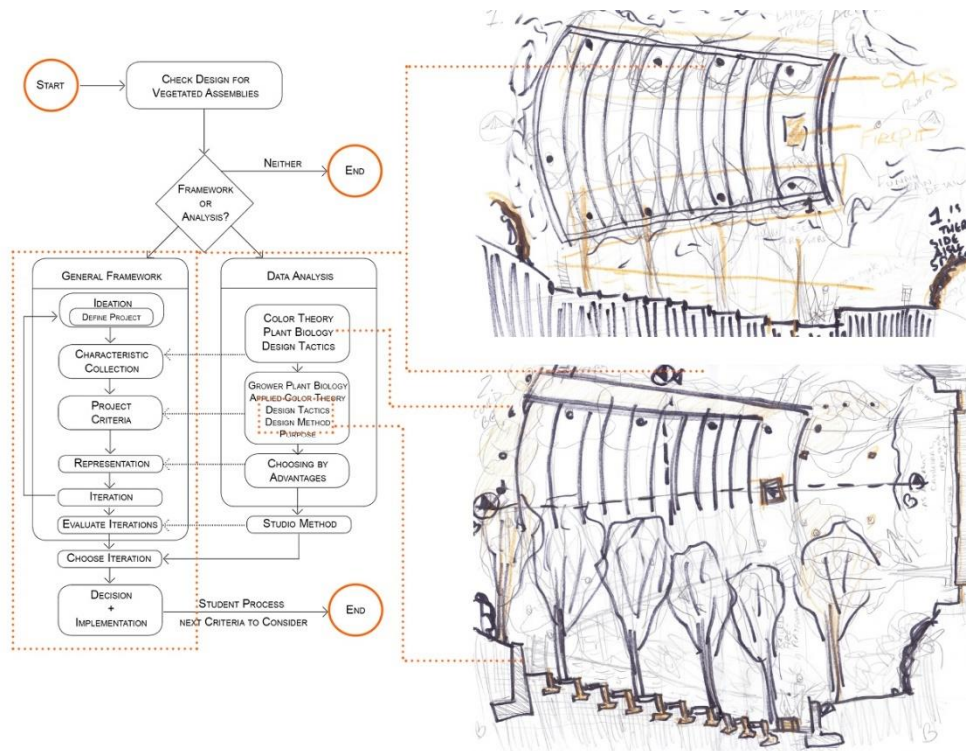
Figure 129: This shows the relationship between the framework and Ron's two iterations completed for the Metaphysical room class. He used plant biology to place trees and provide cover for the amphitheater. He also recognized the eroding slope in the rear of the space and implemented a retaining wall. He also includes his own ideas about sight lines and the symmetry of the space. In terms of color he used black and pencil to show conditions and orange to highlight critical aspects of the intervention.
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The Framework: RDF Wall to Solar Lounge - Ron, and Jake + Sean

Now the RDF Wall project will be reviewed in more detail. Really the project I will describe is an extension of the final RDF Wall project in the first semester (Fall 2015) of the Metaphysical Room class that Ron and Jake were both in (see figure 54). The project occurred over March to May 2016, the second half of the Spring 2016 semester.

I am more interested in what students do with their work after a class ends and how it influences them. The RDF Wall project, which would later be named the Solar Lounge, is an example of what happens in the space and time between classes when students become interested in a topic or method and wish to explore further. Sometimes these explorations are formalized into an independent study or other specialized courses; however this project was, as I have described it, for fun. And that is what I have hoped design becomes for others. I believe that something that is fun or enjoyable becomes engaging. The Solar Lounge would also become a case study based on the availability of funding from the Student Initiated Research Grant program funded by the college. When I was first approached, I was caught off guard a bit. I have never had a student ask what to do if they wanted to design a project outside the bounds of studio.

First things first: you do not need my permission to design. Jake had wanted to build a project for a while, and one of his studiomates, Sean, joined up with him to ask about potentially building something. I had mentioned in the Metaphysical Room class that we would try to build something at full-scale, but time simply ran out in the class and funding was scarce at the time. Jake asked me at the beginning of the next semester, but I

was quite busy between a number of responsibilities and told him that I might not be able to directly help, but could see and review designs.

I told Sean and Jake about Ron's RDF Wall project from the Metaphysical Room studio-like course the semester prior and that might be a good place to start with designing the Solar Lounge and to ask him to join the team. While Ron was too busy with thesis to join, with his permission Jake and Sean began to continue designing. With a stroke of luck and shuffling some work around I was also able to help them with the grant proposals and procuring materials. In the end the Student Initiated Grants did not have any more funding for projects so we turned to the Doctoral Program for funds. Originally, I did not have the interest in making the Solar Lounge a case study, but why not. We were able to put the proposal forward and recieved the funding. The Solar Lounge would now become an immersive case study with my students. A short description of the project to receive funding follows:

> The objective is to show students in second year the process of full-scale construction testing and how vegetation can be used and integrated in architecture. This work is the continuation of a class that was conducted in Fall 2015 and will be part of a class conducted in Spring 2016. The completed test sections would be installed in one of the CMU walls at RDF as a visual representation of the project, of student work, and as a greeting to RDF and the parking lot. From this experience the design of both the Solar Garage and the vegetated assembly framework will be revised and then implemented as part of the dissertation and learning process of myself and other students.

I neither find this project to be purely luck, nor really providence. If anything, prior preparation and an off-handed comment to my class and their preparation of initial ideas led to the development of the full-scale work. So what does this mean for the framework in relation to the Solar Lounge?

The framework is much better utilized as a part of the initial design process rather than applied to the end of a project (as was done with the Solar Garage). Most decisions in the design process are better integrated the earlier they are brought into a design. Since the vegetated assemblies and the intent for a student project scaffold were a part of the original design intent, the structure and the methods for generating the Solar Lounge could more easily find adaptations into the work. While initial designs were quite grand, the final project was more interesting and meaningful when a rather tight budget was applied.

Design constraints from the site also helped to limit the scope of the project and reveal what was critical to the design rather than what we all wanted to be present. This meant that a rather robust enclosure was reduced to more of a cantilevered overhang; however the expression of forces on the structure was retained in the joining of wood and steel wire. The wood functioned in areas of compression forces and the wire in tension. Finally, the inclusion of a pallet served as the first assembly integrated into the Solar Lounge. Initial drawings are presented in the next spreads along with the final constructed project. This work is from the Metaphysical Room course by Ron and Jake, prior to Sean joining for adapting the two projects to become the Solar Lounge case study. This work is shown in figure 130.

The Framework: students using the framework - Ron, and Jake

These are the beginning of the Solar Lounge project with work from the prior Metaphysical Room course done by Ron and Jake who were in the metaphysical room studio-like discussion course. These show the different in methods used to represent the different ideas (figure 130). The difference the interpretation of their work is done in more detail in the validation chapter however it is important to note that different students represent and engage the design process in different manners. Ignoring the data analysis aspects of the framework regarding color theory, plant biology we find that design tactics and methods while using the iterative process of design become critical to the student's individual architectural process.

This show the relationship between the framework and the work completed for Metaphysical Room course by Ron and Jake prior to it becoming the Solar Lounge case study. Both students used methods form the whole general framework side and areas of data analysis. An you can see the use of color to represent plants, depth, and other methods for constructing a possible vegetated assembly on the site. These two students engaged the project differently. Figure 130, Ron (above) looked at material and its interaction with plants while Jake (below) took inspiration from nearby structures integrating a structure into a frame for vegetation between his intervention and the existing wall and building.
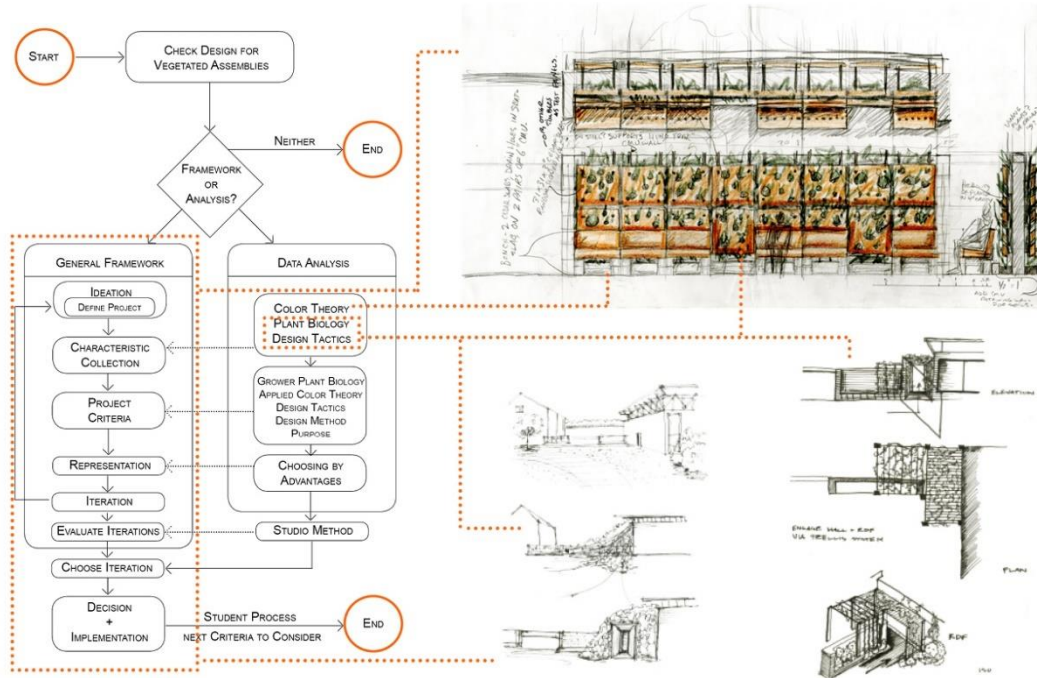
Figure 130: The work for the RDF Wall Project of Ron and Jake from the Fall 2015 Metaphysical Room studio-like course that became the basis for the Solar Lounge case study (figure 131) which was constructed in Spring 2016.

Figure 131: The built Solar Lounge project with Jake and Sean in the Spring of 2016. This view shows the sitting place for rest and the shaded cantilever over the south-facing original CMU wall and the beginning of the testing modules for vegetated assemblies for the Solar Garage case study (case studies are explained in further depth in figures 65-73, 110-122).

The comments from Ron, Jake, and Sean, combined with the reviews from the second year of the design exercise led to the development of the digital website application of the framework to review its overall aesthetic and representation. This project further solidified and confirmed the issues of implementing the paper version of the framework as found after incorporating Tim's comments from the 2002 Solar House renovation independent study in the form of a general framework portion and expansion of the data analysis aspects (see figures 101-103).

Overall, the project was enjoyable, and that is important to me. It became a project that Jake and Sean show others and helps them in the future when designing or to include in their portfolio when looking to emerge into the profession. If the project helps me personally, fine, but I really want these case studies to help others as well, be it experience, portfolio building, or to simply learn something new.

Effect on decision making and its improvement developed by the framework?

These excerpts taken from *Educators as a Filtering Information Node: Design Frameworks* (Black, 2016) presented at the Passive and Low Energy Architecture in Los Angeles in July 216, summarizes the work of reviewing the first semester of the Metaphysical Room course:

"[S]tudents had varying access to working environments and design experience without direct peer interaction or co-mentoring [the ability to mentor each other together with the teacher] while designing in a previous part of the semester. This developed individual ideas and design methods a little beforehand. While the

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differences are not easily apparent in the initial design phases, experience widens this gap through the full design process. Third, the project was about discovering their own design process and delivering a designed response according to their personal expertise and environmental concerns. Each of the projects had a different main inquiry or consideration, which was often related to the personal interests of the individual.

[...]

The students desired even more face-to-face mentoring time. As a three credit course instead of studio's 6-9 hours, it simply was not enough time to have a similar experience to a traditional studio. The students wanted more class time, more often during the week, in a studio-like environment to further develop their design process. This suggests that a vertical studio (different years of experience) or integrated studio (different disciplines) might be a better choice for organizing the class in the future. The students wanted to have defined prompts with more limitations, too much freedom and inexperience made it difficult to narrow down their design intentions. It seemed that they had never been asked what they enjoyed doing and by giving them the ability to choose what interested them, it confused them into indecision."

These comments remind us that the physical environment that we teach our students in is just as important as the time given and the grounding of the course either in literature or

thought. I received feedback from the students on the projects that involved the framework, not only those I shared here such as the amphitheater project and the solar lounge. These are only a few of the quotes that speak to the idea of working together to iterate and ideate and how perhaps the framework also was, at least tangentially, involved.

"I feel that the new flow chart framework you sent out really aided my backup research on this project; I was able to better structure my characteristic collection phase toward relevant plant biology and train designs."

"Overall, ideating within a group is really exciting and inspiring, because we could bounce ideas off of each other and see our original idea shape into the final idea."

"While we didn't actively work with the framework, I was definitely working with an awareness of its existence and content, which I remember helped to push certain directions."

"I think I learned more working beside a design major than working on my own. Working with her is great because it affords me an opportunity to see how to design and how to communicate a design from someone who is still learning as well."

I believe that the framework has the potential to become much more than only reviewing vegetated assemblies and color theory, but also expanding color back to light

and daylighting. Combining vegetation and light into beautiful spaces hold as much potential as developing the framework into other representations that students will find useful when working in groups to develop designs. Through these projects and different courses both in studio and elsewhere, I have found that as a thought process builds it is supported by the framework and organized along an iterative path that can, with experience, begin to influence student designers and ultimately the profession. That when a student becomes familiar with the framework it serves as a better resource after introducing then to new and different information pertaining to vegetated assemblies and general systematic design processes, choosing methodology between iterations and drawing techniques to use in design.

Further, designers will interact and need to understand different disciplines associated with design and construction, but also from other disciplines that will serve as knowledge domains on particular projects. We simply cannot work alone in a vacuum, and can learn much from other's perspectives and experiences.

The framework becomes a part of, even an extension of, the learning environment that student will use to become familiar with topics in pursuit of their understanding of the discipline and their place in the world. This means that the prompts are crafted with the same attention as the resulting designs receive. I am not seeking to change or have a total overhaul of studio. I am simply seeking to find a way to infuse research into the studio.

The framework improves decision making via the direct access and introduction of new information. Though it may not be used literally in every instance, examples from various projects have been presented. Tim's work with the Solar Decathlon house, the

transformation of Jake's work in the initial amphitheater project in two different courses (Arch 2015 and the Metaphysical Room course), the expanded RDF Wall project which became the Solar Lounge case study, and the design exercise reviews show directly how the framework can be used in various teaching environments. The framework helps to improve decision-making by focusing on Nigel Cross suggests: that our ability as designers is to take these topics and distil them to their properties, elements, or characteristics that are uniquely interesting to us, or at least purposeful in our design process (Cross, 2007). The different figures in the last three chapters allow us to trace this effect described by Cross.

Our previous experiences influence who we are as designers. It is the phenomena and its worth that generates ideas that we can use in our designs, however without directly experiencing this we cannot begin to know it. Thus the framework works as a conduit for students to use my experiences to generate their own. From these experiences in their subsequent design work they then can make more informed choices in their future work. By using the framework and the expertise of the mentor-professor in studio-like courses students can become active learners, resisting the passive lecturing model. When developing such environments the mentor-professor must maintain an interactive and engaging environment. I see the framework as an extension of this goal and my approach to learning and teaching. Figure 132, is a summary of the influence that different students and classes had on the framework. This reciprocal nature of students being informed by and then informing the framework strengthened the framework considerably.
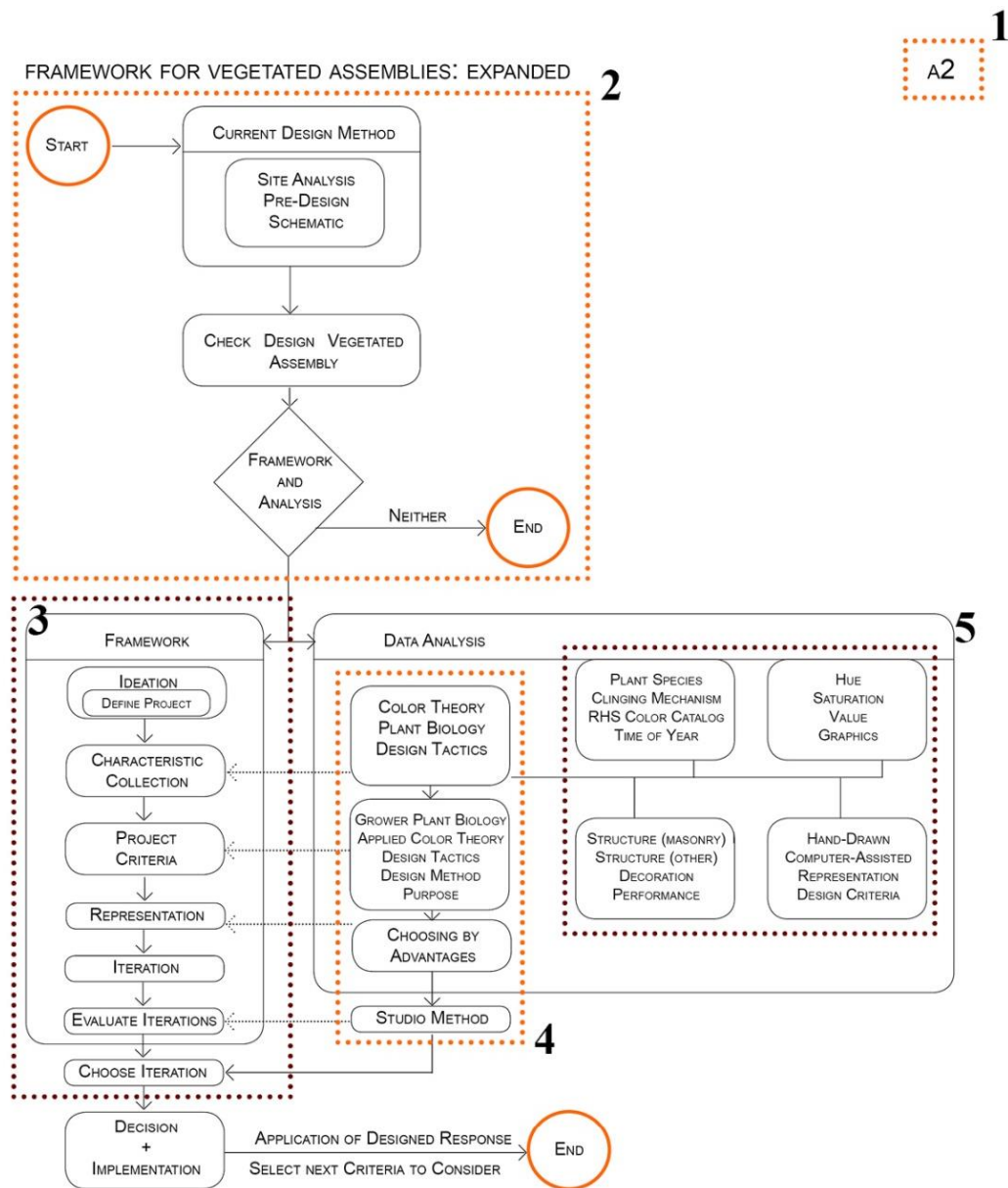
Figure 132: The different steps of the dissertation's methodology and how they influenced the development of the framework. The differently labeled sections (1-5) are explained in further detail pertaining to the sequence and use of the appendix page and the different parts that were added and developed over the course of the study using observation, interpretation, and drawn work from students.

Section of the Expanded Framework and their influences:

1: Appendix A2: This is the expanded version of the framework, showing the considerations that go into the main topics of color theory, plant biology and design tactics. Each of these considerations then has its own appendix of information that further explains its relevance to the topic and needed information. I typically use this expanded framework to choose which of the considerations of subtopics to bring to the forefront for a particular design. Sometimes it might be the desire to work with a particular species of plant, or its flower color based on a desired color scheme. Perhaps a particular structure is available and that informs what species to use based on the applicability of its climbing mechanism.

2: The original framework stripped of the mental map processes and topical considerations. This was developed to limit the designs of the framework to, at most, schematic design.

3: After introducing the concept, to a thesis student we will call Tim, the general design process was added to help those who may not have a solidified process, or who need assistance with developing design and tool techniques.

4: Prior to the questionnaires with students in the second year studios, topics were identified as knowledge domains that the data analysis or information gathering portion of the framework would need to address. These three domain areas of color theory, plant biology and then design tactics were then applied to reveal five others. Finally at this time, choosing by advantages was selected as the process to make decisions between iterations based on the information gathered during the design process.

5: After introducing the concept to students involved with the two years of the questionnaire exercises, the more detailed topics were added to the initial overall framework and an extra layer of detail was added to the framework. This expansion grew the framework from 6 pages to 38 pages total. This also included an expansion of the design framework introduced from the work and experience with Tim.

Prior to the questionnaires and design exercises with students in the second year studios, topics were identified as knowledge domains that either portion of the framework would need to address. These three domain areas of color theory, plant biology and then design tactics were then applied to reveal five others. Finally at this time, Choosing By Advantages was selected as the process to make decisions between iterations based on the information gathered during the design process.

6.2 Significance of Learning Environments and Student Examples

What ought it be? Remember that there are many different ways to design and none of the representations of a mental process truly capture them. None of these methods or representations are correct or incorrect, they simply are. When you stop to think about how we inspire our students and the work that they do, and ask what they wish to do, rather than solely what they have to do, we can find meaning in teaching and learning. Granted there is a base understanding of what have to occur for responsible and safe design of spaces and this should always be done as a design professional or architect.

I believe that the experiences of asking what students want to do with their lives rather than assuming brings out a stronger attachment to the essence of the person. It brings us one step closer to understanding who we teach rather than what we teach. The framework ought to be many things. It ought to be a scaffold to aid in learning. It ought to be a conversation starter. It ought to be a guide. It ought to be a way of thinking. However, most importantly it ought to inspire. This framework organizes thoughts and asks the designer what it means for them to design.

These examples are in a microcosm the process for determining how immersive case studies, teaching surveys, and observation lead to larger questions about teaching and design. For me the framework is the beginning of something larger, a line of inquiry into teaching and design. All of the publications and case studies were done to try to understand how students might learn, but also how they might want to learn. This is discussed in the validation as topical discussions within the realm of publishing.

Asking what students want to learn is significant because when asked, students tended not to know what they enjoyed doing. They have spent so much time being told

what to think and what they ought to enjoy that by the time they have a large enough technical knowledge they are sometimes burned out on what to apply it to.

Learning environments each have advantages and disadvantages. A traditional studio differs from a non-traditional one on the basis of physical environment and time allotted to design. The independent study gives one person an in-depth view of something, but does not allow for that experience to be easily transferred to others. This entire process of trying to understand how a framework would be useful in different types of teaching environments began with a lecture on vegetated assemblies and color theory to an introductory course and realizing from a lack of engagement that the topical information was not being conveyed in the manner that I hoped it would.

Further, different students will engage the framework in different ways according to their previous experiences and personal design process. These differences allow for the framework to be evaluated for its influence on students and depending on the experience of the student, it might influence them in different ways. Depending on desire and need, students can incorporate the framework to completely explore new techniques, or only to augment their developed methods in minor ways.

There is no basis for conclusions as to whether the framework will change techniques in particular ways, only that the framework does indeed serve as a knowledge sharing device and influences decision-making, and that with more information these decisions are more refined and improved as compared to not using the framework. Overall, the framework does not seem to inhibit design processes by restricting ability of the designer to choose whereas a decision-making tool might do so. This allows them to retain control of the design and not rely on the framework to make decisions for them.

The student examples presented show the variety of different ways that the framework can be used including to inform fundamental design techniques, to augment different design choices, and to assist in the making of iterations. These iterations are then selected based on the desire of the student and the influence that their personalized design process has on the framework itself. In a way, the framework is only as effective as the student wishes it to be. This stems from the decision-support nature of the framework rather than the decision-making nature of a tool.

The framework thought it does not directly cause it, serves as a scaffold for other projects and for extensions of lines of inquiry. This allows for students to be able to see beyond a single project and see how the information that they have learned might be applied again in the future. This occurred in the Solar Lounge project, allowing a re-designed RDF wall project from the Metaphysical Room course as a case study to be built at full scale by Jake, Sean and me with the support of a Student Initiated Research Grant. That is the potential power of the framework. To show students that when ideas converge their interface holds potential for exciting designs and lines of inquiry, as well as to inform and improve those decisions according to their own personal design processes.

Chapter 7: Conclusion and Continuation

7.1 Conclusion and Continuation of the Framework

Overview:

The framework for vegetated assemblies has been grounded, designed, developed, tested, evaluated, and then discussed. However, where does the framework go from here and what conclusions can we draw from all of this?

The framework serves as a knowledge-sharing device when the expert or professor is not available or present and can do this from many places as a website application. It provided positive contributions to teaching and design in a multitude of learning environments. Since the framework is a scaffold for the interactions of ideas and design using the iterative process, it is adaptable to many design topics, and can be developed further and disseminated more. There are a number of lessons that can be learned from this experience and can serve to aid not only myself but others in the future.

We need to look back before moving forward in our research and draw conclusions from the first trail project in 2003 to the most current project of the Solar Garage in 2016. It becomes a part of a larger research agenda and combines the potential for outreach, future research and improved teaching. From this reflection on past work, a longer-scale plan for the next decade can be developed with the framework serving as a pedagogical model.

As a part of this long-term plan, the framework for vegetated assemblies as they relate to color theory will be evaluated and summarized for its current merits and then positioned for direct future works through a 10 year plan, based on the known gaps in the

body of knowledge and how it relates to the ideas presented in the beginning of this dissertation.

What does it all mean for me? For others?

I wish to begin where we started this work: with a series of questions aimed at myself as an architect, educator, and researcher. This entire work came from a rather long, but single question. The inquiry is: how do we as designers begin to use, through the normative design process and frameworks, the aesthetic that is created when plants over time interact with each other spatially and chromatically in vegetated walls? Further: how can this be used in a representational framework to synthesize plant biology, color theory, and design-decision making? This question became so much more than simply how to utilize vegetated assemblies within the normative design process. It quickly expanded into how to use this framework for teaching others the knowledge that I had gathered as a knowledge-sharing device. This addition to the research makes me, as a teacher and researcher, a node for information and the framework a knowledge sharing method.

This method is grounded in a number of methods, most importantly that of phenomenology through interpretation and the act of learning by doing, by making. The way that I interact with and interpret an object, situation, or occurrence through phenomenology influences how I research, teach, and design. This method culminated in a way that I understand the world around me and my place within it, and this view constantly is reviewed and updated.

Visual communication and by extension representation, are some of the most important tasks and skills that designers must develop, understand and maintain in order to have a systematic design process. However designers do not simply do a design once, they iterate. Further, somehow they must come up with an idea in the first place; this is ideation. This can be represented diagrammatically as:

Figure 133: The method of ideation, representation and iteration influencing each other in the design process.

This leads to how we begin to ask questions of something to come to an understanding of it and then begin to generate ideas. This process of ideation underpins the dissertation and its formulation of the framework. So we go back to the questions that we started with to structure this work and reevaluate them to now begin to answer them:

About the design process:

Why use the studio method in explaining and showing others our work?

Why is organized thought important to a framework and to us?

Why does our topic, drive our scholarship or professional direction?

Why is it difficult to introduce new ideas to others using full technical manuals?

Why don't we get it sometimes?

Throughout the experiences I have had with the framework while being able to teach at Virginia Tech, I have consistently tied my research back to studio. This work is based in phenomenology. Simply, I cannot know what I am attempting to know unless I have yet experienced it. To suggest that the framework is or is not useful, or to a certain extent useful in studio, requires this previous experience. The methodology of the school in both its method of learning by exploring and making is grounded in the Bauhaus (Charles Burchard via Gropius) and to some extent with the Ulm School (Olivio Ferrari after attending the Ulm School). The same suggestions I made about how a traditional studio and studio-like courses ought to be grounded are consistent from beginning to end. These suggestions are a summary of the School of Architecture and Design's intent based in these traditions from the Bauhaus and Ulm schools of thought:

> The students and faculty work together in co-learning; disciplined work is informed by experience; exploration is given enough time and space; students must write, design and represent work; they are self-reliant; students design from a line of inquiry for life as the continuation of the discipline; and professors are guides and held firm.

The environment that we teach and introduce topics to students in is as important as the process they use to design (see the discussion in chapter 6 and figures 124-130). This atmosphere must allow for ideation, representation and iteration. Granted, some of the framework's portions now directly reflect these tenets (see figure 132). This was mainly from the interactions I had with those who used the framework. Their experiences

with using the framework lead to its improvement. This process of being systematic, no matter what you are designing, is vitally important. It can be a spoon, a car, a house, a skyscraper, to an unimaginable spaceship; you must be systematic in your personalized design process. I applied this same process of design to the development of the framework and I believe it has served it well.

And the framework served as an example of how something can become so much more than simply a topic to research. I initially wished to build a structure that would then have plants growing on it. Easy enough, right? Well, not exactly. While some of the case studies are immersive and at full scale, the initial project I proposed was not the caliber of a Doctoral research agenda. The initial proposal I had is actually just one of the three main case studies used to support this larger idea of the framework: the Solar Garage. From learning how to teach someone a topic and develop the knowledge sharing device that became the framework and the website, I discovered it was not consulting, but teaching that drove me.

This shift in mindset over a few lines and words on a page is as incredible as the students who helped me to get there. While it might be anecdotal, and as I pass them in the hallways or in studio, many of the students have told me that they continue to use vegetated assemblies in their work. They mention that the questionnaire exercise and framework experience was a small part of that. This is all I asked for. That by introducing a topic to students they might begin to have experience with it and then this information led to better decision making. Some of these students continue to use vegetated assemblies in their work suggesting a line of inquiry into these assemblies. If this is the case then it suggests they will continue to use them in the future and impact the

profession. The framework might only be used individually or in small groups, but its implications for the profession are larger than I previously realized.

The framework is not a technical manual and is not all inclusive, but it is a resource students can use to begin to come to an understanding of vegetated assemblies and their interaction with color theory. With the guidance that was given from multiple places on the framework, it expanded to have a portion on the design process as well to help with developing a systematic design process for those who use the framework. A technical manual does not do these things; it provides an over-abundance of information that overwhelms an inexperienced reader, or even an experienced one. The framework is a resource, but not a technical manual.

Sometimes when we design it just does not click at first. We see the prompt, but a gut instinct for a response eludes us. The framework has topics that can help, but it ultimately relies on the designer to make this initial ideation occur. The framework will not do it for the designer; it will not make the decision for the designer. We retain that choice and must be able to think systematically and critically to develop our ideas. This takes time, experience, and knowledge.

I enjoy thinking of new designs and ideas. When students come and ask questions about a project that is in a different studio, it not only means a great deal that they trust me, but the conversations are often interesting and provide insight into the students as designers. These questions have help me to get started on ideas and I have advised many along similar lines:

About finding an idea:

What if I am not a 'designer'?

How do I even know where to start?

What is your idea, your topic, is there something that is interesting to you?

Something in your life that has followed you in your mind?

An underlying interest in many projects or other works throughout the years?

What is this about a framework and why would I use one?

After working on the framework with a variety of different students, all in different disciplines, I have found that almost anyone can be a 'designer'. This does not mean that everyone is equally prepared or equally talented; it only means that everyone can begin to think in a manner becoming of a designer. The desire to improve, to understand, to make, and to think systematically in the pursuit of a design - these make a designer. The desire to make and to do and learn is ever present. I believe that at no point in time does someone suddenly become a designer, only that they build upon previous experiences. For me, I point to the first time I set foot in an architectural office in 2006, for others it was when they started drawing for the first time. If anything, having a good drafting pencil and a solid pen with a useful sketchbook will set you on your way. These three tools allow for a multitude of techniques that allow for learning, observing and recording the world around you in an attempt to understand the world and your place in it.

The framework assists in the development of ideas by reminding us that ideas come from the intersection of our previous experiences with what is currently around us.

It asks the choice of what topics, in my case color theory and vegetated assemblies, and questions designers to review their own process in relation to these topics. However, at the root level it cannot give the true impetus for an idea. At least in some part that must come from the designer, but the framework can assist in its further development.

What is your idea? I have found that allowing for topics that appear unrelated to merge often develop into the most interesting propositions. These ideas do not have to be grand, only genuine and authentic. The topics and then the idea simply are. They are not right, they are not wrong. They are yours. What are your current interests? Past ones? I have been fortunate to look back at a string of projects that involved building at full scale as I have found this interesting to me. These ideas when thought over multiple iterations or works start to form a line of inquiry and now formulate the foundation for much of my design work. Starting with my Eagle Scout project in 2003 (below) to the most recent Solar Garage project in 2016, I have found many ways to merge my interest in the full-scale with nature and natural settings. I have found that my architecture is responsive to the place, a designed response.

Figure 134: The before and after of the same area of the walking trail in Rota, Spain. This was the first time a project was constructed at full scale in a natural setting. The project had a large amount of help for a local Battalion of SeaBees (combat engineers for the Navy) who had heard about the free lunch offered.

About frameworks or decision support systems:

What is it; isn't this just another flow-chart?

Why use frameworks at all?

Is it the frame to which we hold our thoughts?

Is it the method in which we think in order to understand?

How do we operate within our place in the world?

Frameworks are just that: a scaffold to build ideas into more complete designs. When diagrammed, I have found many people believe that a framework is just another flow chart. It is not. A framework is something that can be returned to over and over again and develop a different idea every single time. A flow chart suggests a single or consistent outcome. The framework designed here is meant to visually represent my thought pattern. It presents information I have learned and represents it to others so that with more information they may begin to make more informed and improved decision making in their own works.

We then iterate and refine our ideas. Based on our previous thoughts the framework gains more context and then becomes a method to use what we know about the world and begin to aid students in design. This, for me, is best found in the studio where the framework is used as a supplementary resource to the mentorship of the professor. The information then guides students towards influencing the profession. These next images are examples of how we bring our ideas into the physical realm and support the development of a larger line of inquiry. These projects served to develop the

framework as a knowledge-sharing device, but also serve as inquiry into vegetated assemblies and light (see figures 65-73, 110-122 for information on the case studies).
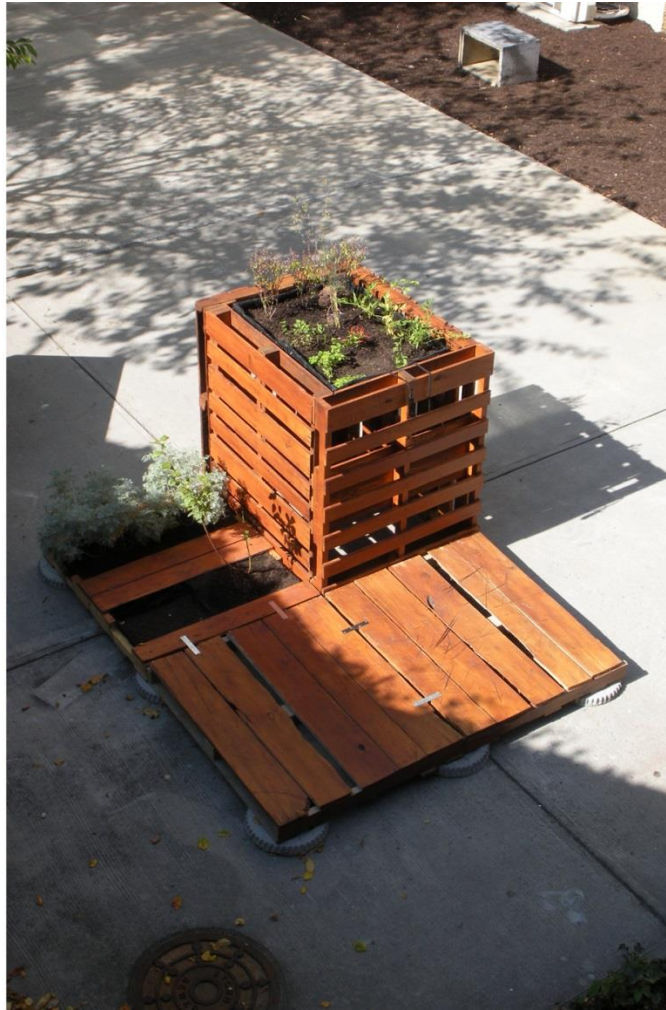
Figure 135: The impetus for vegetated assemblies in my design work with a studiomate began in 2006 with the Deck and planter project for a competition.

These next images also show the development of watercolor and the study of color theory in different manners. Figure 136 is an initial study of depth and superposition to create depth within a flat surface. It studies complementary colors as well in a different manner from Figure 137. Figure 136 uses the colors to make and abstract composition while figure 137 uses the mixing of complementary color to provide depth in a drawing of

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poplar leaves. Figure 138 is a false color study of Frank Lloyd Wright using a

pixelization method of using 2.5 inch square pieces of watercolor wash to make an

image.
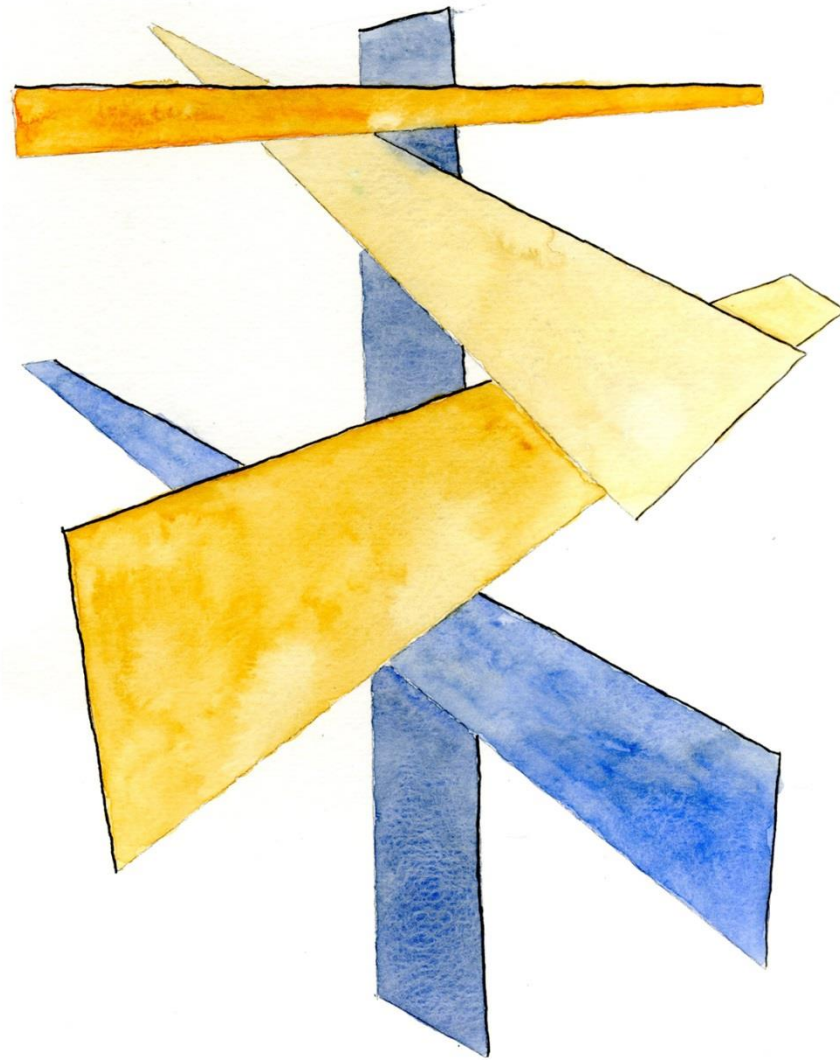
Figure 136: A watercolor in orange, blue and its mixes to study depth and void used to study color theory
for its use in the decision support system.

Figure 137: A watercolor study of a set of poplar leaves. This studied different mixing and color wash techniques as compared to figure 136 on color theory for its use in the decision support system for the dissertation.

Figure 138: Two different false color studies, a computer-made ideal version to the left side and its black and white image to show depth, and the physically made composition to the right with its black and white image. It is important because this makes the designer think about the relative nature of colors. The left two are the ideal images, made only with colors that exactly matched the value (amount of black) in the original image. The right two reflect the realistic setting, where the tiles available could not be duplicated as needed. This difference teaches the eye to see relative differences in depth, eliminating the false color of the initial images, reading the underlying depth. It also teaches the designer how to create an image with intensive limits placed on the products available.

These next few images (figures 139-141) are examples of the full scale components of the immersive case studies near Blacksburg Virginia (see figures 65-73, 110-122 for information on the case studies). Figure 139 is Turtletown which used the framework as a paper appendix to study the relation of ideation, in this case a shading

system and turtle enclosure programmatic elements were added to the vegetated

assemblies and color theory of the framework. Figure 140 is the Solar Lounge at the

Research and Demonstration Facility (RDF), which served as an example of how ideas

from students can move beyond the classroom and develop into a longer line of inquiry.

Two students, one from the ARCH 2015 studio course I assisted with and one from the

Metaphysical Room studio-like course developed the idea and we adapted it based on the

funding that was secured from the College of Architecture and Urban Studies at Virginia

Tech. Figure 141 is the Solar Garage at RDF. It is the largest and most involved case

study in the dissertation serving as an example of reclaimed materials and repeating bay

construction with shipping pallets. This project will be used as a garage for charging an

electric car for the Electrical and Computer Engineering Department at Virginia Tech.

Figure 1639: Turtletown, one of the case studies for the dissertation, was developed to test the initial developed framework.

Figure 140: The Solar Lounge case study was developed to test assemblies to be used in the Solar Garage as well as provide students with full scale experience.

Figure 141: An opportunity arose with funding and reclaimed materials and repeating bay construction. Thus, the Solar Garage was developed to provide a space for the electric car owned by the ECE department at Virginia Tech.

About how you use frameworks:

How will the framework change or influence the process of design?

What happens when a designer becomes the expert over time?

The framework presented here is only the beginning of a longer line of frameworks related to the use and design of vegetated assemblies. The original paper appendices were updated to a website application to better serve students and potentially the world. It serves as a way to support design processes and decision making. The hope is that it can inspire you to either use vegetated assemblies or color theory in future work. If neither of these interest you, then perhaps, it serves as a way to shake up your standard method of designing to see if some new, interesting ideas were right next to you the whole time. If you find information in the framework you do not agree with, do not simply ignore it. These are your designs, but the more you consider from the framework the more complete your designs will be in relation to vegetated assemblies and color theory.

At some point after using the framework for a while you get used to it and begin to specialize enough to be considered an expert. At this time it becomes a resource to turn to for confirmation and to share with others. I find that it does not matter if I know the information alone, but it means everything if I have been able to share my experiences with others to help them develop as designers as well. Nothing says that you cannot update the framework with your own experiences or begin to think of your own topics to include. This is the power of a framework: to adapt and evolve as needed throughout a line of inquiry or as each individual design demands.

About studio and its relation to other learning environments:

What is it about the studio environment that helps to explore ideas?

How does studio help to teach us about the world around us?

Why and how do critiques and discussion of design foster the creative method?

When does the student or professional become a teacher or mentor for others?

How does this transition help to understand studio and transformative education?

The traditional studio environment allows for two things: time and space. These in turn allow for systematic exploration into a line of inquiry. The framework serves to support this goal of introducing new ideas or topics that can inform these lines of inquiry into the profession. I have found, through assisting to teach studio, that I explore and learn so that I may begin to know and at some point understand.

Studio is not something that you experience in isolation. This means that the first time a student shows another a diagram, a drawing, a picture of an interesting building they are teaching and learning from each other under the guidance of one another in studio. From a single prompt (which can be written in almost an infinite number of ways) we can find precedents in places all over the world, experiences written and told to us by others from all walks of life. Studio provides the opportunity to learn from others and incorporate new ideas into our own works. Often I have heard that "an amateur copies, an architect steals". This means that experienced designers, such as an architect, can see an idea, adapt it to what they need, and make it their own. Amateurs will see something they like and copy it without thought.

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However, as a future educator I need to be able to filter the information that I know and what students come to me with. It will become vital to develop future designers, not just copies of myself. I prompt my students, both literally with a prompt, but also by giving them information that will allow them to explore with giving answers. What is important to understand is that while I might be more experienced, I learn every day with my students. This is called co-learning and studio has this unique method of traditionally fostering problem-based learning in the form of design projects which are valued in contemporary educational practices and transformative education. These in turn, hopefully develop intrinsically motivated students who begin to engage a line of inquiry, whether or not it is related to the framework. However, the framework has been developed to be used in conjunction with these goals as a reference for students who wish to go above and beyond typically performed inquiry into vegetated assemblies.

Final Comments for the work

The professor in direct contact with students has the most control over the information presented and comprehended. This means that the professor becomes a node and filtering agent for the students, especially in design where the mentoring aspect is heavily relied upon in the traditional studio environment. The framework serves as a knowledge sharing method in the temporary absence of this mentoring professor.

The questionnaires and immersive case studies tested and updated the framework with different revisions ranging from the inclusion of more detailed topics to the inclusion of a summary of the entire typical design process. The students and advisors who participated in the research and provided critical feedback have my greatest thanks.

Time and time again the mindset of being open to suggestions and to merge and fuse ideas strengthened the framework. Projects such as the Solar Garage, Solar Lounge, Turtletown, and the independent study mainly on renovations to the Solar house that might become to be names the "Solar House Deck" were founded in ideas tangential to the framework and vegetated assemblies. Then the lessons learned were returned to the framework to improve its decision support capability.

Overall, the framework indeed improves decision making and supports the exposure of students to new ideas that they can include in future designs. Since students have access to more information, decision making is improved. What is central to the framework is that while decision making is improved and supported, it leaves the final decision to the designer. This separates it from a decision making tool which takes the decision out of the hands of the designer. If we allow technology to make decisions as a black box with neither our input nor potentially even our review, then why do we design at all?

This framework using vegetated assemblies as they relate to color theory begins to show a method for how designers can 'see' a mental process or design process and utilize it for their benefit should a mentor not be present. I believe that these frameworks hold vast potential to teach others the relationships between topics and then be able to integrate them into design processes. Further it is not only the information contained within that holds this potential, but simultaneously the process the decision support system has to develop future work and ideas generated from seemingly unrelated topics as a knowledge-sharing device.

As a future educator I serve those who desire to learn. With this is mind, continued inquiry serves as the foundation for the pattern language for vegetated assemblies. The framework is a scaffold to think about design and is as much a process for myself as it can be for others. If I personally do not believe in the process devised, then how can I expect others to be moved in a way to try and learn from it as well? This interaction happens in the studio and that environment is where the pattern language for vegetated assemblies will be most useful and best developed. A possible long-term plan for developing this language in frameworks serves as the continuation of the dissertation.

The framework has the potential to serve as a process for integrating interests and ideas as I, and others, move through our design processes as a perceived continuum. As I move through different topics and questions as they relate to vegetated assemblies and color, a pattern language can emerge over the course of many years for vegetated assemblies. This also raises the question of, decision support and technology-supported generation of frameworks using Business Process Modeling Notation such as the development of framework using voice interpretation or other applications such as Google's .io feature in its Drive platform.

This serves enhanced ideation as there is less time spent finding information from a wide variety of sources, allowing designers to work faster. This also allows for new, or other views, of overlapping disciplines and design, for example biomimicry or bio-generated design.

The framework also has a place in new classroom and learning models such as the inverted classroom where students learn at home and then apply, do, and discuss in the class itself. With the frameworks students would be able to use the framework as it is, or

to apply new information to the underlying scaffold and continue to improve upon its decision-support ability. Should the framework continue digital development, it could become interactive in more depth than what the current website application can accommodate.

This process of information gathering and methodological or pedagogical application extends the boundaries for how topics are presented to architecture students such as topics in engineering, biology, chemistry, math, and many more. The list is extensive, only limited by the time and resources to analyze and adapt information for others.

This process of discovering topics has lead me to be interested in adapting other dissertations to the framework concept making summarized 'reader's digest' versions of dissertations including a framework-adapted process of the information as I am able to interpret it. For now these dissertation could be from topics related to architecture, but in time could branch out into other subjects that tie into vegetated assemblies and color theory.

This fount of information could then influence how the Master's or Doctoral program develops, or at least how it had developed up to the point of my presence at the school. It could also review the method of advising and the resulting methods of thesis and doctoral works over time. This process could then attempt to understand the trajectory of the school as compared to other institutions or even inform it.

Finally, it ought to be enthusiasm and drive that leads design to its next iteration, its next work. When students begin to own their work they begin to take pride in the act of designing, and this difference is readily apparent in the works proposed and reviewed

in the papers, in the exercises, in the immersive case studies. Students have to want it, desire an outcome, for design to have meaning. The framework introduces them to this possibility; it introduces the beginning of a line of thought. Design is amorphous in scope. With a nearly limitless number of facts and considerations, design needs educators to synthesize situations, processes, and technical information to help students. This synthesis is not inherent in someone, it is found in experience. What can be considered genius is built from experience, its ideas, iterating upon them and representing such designs and personal interests. Success then is not an accident, and good luck is not providence. Rather these two things are created by habits and thoughts which combine with prior planning to generate ideas and action. These ideas are not reproductions of other objects in our world, but are instead our interpretation and interaction with our world as it is applied to our design process and skill. I find there is nothing better than the spark and enthusiasm students show when they begin to enjoy the discipline that will become their life's work.

7.2 Continuation: Ten Years in, Ten Years out

The first time I set foot in an architecture office was in the summer of 2006. It was in late May. I remember it being humid and hot as always and the office air immediately condensed on my glasses. I was taken on a tour of the office and a few weeks later I was working with a mentor and had my first set of red lines and began learning how to use AutoCAD 2004. I worked with a project involving a mechanical high bay for tanks. The program I was in with my high school needed three essays on concepts that you had worked on in your summer mentorship. I chose to review code in fire safety, ADA accessibility, and computer aided design.

My world was filled with fire dampers, type 4 construction and a whole host of where grab bars and wheelchair dimensions and accessibility placards were located and designed. I got so specific that my first drawing was an elevation of a fire extinguisher casement. My second drawing was even more mundane: the total design of a trash can for a sub sandwich chain restaurant that is now defunct.

If you had asked me what I thought I would be doing 10 years from 2006, my answer would have been that I got my degree from most likely Virginia Tech in Architecture and then went back to continue working to achieve my licensure with that firm. As you can see from this dissertation, life has a way of making its own plans. I believe that I will be teaching for some university in the United States. I have no intention of permanently being overseas in a teaching or research position. The longer version revolves around further developing a series of frameworks and using the adjacent possible to discover more engaging intersections of vegetated assemblies and other topics.

It will be fascinating to see where the intersection of frameworks for vegetated assemblies and light and daylighting at full-scale takes me. I have followed the typology of the Solar Decathlon House for a while and working with one has been a goal for the last 5 years, though I do not think I ever will, only that I am inspired by it. This type of home also translates to small or high efficiency dwellings, not only for environmentally conscious design, but also spatially. The implication of one room serving two or even three functions for those in need serves to drive this micro-housing method.

My desire is to continuously and conscientiously bring what I learn in my research and tie it back to studio. I have worked to integrate research and teaching into the studio. I am currently looking at how the function of research might pertain to the foundation studio courses and to relearn what it means to be truly introduced to a new and vibrant way of thinking. I wish to share what I have learned in the best way possible for each student. I have worked with different studio levels ranging from second year to fifth year thesis and documentation and now have the opportunity to work more closely with the foundation year. This branches out from studio laboratories to gaining more experience with independent studies, special studies courses, studio-like courses and traditional classroom environments. This shows my intent to teach at both the undergraduate and graduate levels. I believe that both have something to offer the other.

This new avenue of research is currently being performed in the redesign and development of the Masters of Science program that I experienced to be quite interesting. Perhaps curriculum design or other aspects of applying or advising students in their own work would be appealing. This is due to the fact I have found the Environmental Design Research course that I had the opportunity to teach to be particularly insightful because I

learned the different topics that everyone in the Master of Science and Doctoral programs associated with the design school are doing. This exposure to new ideas and others' interests is engaging to both me (since I enjoy new things) and the students (because it is their interest).

From color I have realized light and its qualities have much to offer as light is the progenitor of color. I have worked with daylighting in the Solar Garage, one of the case studies for the dissertation, and realized that a focus or specialization in daylighting would be enjoyable. When low vision and daylighting as a specialty was suggested, it showed me again that the adjacent ideas and topics are always present and lead to a more complete line of inquiry into design. The next step is to see if or should vegetated assemblies or color have any role to play in these new areas and how this might be in species other than vines to expand the list of plants found locally in Blacksburg (figure 142) in the decision support system outside of only vining plants as well as color over times of the year in other species such as various sedums (figure 143).

Figure 142: Different collected and pressed leaves from around Blacksburg, Virginia. The intent is to develop a repertoire of color that would remind us of Blacksburg, and perhaps of home.

Figure 143: Images of the green roof modules at the Research and Demonstration Facility. From the upper left to lower right are the colors of the roof in: January, February, June, and October over the course of the year. These images show how quickly color can change especially between January and February from a deep maroon to a brighter red. Each species then had a different time to become green, with most done in October (photos by Elizabeth Grant).

These images show us that plant selection for an assembly does have an annual cycle. This is mentioned in the developed decision support system, however now the design is augmented to understand how ought or should we use the dynamics of temporal color in vegetated assemblies. This aspect of time, rather than one ideal condition (often green) for vegetated assemblies, is something that will be a focus of implementing vegetated assemblies on the developed case studies. For example in one of the sketches

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for the Solar Garage, we find an ideal condition in the section, using what most resembles

summer grapes (figure 144).
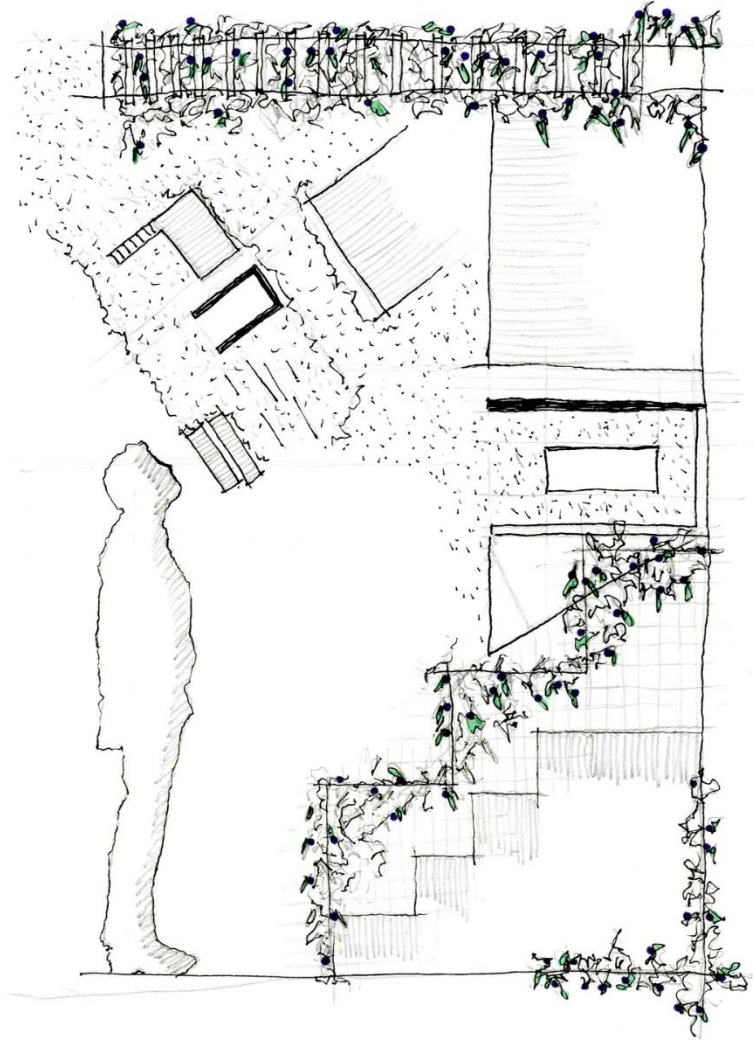
Figure 144: This sketch shows a possible plant selection for the vegetated bay of the solar garage case study to be implemented in future study. At the time the thought was to use summer grapes that could then be a source of food for birds in the area.

This method of representing a vegetated assembly is fairly consistent across hand-drawn

version of working out the Solar Garage, as shown in figure 145, another sketch,

reviewing where vegetated assemblies should be, and how they might interact with current constructed assemblies.
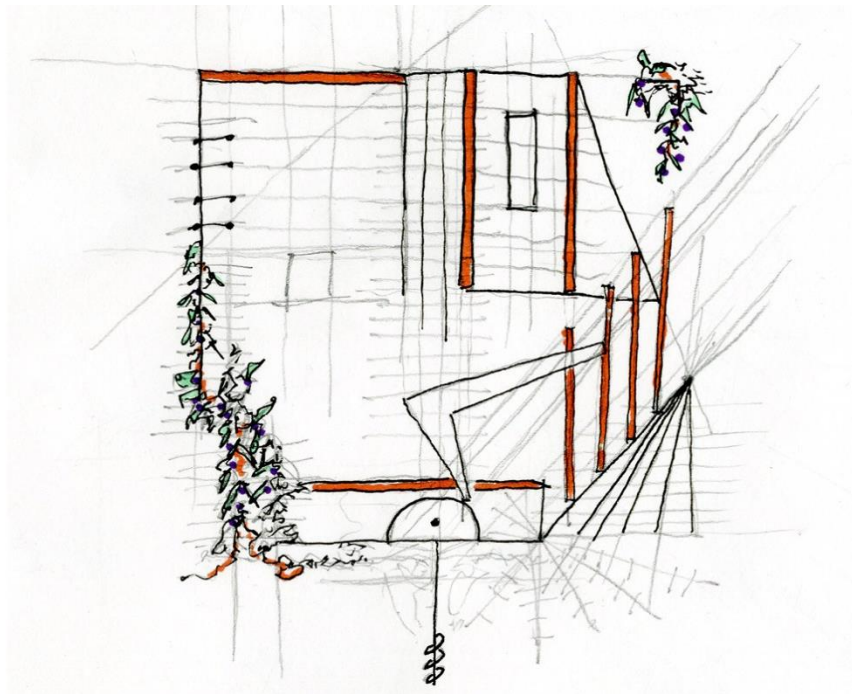
Figure 145: The process of working out a possible vegetated assembly in the constructed wall assembly of the Solar Garage. This process of representing a vegetated assembly as a matrix-based vegetated system was a common thread of the project, visualized as a species of summer grape.

While the summer grape was selected as a species that appeared most similar to the representations in the initial sketches of the Solar Garage, more work is needed to see how the grape would interact with the structure, how it would develop in non-ideal soil, and what matrix would be best for its twining vines and be able to support an ever increasing amount of plant matter on the assembly. This is currently being developed in the other case study called the Solar Lounge. Systems have been installed and in time plants will be tested. However, this wall is north facing, and depending on the requirements of a summer grape, more assemblies will be added to the southern side of the wall. This process of the Solar Garage and the selected summer grape shows how a

plant might be selected for the aesthetic or representational character and color first, and then used in appropriate areas of a project.

However, many projects do not have this luxury, and need to select a plant based on its biological characteristics. Considering the northern wall of the Solar Lounge where students will sit, a plant that can flourish in shade or semi-shade is needed. The list on the developed website (livingwalldesigner-prototype.org) in the useful species list, multiple plants could be used. The one that was selected was a hydrangea (see figure 146 provided by Dr. Niemiera). A Hydrangea was selected as it has a variety of color, and grow in semi-shaded conditions.
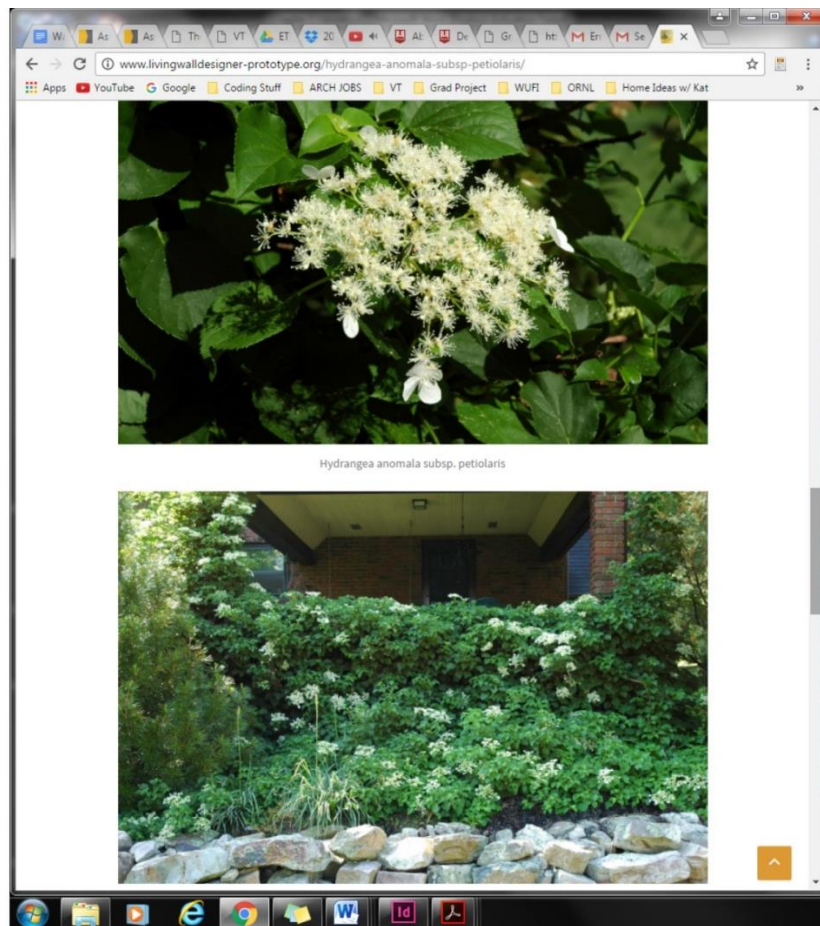
Figure 146: Image of a Hydrangea from the developed website application (image credit Dr. Niemiera), specifically *Hydrangea anomala* subsp. petiolaris. This Vining Plant was selected for the north side of the Solar Garage as it grows well in semi-shade.

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Though most of my work has been with full-scale construction of case studies, I have begun working with daylighting simulation to see how my built projects compare to their simulated counterparts. This process can teach me more about the simulation programs and begin to understand not only how to use the program, but bend it to begin designing spaces as I wish to see them: closer to that of the physical realm. This line of inquiry should and will require partnerships with companies and across the university faculty that are interested in the use simulation or full-scale design (or other discovered adjacent topics), not only quantitatively but also qualitatively, to assist in understanding questions and needs important to them. Homeless or housing building co-operatives might be interested in the work of the frameworks with the development of high-efficiency tiny homes. Waste management groups and other companies with consistent useful waste would be interested in seeing recycled materials being used for unique ideas and renewable systems. Low-vision groups would be interested in the development of simulation techniques to study spaces with daylighting to see how dynamic lighting conditions would affect vision in a space.

Focus areas such as these (color theory, vegetated assemblies, and micro-housing) or others could form different research areas in lab groups centered on decision support. These groups would be formed with 3-6 doctoral students and associated masters students centered on the topics and funded by interested parties involved with each group. Doctoral students would work on one of the main topical areas of the frameworks that are being developed in an aspect of design, for example low-vision or light, small house design, or reclaimed materials. The Master of Science students would work on broader topic to find what interests them specifically with most transitioning into the PhD after 2

years. A masters and doctoral student would be working together, most often in pairs, as part of a mentoring process. This would generate peer mentoring between the two levels. The Masters of Science students would be finding and developing their topic of inquiry while the doctoral students are implementing theirs. This would allow the masters students to watch the doctoral students in action and each learns from the other. Further these students would have a particular intent to their degrees: either teaching, research, consulting, or the profession.

An example of this pairing would be the students, who we will call Rachel and Kevin, working with simulated daylighting and Virginia Homeless Solutions Program (VHSP). VHSP has the desire to end or at least shorten and reduce those in homelessness in Virginia. Rachel is interested in daylighting simulation as a function of small house design with the intent to teach in the future after doing her masters and doctoral studies in the accelerated program. Kevin is interested in the development of more circular waste streams to take waste and transform it into viable components in construction and design with the intent to start a small firm. He was licensed before coming back for a doctoral degree after receiving a M. Arch degree. They work together to design a beautiful, small, movable home to meet VHSP's mission.

Working within the partnership, the two students act on different research interests and intents but work together to develop a line of inquiry related to the larger research area that the lab group has related to small home design and renewable systems. The larger topic tying all of the work together is daylighting and simulation, perhaps with Rachel's interest to simulate potential prototypes and then design a program to center her work around in her future university position. This simulation then informs Kevin's work

to full-scale prototype a small home for the partnership that could become a connection for him in his future firm's work.

They both have set their own research agendas within the larger focus area, and their work informs the development of frameworks to build a repertoire of related topics in relation to my core area of vegetated assemblies. These frameworks would then be made available to students in undergraduate studies to influence their work and introduce them to other topics further influencing the profession.

All of these topics are then related back to the mindset of how phenomenology allows us to perceive the world around us and would be present in our methodology together. Immersive case studies and other interpretive tactics would inform their view of the topics and subsequently their place in the profession, teaching and world.

Having such a large and developed lab has to start somewhere. The dissertation reveals that both the topics and the mechanics and methodology of how to do such a dissertation and for how future advising of research could be handled are equally important. These are critical as they try to give a method for the advancement of science. Future research will see how decision support systems as well as the methods used in the dissertation contribute to the themes and concepts of the advancement of science starting by further considering the works of Thomas Kuhn, Karl Popper, Imre Lakatos and Edmund Husserl.

In summary, the decision support system developed by the dissertation improves decision making while leaving the final decisions to the designer. This difference of leaving the final decision to the designer separates it from a decision-making tool. Decision support such as this developed framework on vegetated assemblies and color

theory can teach others the relationships between different topics and how to integrate them. It is not only the information that is in the decision support system, but also the process of the system itself that can be a knowledge sharing device in the absence of a mentoring teacher.

From this decision support system, other topics could be included in the future, such as daylighting or low-vision. Due to this possibility, the developed website application serves as a living document and as the basis for a more developed decision making tool in the future. Decision support also has potential in the classroom, specifically in the inverted classroom model, in many subjects where information can be introduced outside of class and then applied during scheduled class time as an interactive method. This method of teaching therefore also has implications for the designed space itself as pedagogy evolves using experimentation.

Further, with different topics being introduced to decisions support, a method of "Reader's Digest" versions of my own and other works can distill critical process and influence background knowledge for use in the student's design processes. These interesting topics can then be made into their own decision support systems in the future as well.

Considering the development of classroom methods, we can expand to program pedagogy for the development of specialized topical courses, develop focus areas for programs such as decision support, and then use this as a common thread through a line of study. These methods for ordering and guiding a dissertation can be used in the future as well.

It is in this mindset of methodology where the dissertation and its process contribute greatly to the body of knowledge as a proof of concept. The dissertation includes classroom pedagogy, interpretation, diagrammatic decision-support, immersive case studies, and publication and combines them to discover, development, and demonstrate the potential of the developed decision-support system. The inverted classroom is also useful outside of only architecture as a teaching model and as a way of engagement in the future. Interpretation, in a subjective discipline, is a vital skill to understand a critique a work especially if the intent is to then teach as a profession. Further the methods used show that work can be interpreted and be a vital part of developing a new process or system. This also demonstrates that the use of design exercise as a common model for producing such works is beneficial. Diagramming is already a core part of design, and should be used to distill elements of chapters to an image and order and organize thought and decision making. In this vein, the use of the immersive case studies to test and understand a process should not be underestimated and brings new clarity to a potential process or system, being adaptable to the qualitative design process. Immersive case studies allow researchers and others to learn by doing, rather than speculation. Using publication as a method of verification, the dissertation is conducted to contribute to the body of knowledge and through publication this knowledge is verified and then disseminated to a wider audience.

Finally, as in design, the process of how the product was developed is as important as the thing that was made. A strong process, a strong methodology, often results in a clear result. The result of this dissertation from its method is to provide

knowledge sharing through engaged pedagogy and decision support, which allows for

more informed decisions by students of architecture.

Backmatter

8.1 Appendix

Overview:

The thing in itself often does not show the time and effort needed in developing the object. The concept behind the framework and examples of students using the framework gives it meaning. The words, circles, and boxes on the page have a purpose: to give designers the information that will help aid in their decision making. If nothing else it is important to recognize that this framework is a decision support system, a way to frame the project, the work that a person designs. It supports, but it does not make a decision for you.

Introduction to using the Framework

This support comes from experience and observation, things that we can build upon for the rest of our lives, and still have perspectives that elude us, or senses that deceive us. Because I am only one person, feel free to change or augment the framework as you wish the one here is a general framework to help you get started and, over time as experience builds, there is the opportunity to fine tune it to your personal design method. The appendix below is the way I have used the framework, however it is not strictly only done this way. Though I have found this to be helpful in my design process, each of the topics can be reviewed at any time, not solely in the manner presented in the matrix, appendix A.

The framework in its entirety is presented here with short descriptions of each page. There is also more information online at livingwalldesigner-prototype.org, specifically more examples of work. The framework here starts off more general and

becomes more specific as it dives into topics. The last part is a summary of the design process to help those who are new to an iterative design method. This portion asks the reader questions to think more broadly about design and representation, specifically from an architectural perspective.

There are two main types of pages, overarching themes (A1-A6) such as plant biology, color theory, or design tactics, which will direct your process to different subtopics (A7-A23) within each. Each of these has a similar format with similar information in consistent areas of the page. Each of the pages has a short description aimed at how I use each page during my design process as a starting point for you. There is also a series of pages for design methods in studio, appendices AA-AN. Design is an open-ended adventure. There is not one correct answer to a design situation and that is what makes it so invaluable. For every designer there is a different proposal to a given task. Finally, it is important to remember that when you design it is supposed to be fun, and enjoyable. You give meaning to your work. The framework is written in BPMN which is business process modeling notation. This makes the framework look similar to a flow chart. This does not mean that to design you must do every step and every topic to have a complete design; it is a reference. Major topics are explained in more detail in following pages. For example in Color Theory (appendix A3) there are hue, saturation, value, and graphics (A7-A11). As the designer you have the choice of using color theory in your design. In appendix AA, there is an example of how the other overarching appendices fit into the decision support system. The example shows each of the appendices would be used, suggests when each might have information for a particular step and how this uses the iterative design process commonly found in studio.

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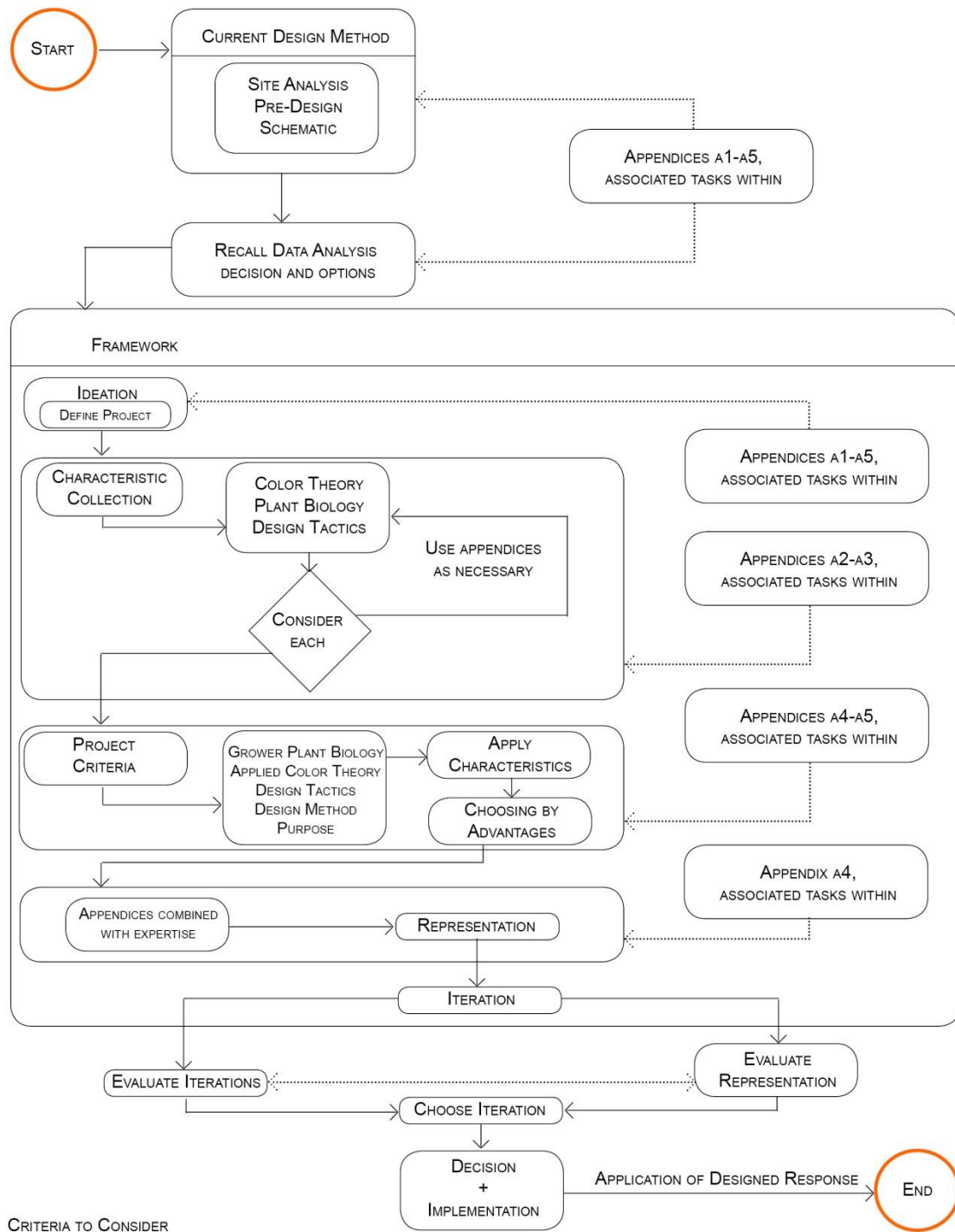
Appendix AA: is an example of how the other overarching appendices fit into the decision support system. The example shows where each of the appendices would be used, suggests when each might have information for a particular step and how this uses the iterative design process commonly found in studio.

Appendix A0-A6 are topical overviews of the overarching topics. Appendix A7 - A23 serve as introductory information to each of the subtopics for instance, hue. They are a reference for projects, but the final decisions are left to you, the designer. After each, go back to the main topics A1-A6 to find other information. Appendices AB-AN review and introduce the iterative design process for new designers. These appendices are an introduction to the design process and much of the information revolves around architecture, but there are later appendices that are about design in general and design representation of drawings both analog and digital.

The point of the framework is to serve as an introduction to these topics and also to assist those who have not seen or used a design process before. For this reason it is a reference to design and a decision support system. However it neither replaces the experience of the designer nor the teacher.

For those who have previous design experience, remember that the framework is designed to be a support mechanism not a decision-making tool. This means that the framework should influence the information that you are working with, but not overhaul the inherent personal design process. This information ought to be able to help you make a more informed decision, where improved decision making is the result of more information.

Examples of using the process are found later in the dissertation in the form of different immersive case studies (figures 65-73, 110-122). These move through using the framework as a visual example paired with written notation. Turtletown was a single project, while the RDF Wall has multiple examples of the same project by different designers.

This is important to understand. The framework is not a single step-by-step process, but a series of iterative loops that can be used to improve designs. As designers, the freedom to iterate and achieve different results from our peers is the basis for the profession. As with most reference materials, the framework can be simply ignored or used in a minimal way. The point of the framework is to inform the individual of the possibilities that color theory and vegetated assemblies have, and then provide the information to allow the designer to make informed decisions.

Think of the framework as choosing your own adventure in design. If you are interested in a particular topic turn to that page, if not, then find a topic that does interest you.

Appendix A0: This is a visual overview of the framework and where much of the beginning information can be found in following appendices. Pages that are A# (letter, number) are focusing in vegetated assemblies and color theory, while pages AA (letter, letter) focus on the more general design process. I use this page to get my bearings by collecting information for the site analysis and pre-design for the current project and then determine characteristics that will be the most important to me and then guide decisions for other areas of interest. For example, one project might be focused on color theory, and plant biology is picked based on desired color compositions.
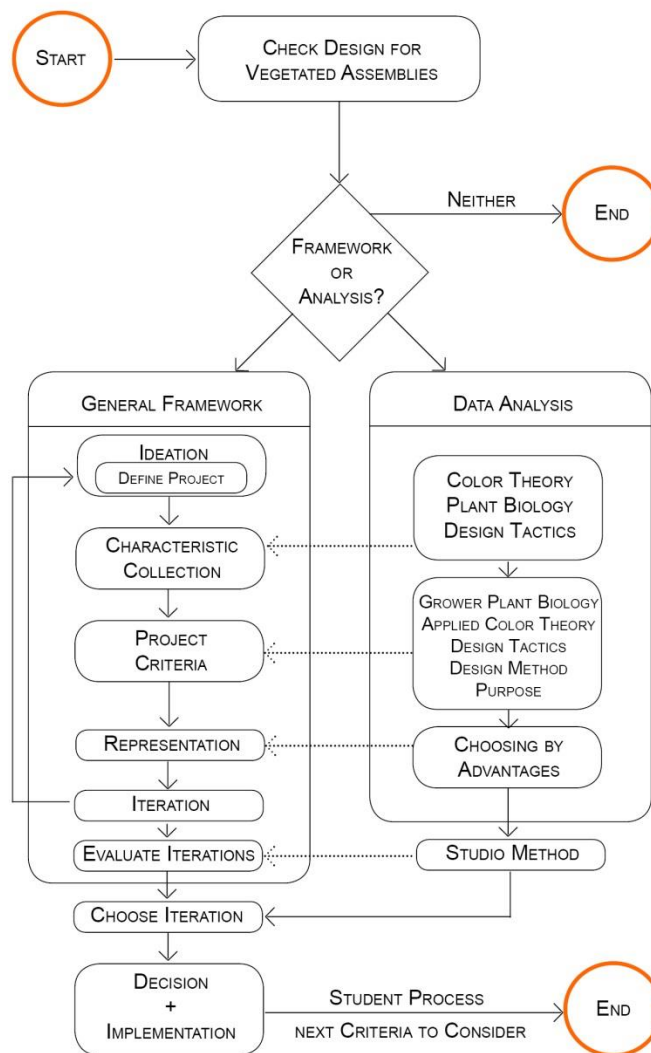
Appendix A1: This serves as a condensed version of the entire framework. It allows you to see the concurrent or simultaneous process that the framework uses. Information found in the data analysis portion is then used in the general framework. These representations of the projects then inform what sort of new data or information is needed to complete more refined iterations. This serves as a place to start. I use this to remind myself of what this project needs and how to begin. For example, if there is another major topic other than color theory and plant biology, this is where it gets written in and then information is collected to make informed design decisions.
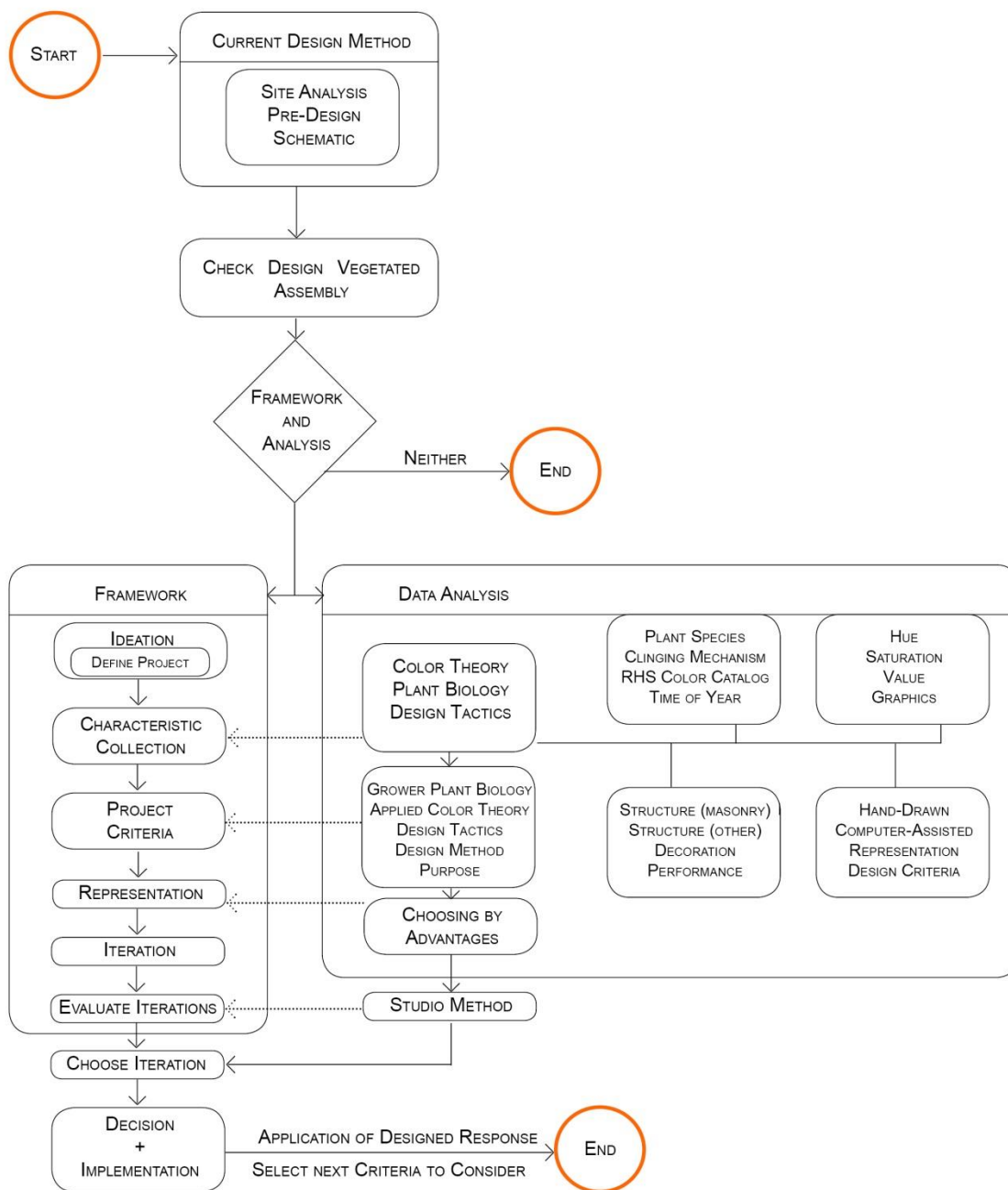
Appendix A2: This is the expanded version of the framework, showing the considerations that go into the main topics of Color Theory, plant biology and design tactics. Each of these considerations then has its own appendix of information that further explains its relevance to the topic and needed information. I typically use this expanded framework to choose which of the consideration of subtopics to bring to the forefront for a particular design. Sometimes it might be the desire to work with a particular species of plant, or its flower color based on a desired color scheme. Perhaps a particular structure is available and that informs what species to use based on applicability of its climbing mechanism.
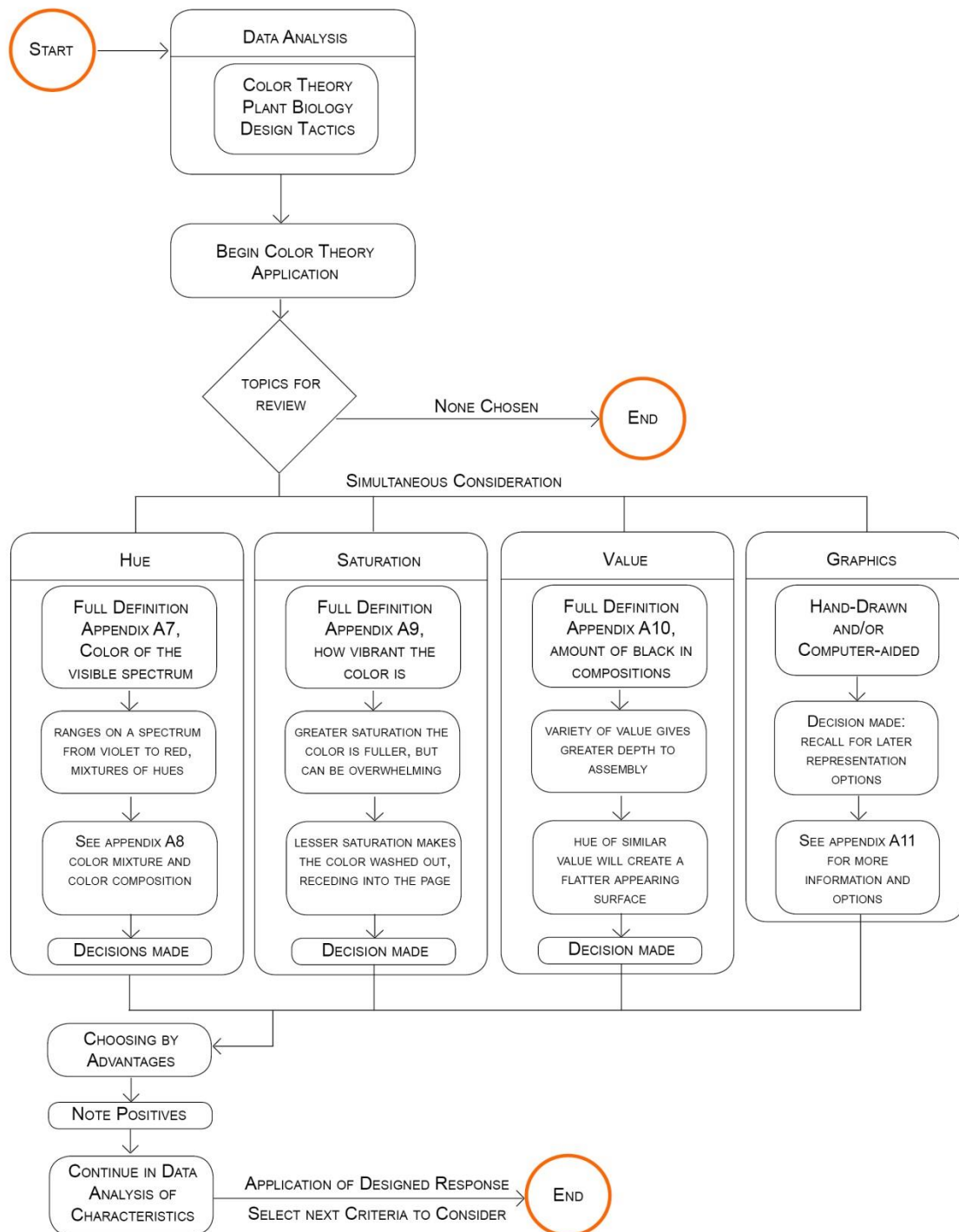
Appendix A3: This shows the considerations into color theory. I use this to organize my thoughts and use each to inform the other. For example different graphic methods can mean a change in how colors are read, the expression of the hue and its value found in A11.

```
   ┌─────────┐        ┌──────────────────────────┐
   │  START  │───────▶│      DATA ANALYSIS       │
   └─────────┘        │  ┌────────────────────┐  │
                      │  │   COLOR THEORY     │  │
                      │  │   PLANT BIOLOGY    │  │
                      │  │   DESIGN TACTICS   │  │
                      │  └────────────────────┘  │
                      └──────────────────────────┘
                                   │
                                   ▼
                      ┌──────────────────────────┐
                      │   BEGIN PLANT BIOLOGY    │
                      │       APPLICATION        │
                      └──────────────────────────┘
                                   │
                                   ▼
                              ◇ TOPICS FOR ◇     NONE CHOSEN    ┌─────┐
                              ◇  REVIEW   ◇ ─────────────────▶ │ END │
                              ◇          ◇                     └─────┘
                                   │
                         SIMULTANEOUS CONSIDERATION
```

PLANT SPECIES	CLIMBING MECHANISM	ROYAL HORTICULTURE SOCIETY	TIME OF YEAR
FULL DEFINITION APPENDIX A12 GROWER AVAILABLE VINES IN AREA	FULL DEFINITION APPENDIX A14, ATTACHMENT TO DESIGNED RESPONSE	FULL DEFINITION APPENDIX A15 COLOR MATCHING FOR PLANT SPECIES	SPRING, SUMMER, FALL, WINTER,
NATIVE VS NON-NATIVE CONSIDERATIONS SEE APPENDIX A13	CERTAIN MECHANISMS ARE BETTER FOR CERTAIN DESIGNED STRUCTURES	REFERENCE TEXT FOR IDENTIFYING COLOR OF PLANTS IN THE FIELD	DO NOT DESIGN FOR ONLY IDEAL, BUT COMPOSITION OVER THE YEAR
STEWARDSHIP OF THE SITE AND LIMIT HARMFULLY INVASIVE PLANT SPECIES	CERTAIN CLIMBING MECHANISMS CAN CAUSE DAMAGE TO THE STRUCTURE, OR WILL NOT GROW ON STRUCTURE	RHS COLOR CHART FOUND ONLINE AT WWW.RHSSHOP.CO.UK/ CATEGORY.ASPX?ID=10000006	RESEARCH DIAGRAM OF PLANT COLOR OVER ANNUAL CYCLES
DECISIONS MADE	DECISION MADE	CONSIDERED	REINTRODUCE INTO DECISION STREAM

```
   ┌──────────────┐
   │  CHOOSING BY │◀──────
   │  ADVANTAGES  │
   └──────────────┘
          │
          ▼
   ┌──────────────┐
   │ NOTE POSITIVES│
   └──────────────┘
          │
          ▼
   ┌──────────────┐  APPLICATION OF DESIGNED RESPONSE   ┌─────┐
   │ CONTINUE IN  │─────────────────────────────────────│ END │
   │  DATA        │  SELECT NEXT CRITERIA TO CONSIDER    └─────┘
   │ ANALYSIS OF  │
   │CHARACTERISTICS│
   └──────────────┘
```

Appendix A4: This shows the considerations into plant biology. I typically start with plant species and climbing mechanism simultaneously as this will inform structure, its blooms, and color. The choices here will influence other topics.
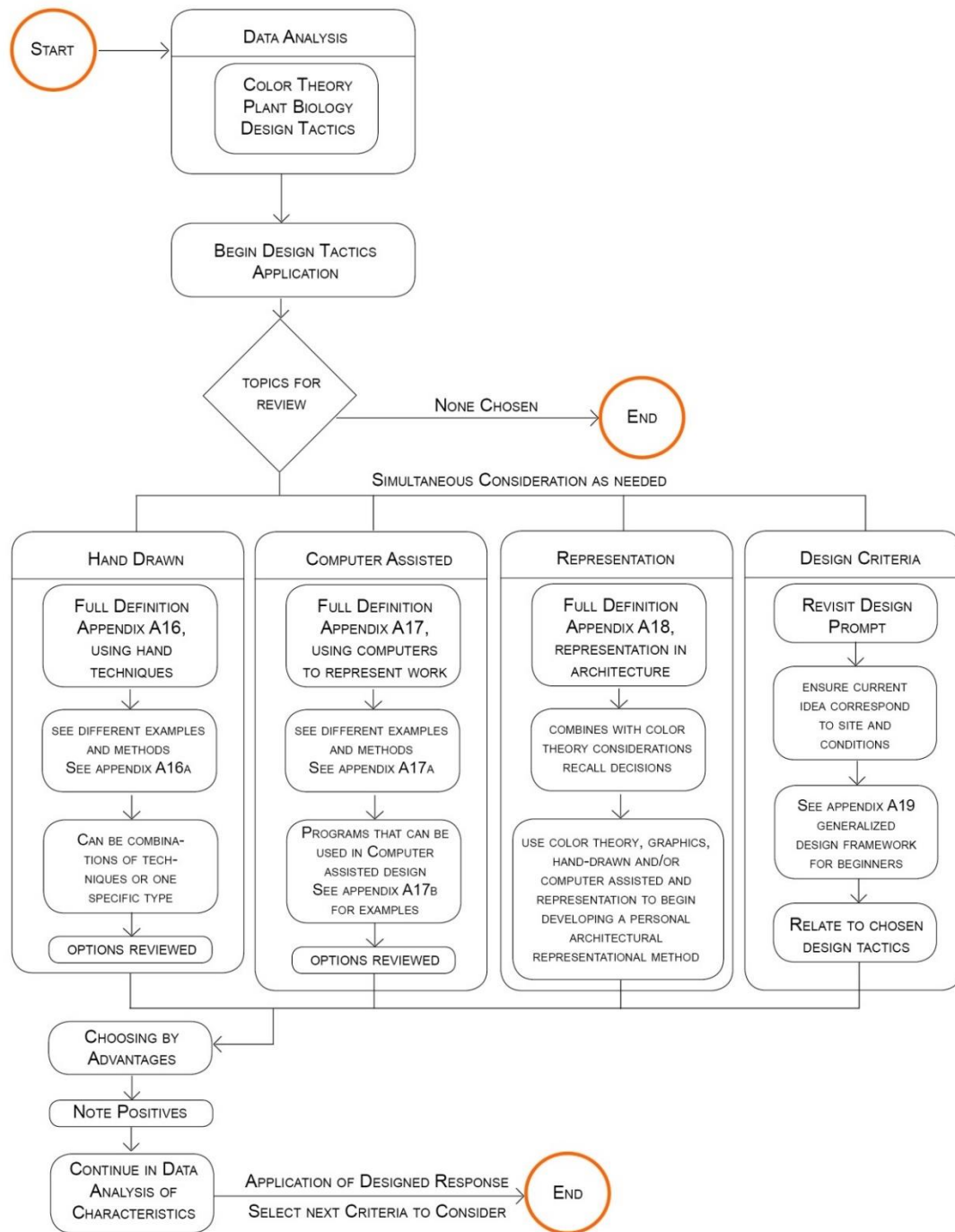
Appendix A5: This shows the considerations for design tactics which can be based on what method or mixed methods of representation used. I typically used mixed methods, taking advantage of the positives in both. Depending on access or skill one or the other will be more useful. Note that young designers should often push themselves to use different media as the project demands, even when they don't have fully-developed skills yet.
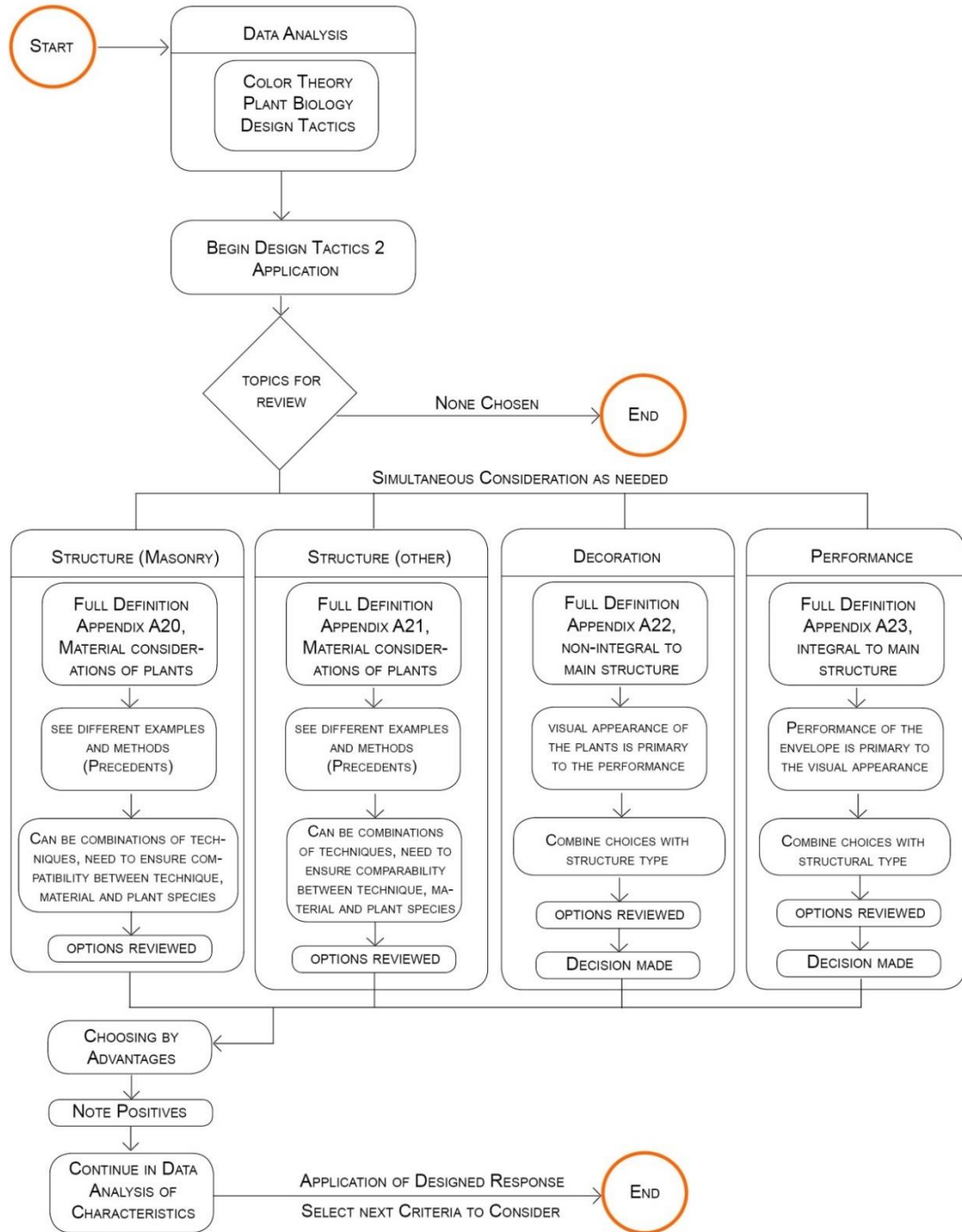
Appendix A6: This shows project considerations of the representations and characteristics of materials. For example, it is important to know the substrate the plants are on and what the intent of the project is in reference to its performance, decoration, or their integration. The best designs usually integrate the two in a beautiful manner.

START

DECISION FACTOR

CHOOSE HUES THAT
WILL BE COMPARED
WITHIN PLANTS

CHECK DESIGN VEGETATED
ASSEMBLY   LIST OF CONSIDERATIONS

FRAMEWORK
AND
ANALYSIS

NO PLANT   END

RELATIONS TO COLOR THEORY

CONSIDER THE CLASSIFICATION OF COLOR:
PRIMARY, SECONDARY AND TERTIARY
AND HOW THIS CAN CREATE SCHEMES IN THE DESIGN

SHOW THE HUES IN YOUR WORK
IMPLEMENT EFFECTS OF COLORS IN THE DESIGN: THE ABILITY FOR COLOR
TO CREATE SPACE AND CONTRAST WITH A BACKGROUND AND HOW TO
CREATE A COMPOSITION

RESEARCH THE HUES OF EACH PLANT:
SEASON CHANGES WILL AFFECT THE COLORS OF THE PLANTS,
THUS ALLOWING FOR DIVERSITY IN DECISION MAKING PROCESS

HUES IN RELATION
TO PLANTS AND
WALL TYPES   LIST OF CONSIDERATIONS

IMPLEMENT IN
DESIGN
ITERATE WITH MAIN
FRAMEWORK

CRITERIA TO CONSIDER

HUE SELECTION CRITERIA

HUE OF A COLOR IS HOW YOU, AS THE
DESIGNER SEE IT. PEOPLE WILL IDENTIFY
COLOR SLIGHTLY DIFFERENTLY, BUT THE
MAIN HUE WILL OFTEN BE THE SAME.

LAWS OF NATURE, SUCH AS LIGHT AND
COLOR WILL ALWAYS EXIST, BUT AN OR-
GAN SUCH AS THE EYE MUST BE PRESENT
TO MANIFEST THE PHYSICAL CONDITION.

THE EYE DOES NOT CAUSE LIGHT AND
COLOR TO OCCUR, BUT ALLOWS IT TO AP-
PEAR TO US.

IT IS VITALLY IMPORTANT NOT TO REDUCE
VISION, COLOR, OR REPRESENTATION TO
SIMPLY A PICTURE.

THEREFORE, WHEN CONSTRUCTING AND
DESIGNING VEGETATED ASSEMBLIES, IT IS
NOT ONLY IMPORTANT TO CONSIDER THE
EDGE AS A DESIGN INTERVENTION, BUT
ALSO FROM THE EYE'S NEED TO DIFFER-
ENTIATE SPACE.

THE EDGE OF THE ASSEMBLY NOT ONLY
CAN DEFINE THE SPACE, BUT ALSO THE
CHARACTER OF THE INTERNAL FIELD OF
VEGETATION AND ITS COLOR.

SPECIES OF THE PLANT WILL DETERMINE
THE HUES THAT ARE AVAILABLE.

THIS CAN ALSO CHANGE DURING THE
YEAR DEPENDING ON FRUIT, LEAVES,
FLOWERS.

THUS, OUR PLANTS (PIGMENTS), OUR AS-
SEMBLY (MEDIUM), OUR SPACE (PAPER),
AND OUR DESIGN (METHODS) MUST BE IN
RELATION TO EACH OTHER AND THOUGHT
OF IN A COHESIVE WHOLE.

CONSIDER REVIEWING:
ALBERS, GOETHE, LUIS BARRAGAN,
AND NEWTON

Appendix A7: Hue is the family of a color, for example red, green, or blue. These colors can create different color schemes and compositions when applied to plants in vegetated assemblies.

Appendix A8: Color mixtures and compositions are when hues begin to be used together in an image or in architecture such as our vegetated assemblies. I use this to determine how I will use color in a project. Is it inspired by nature? By representation? Or of other color harmonies?

START

DECISION FACTOR

SATURATION IN RELATION TO COLOR THEORY

CHECK DESIGN VEGETATED ASSEMBLY

LIST OF CONSIDERATIONS

FRAMEWORK AND ANALYSIS

NO PLANT

END

TOPICS ON SATURATION

A COMPOSITION MUST BE APPEAR TO BE BALANCED FOR SATURATION IN THE DESIGN OF THESE WALLS. SATURATION ACHIEVES DIFFERENT EFFECTS LIKE BALANCE AND HARMONY

REPRESENTATION IS NOT A PICTURE
GRAPHICAL REPRESENTATION OF SATURATION DOES NOT NECESSARILY TRANSLATE DIRECTLY TO AN ACTUAL VEGETATED WALL HOWEVER, OFTEN REPRESENTATION IS NOT A DIRECT PARALLEL TO REALITY

SATURATION IS A COMPONENT OF COLOR MIXING AND COLOR BALANCING IN CONJUNCTION WITH HUE AND VALUE. ALL THREE MUST BE OBSERVED TO MAKE A COMPOSITION.

SATURATION
CHOSEN BY TYPE AND SPECIE(S)

LIST OF CONSIDERATIONS

IMPLEMENT IN DESIGN
ITERATE WITH MAIN FRAMEWORK

CRITERIA TO CONSIDER

SATURATION CRITERIA

REMEMBER THAT ANY HUES CAN MAKE A COMPOSITION, BUT THAT THE COMPLEMENTARY SETS OFTEN CAN BEGIN TO CREATE HARMONY.

SATURATION CAN ALSO BE CONSIDERED THE INTENSITY OF A HUE WHEN USED IN A COMPOSITION.

THIS PURITY OF COLOR IS IMPORTANT TO THE OVERALL COMPOSITION OF AN IMAGE OR REPRESENTATION.

IF THE SATURATION OF AN IMAGE IS NOT EVEN, THEN THE IMAGE WILL APPEAR WASHED OUT OR INCOMPLETE. THIS CAN OCCUR IN THE OPPOSITE DIRECTION IF AN IMAGE IS OVER-SATURATED.

THEREFORE AN IMAGE CAN ACHIEVE BALANCE OR HARMONY THOUGH EVEN SATURATION.

IF THERE ARE A GREAT NUMBER OF HUES AND THE COMPOSITION APPEARS TO BE IN BALANCE IT IS FROM AN EVEN SATURATION AND THE COLOR ARE OF THE SAME HUE OR FAMILY OF ANALOGOUS HUES.

THE CHARACTERISTICS OF COLOR REVIEWED IN THE LITERATURE (HUE, SATURATION, AND VALUE) CAN BE QUANTIFIED AND SCALED, BUT SOLELY QUANTIFYING COLOR DOES NOT RELATE TO AN ARCHITECT ATTEMPTING TO REPRESENT A SPACE IN A TWO OR THREE DIMENSIONAL MANNER.

I RECOMMEND FINDING COLOR FOUND IN NATURE AS THESE ARE OFTEN IN COMPOSITION AND NOT OVER-SATURATED.

CONSIDER THESE:
ARNHEIM, PALLASMAA, AND THE THEORY OF PHENOMENOLOGY

Appendix A9: How bright or muted are the colors you are using? Is neon green needed in the design or is it a pastel yellow that is found in a flowering vine? Saturation of color depends on the plant species too, showing that they are intertwined. A visual list of useful vines is shown on the website livingwalldesigner-prototype.org.

START

DECISION FACTOR

VALUE IN RELATION
TO COLOR THEORY

CHECK DESIGN VEGETATED
ASSEMBLY ———— LIST OF CONSIDERATIONS

FRAMEWORK
AND
ANALYSIS

NO PLANT ———— END

TOPICS ON VALUE

BENEFIT OF VALUE:
VALUE CAN CREATE DEPTH IN 2-DIMENSIONAL REPRESENTA-
TIONS AS OPPOSED TO STATIC OF FLAT APPEARING IMAGES.

READING DEPTH:
APPARENT DEPTH IS CAUSED BY VALUE AND PLANT STRUCTURE OR
PHYSIOLOGY. THEREFORE, DEPTH IS ACHIEVED THROUGH LIGHT AND
SHADOW ON THE VEGETATED WALL ASSEMBLY

USING MULTIPLE SPECIES:
PLANT DIVERSITY ALONG THE WALL AND CREATES A MORE
DYNAMIC PIECE BOTH IN HUE, SATURATION AND DEPTH

VALUE
CHOSEN BY TYPE ———— LIST OF CONSIDERATIONS
AND SPECIE(S)

IMPLEMENT IN
DESIGN
ITERATE WITH MAIN
FRAMEWORK

CRITERIA TO CONSIDER

VALUE SELECTION CRITERIA

DIFFERENT VALUES ARE ALMOST ALWAYS
PRESENT IN A REPRESENTATION. WITH-
OUT THEM, AN IMAGE WILL OFTEN APPEAR
FLAT, OR APPEAR TO HAVE NO DEPTH.

IMAGES CAN HAVE INCORRECT OR FALSE
COLORS, COLOR THAT WE WOULD NOT
SEE OR REPRESENT LIGHT NOT IN THE
VISIBLE SPECTRUM, OR ARE SIMPLY EX-
CHANGED FOR COLORS FOUND IN NATURE

FOR EXAMPLE, A BROWN DOG IS BRIGHT
ORANGE AND WITH THE CORRECT DEPTH
OF VALUE WE WOULD STILL SEE THE IN-
TENDED IMAGE.

FOR EXAMPLE WITH VEGETATED ASSEM-
BLIES: ALL OF THE PLANTS HAVE DIFFER-
ENT VALUES AND SIZES CREATE DEPTH,
WHERE SMALLER AND DARKER PLANTS
RECEDE WHILE LIGHTER AND LARGER
PLANTS COME TO THE FOREGROUND.

DEPENDING ON HOW YOU WANT THE
WALL TO APPEAR, PLANTS CAN BE CHO-
SEN TO:

MAKE A WALL VISUALLY AND LITERALLY
HAVE MORE DEPTH THOUGH DIFFERENT
HUES AND SHADING PATTERNS USING THE
CHARACTERISTICS OF PLANTS OR APPEAR
FLAT BY CHOOSING ONLY ONE SPECIES OR
A FINER OR SHALLOWER PLANT SPECIES.

YOUR EYE PERCEIVES DEPTH THOUGH
THE DIFFERENCES OF HUES AND BY
SHADOW FOUND AT THE EDGES OF DIF-
FERENT ADJACENT PLANTS.

CONSIDER LOOKING AT:
PATRICK BLANC, OR THE BOOK FACADE
GREENERY BY VAN UFFELEN.

Appendix A10: Compositions of color should appear to have depth to them. This is called value and is also characterized by the amount of black an area of a composition has. Value plays a large role in "false-color" images where the value is correct but the hue is not.

START

DECISION FACTOR

GRAPHICS IN
RELATION TO
COLOR THEORY

CHECK DESIGN VEGETATED
ASSEMBLY

LIST OF CONSIDERATIONS

FRAMEWORK
AND
ANALYSIS

NO PLANT

END

GRAPHICS SELECTION CRITERIA

TAKING A STEP BACK, A LINE IS THE SIM-
PLEST FORM OF DIVIDED, OR WITH MUL-
TIPLE LINES, ENCLOSED SPACE. A LINE
DELINEATES, AND CREATES AN EDGE.

LINES ALSO RELATE TO THE CONTEXT OF
THE MEDIUM, ITS RANGE AND EXTENT, OF
THE TWO-DIMENSIONAL FRAME IN WHICH
THEY REST.

IF WE CONSIDER THAT THE EYE IS INVARI-
ABLY ATTRACTED TO AN EDGE CONDITION,
THEN LINES BECOME CRITICAL IN DESIGN
AND COLOR.

IN THE PRINCIPLE OF INTERPOSITION
THAT ALBERS AND KLEE EXPLORED, US-
ING FIELDS (ALBERS) AND LINES (KLEE)
DEPTHS CAN BE CREATED OR REJECTED
BASED ON POSITION.

THIS CONCEPT OF PROXIMITY AND PO-
SITION TO CREATE OR DENY SPACE AND
DEPTH WILL BE CRITICAL TO UNDER-
STANDING COLOR AND ITS RESULTING
EFFECTS.

HERE IS AN EXAMPLE OF FIGURE-GROUND
AND HOW GRAPHICS CAN CREATE DEPTH
AND SPACE.

TOPICS ON GRAPHICS

LINES:
ARE THOUGHT ABOUT IN TWO DIFFERENT WAYS WHEN DRAWING
WITH THE HAND AS OPPOSED TO THE COMPUTER.

LINES:
ARE THE BUILDING BLOCKS FOR CREATING SPACE AND TRANSLATE INTO
PLANES, WHERE EDGE CONDITIONS AND COLOR SEPARATION MAY BE IM-
PORTANT TO LEAD THE VIEWER IN A CERTAIN DIRECTION

GRAPHICS:
LINES, COLOR, AND GRAPHICS SHOW AN IMAGE TO THE VIEWER,
ITS DETAIL AND EFFECT ARE YOURS TO DECIDE

GRAPHICS
CHOSEN BY TYPE
AND SPECIE(S)

LIST OF CONSIDERATIONS

IMPLEMENT IN
DESIGN
ITERATE WITH MAIN
FRAMEWORK

CRITERIA TO CONSIDER

Appendix A11: Lines are the source of graphics and often are specific to each designer. These "pull" a composition or series of compositions together as a unifying theme.

START

DECISION FACTOR

CHOOSE WALL
COVERAGE AND
RATE OF COVERAGE

CHECK DESIGN VEGETATED
ASSEMBLY

LIST OF CONSIDERATIONS

FRAMEWORK
AND
ANALYSIS

NO PLANT

END

THREE MAIN TYPES OF DESIGNS

SIMPLEST
AN IVY OR OTHER PLANT GROWING UP THE SIDE OF A BUILDING
DIRECTLY ON THE SURFACE

INTERMEDIATE
ENGINEERED TRELLIS SYSTEM WITH PLANTS ROOTED IN THE GROUND,
CLIMBING UP A SEPARATE STRUCTURE. ALLOWS MORE VARIETY AND
OPTIONS

COMPLEX
THESE INCLUDE ALL FOUR ELEMENTS: GROWING MEDIA, STRUC-
TURAL SUPPORT, INTEGRATED IRRIGATION AND DRAINAGE SYSTEM

CHOOSE WALL
TYPE AND PLANT
SPECIE(S)

LIST OF CONSIDERATIONS

IMPLEMENT IN
DESIGN
ITERATE WITH MAIN
FRAMEWORK

CRITERIA TO CONSIDER

SPECIES SELECTION CRITERIA

USDA PLANT HARDINESS ZONE

VINE OR NON-VINE
MULTIPLE SPECIES

EVERGREEN OR DECIDUOUS

NATIVE OR NON-NATIVE

AESTHETIC FEATURES
FOLIAGE (SPRING, SUMMER, FALL)
TRACERY (WINTER PATTERN)
FLOWERS
FRUIT

CLIMBING MECHANISM (WALL FEATURES)
TENDRILS (NOT WOOD OF VINYL)
ROOTLETS (NOT WOOD OR VINYL)
TWINING (NEEDS MATRIX FOR SUPPORT)

GROWTH RATE
SLOW (1 FT / YEAR)
MEDIUM (1-2 FT / YEAR)
FAST (>2 FT / YEAR)

CULTURAL REQUIREMENTS

LIGHT
FULL SUN
MORNING SUN, AFTERNOON SHADE
MORNING SHADE. AFTERNOON SUN
FULL SHADE

SOIL ASPECTS
TOP SOIL OR FILL SOIL
SOIL TYPE (SANDY, LOAM, CLAY)
AFFECT WATER RETENTION
SOIL PH
MOISTURE

MAINTENANCE
LEAF/FLOWER/FRUIT LITTER
PRUNE FROM WINDOWS
IRRIGATION SYSTEM UPKEEP
WINTER PREP AND REPAIRS
POTENTIAL PEST ISSUES
INSECT, MITE, DISEASES, BIRDS

Appendix A12: The species of a plant is one if not the most important characteristic to consider for vegetated assemblies. By choosing a species many other characteristics such as color and climbing mechanism and therefore material choices for structure are inter-connected.

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START

DECISION FACTOR

NATIVE / NON-NATIVE IN RELATION TO COLOR THEORY

CHECK DESIGN VEGETATED ASSEMBLY   LIST OF CONSIDERATIONS

FRAMEWORK AND ANALYSIS   NO PLANT   END

TOPICS ON NATIVE / NON-NATIVE

NATIVE:
A SPECIES, SUB-SPECIES, OR LOWER TAXON LIVING WITHIN ITS NATURAL RANGE (PAST OR PRESENT), INCLUDING THE AREA IN WHICH IT CAN REACH AND OCCUPY USING ITS OWN LEGS, WINGS, WIND/WATER-BORNE OR OTHER DISPERSAL SYSTEMS, EVEN IF IT IS SELDOM FOUND THERE.

NON-NATIVE OR ALIEN OR EXOTIC SPECIES IS:
"A SPECIES, SUBSPECIES, OR LOWER TAXON INTRODUCED OUT-SIDE OF ITS NORMAL PAST OR PRESENT DISTRIBUTION; INCLUDES AND PART, GAMETES, SEEDS, EGGS, OR PROPAGULES OF SUCH SPECIES THAT MIGHT SURVIVE AND REPRODUCE.

PLANT
CHOSEN BY TYPE AND SPECIE(S)   LIST OF CONSIDERATIONS

IMPLEMENT IN DESIGN ITERATE WITH MAIN FRAMEWORK

CRITERIA TO CONSIDER

NATIVE / NON-NATIVE CRITERIA

THIS SCIENTIFIC FOCUS ON SPECIES AS A REFERENCE IS WHAT WILL BE USED FOR DEFINING NATIVE AND NON-NATIVE PLANTS FOR THE PURPOSE OF THE STUDY. THE SPREAD OF NONNATIVE SPECIES DOES NOT STOP AT A STATE OR NATIONAL BORDER.

3 MAIN ISSUES:
NATIVE PLANTS ARE OFTEN SOLD IN A SPECIFIC REGION, WHILE NON-NATIVE PLANTS ARE MORE WIDESPREAD. THE FRAMEWORK WILL FOCUS ON PLANTS NATIVE TO THE AREA AND NONNATIVE CULTIVARS.

THE ECONOMICS INVOLVED IN GROWING NATIVES IS MORE EXPENSIVE THAN AND NOT AS ESTABLISHED AS CURRENTLY GROWN CULTIVARS, THUS NOT AS WIDELY AVAILABLE.

THE INDUSTRY HAS A WIDE VARIETY OF DEFINITIONS FOR NATIVE PLANTS AND THE REGULATION THAT SURROUNDS THEM, MAKING IT DIFFICULT TO TRULY KNOW WHAT A CONSTITUTES A NATIVE PLANT.

3 STAGES TO AN INVASIVE PLANT:
WHEN IT IS FIRST INTRODUCED (TRANSPORTED BY HUMANS ACROSS A MAJOR GEOGRAPHICAL BARRIER), THEN IS NATURALIZED (OVERCOMING ABIOTIC AND BIOTIC BARRIERS TO SURVIVAL AND REGULAR REPRODUCTION) AND THEN THE PLANT BECOMES INVASIVE BY MOVING TO A SITE DISTANT FROM THE FIRST INDUCTION. THERE ARE THREE STAGES OF INVASION: WIDESPREAD BUT RARE (IVA), LOCALIZED BUT DOMINANT (IVB) AND WIDESPREAD AND DOMINANT (V)

SEE THESE FOR MORE INFORMATION ON CULTIVAR AND NATIVE AND NON-NATIVE: (NORCINI, 2007) AND THE VIRGINIA NURSERY & LANDSCAPE ASSOCIATION COLAUTTI, & MACISAAC, H. (2004).

Appendix A13: Native-ness of a plant based on where it has historically been found. Where it has been it is native, where it has not, non-native. Some designs may look specifically for the use of native plants. Using only native plants limits the plants for the design as hand. In many cases the use of native plants is not possible as they may not work on the hard conditions of a trellis or wall (similar situation to green roofs, thus why non-native plants are used widely).

Appendix A14: How does the vine or plant grow, move, or climb a surface? Depending on the method certain structures of material types might be more effective or useful. In reverse, if you have a certain structure a particular climbing mechanism might be necessary to use.

START

DECISION FACTOR

RHS CLASSIFIERS
IN RELATION TO
COLOR THEORY

CHECK DESIGN VEGETATED
ASSEMBLY   LIST OF CONSIDERATIONS

FRAMEWORK
AND
ANALYSIS   NO PLANT   END

TOPICS ON RHS CLASSIFICATION

IN REGARDS TO COLOR DOCUMENTATION FOR COLOR THEORY APPLI-
CATIONS, THE ROYAL HORTICULTURE CHART WILL BE USED AS THE
STANDARD REFERENCE FOR PLANT COLOR IDENTIFICATION.

ANALOGOUS COLOR
THE NATURAL COLOR OF THE PLANTS OVER THE COURSE OF THE YEAR IS
WHAT WILL BE USED TO BEGIN SELECTING PLANT SPECIES THAT CAN BE
USED FOR A COMPOSITION

RHS CHART ELSEWHERE:
THIS SAME COLOR CHART IS USED WITH FOOD COLORINGS,
CHEMICAL ENGINEERING COMPANIES AND FABRIC DESIGNERS.

HUE
CHOSEN BY TYPE
AND SPECIE(S)   LIST OF CONSIDERATIONS

IMPLEMENT IN
DESIGN
ITERATE WITH MAIN
FRAMEWORK

CRITERIA TO CONSIDER

RHS CLASSIFICATION CRITERIA

A SCHEME CAN BE ABSTRACTED FROM
THE PLANTS BASED ON ANALOGOUS OR
COMPLIMENTARY COLORS, REFERENCED
AGAINST THE ROYAL HORTICULTURE SO-
CIETY'S MANUAL.

IT IS UP TO THE DESIGNER TO CHOOSE
WHAT SORT OF COMPOSITION TO START
FROM.

FOR EXAMPLE A PLANT DISPLAYS A LIGHT
YELLOW GREEN, MIDDLE, LIGHTER GREEN,
AND THEN FULL GREEN. THIS WOULD BE
AN EXAMPLE OF ANALOGOUS COLOR.

IF YOU TOOK THE RED FROM THE PET-
ALS OF ITS FLOWER AND THEN THE FULL
GREEN FROM ITS LEAVES, IT IS A COM-
PLEMENTARY COLOR COMPOSITION. IN
REVERSE, IF AN ABSTRACTED COMPOSI-
TION IS CREATED, PLANTS THAT HAVE SIM-
ILAR COLOR CAN BE SELECTED AND THEN
PLACED INTO A SYSTEM OF MOSAIC.

BY SELECTING PLANTS BASED ON POSI-
TIVE CHARACTERISTICS AS EXPLAINED BY
THE CHOOSING BY ADVANTAGES MODEL,
PLANTS CAN BE PAIRED BASED ON THE
BEST POSSIBLE OUTCOME, WHILE CON-
SIDERING ALL OF THE CRITERIA, NOT
THOSE ONLY LIMITED TO COLOR THEORY.

AN EXAMPLE OF ANALOGOUS COLOR
FROM A BROWN LEAF IN WATERCOLOR

Appendix A15: The Royal Horticulture Society has a color book to identify the color of a plant's leaves. It provides a standardization for the naming of color, which can vary widely within one language by a person's interpretation, as well as between languages.

Appendix A16: The profession has traditionally used hand techniques to develop representation. There are a vast number of methods and media that combine with a designer's level of mastery to compose representations.

Appendix A17: As computers have become more powerful, more opportunities for using them to assist in the design process developed as well. There are many different options and some are free, others proprietary.

DECISION FACTOR

START

EXAMPLES OF COMPUTER PROGRAMS

CHECK DESIGN VEGETATED ASSEMBLY

LIST OF CONSIDERATIONS

FRAMEWORK AND ANALYSIS

NO PLANT

END

TOPICS ON COMPUTER PROGRAMS

NOT BETTER OR WORSE THAN ONLY DESIGNING BY HAND WITH A PENCIL, BUT THAT BOTH COMPUTERS AND ANALOG HAVE DIFFERENT STRENGTHS, WEAKNESSES AND MERITS.

COMPUTER AIDED DESIGN (CAD)
IS A COMBINATION OF TWO THINGS: FIRST THAT A TYPE OF SOFTWARE IS USED TO DESIGN, AND THE MECHANICAL HARDWARE ON WHICH SOFTWARE OPERATES.

EXPERIENCE IS KEY:
IT IS UP TO THE DESIGNER TO KNOW WHEN AND HOW TO USES THESE DIFFERENT METHODS APPROPRIATELY

DESIRED COMPUTER PROGRAM USED IF ANY

LIST OF CONSIDERATIONS

IMPLEMENT IN DESIGN ITERATE WITH MAIN FRAMEWORK

CRITERIA TO CONSIDER

COMPUTER PROGRAM CRITERIA

THE COMPUTER AND INSTALLED PROGRAMS (SOFTWARE) ARE TOOLS THAT HELP DESIGNERS TO DESIGN. DEPENDING ON THE TASK AT HAND, CAD CAN BE A GREAT RESOURCE. HOWEVER, NOT ALL DESIGN SHOULD BE DONE ON THE COMPUTER ALONE.

PROGRAMS OFTEN USED: PHOTOSHOP, RHINOCEROS, GRASSHOPPER, AND GOOGLE SKETCH-UP.

THERE ARE MULTIPLE PROGRAMS AS DESIGNERS AND STUDENTS NEED OPTIONS, AS NOT ALL ARE COMFORTABLE WITH ALL TYPES OF SOFTWARE. TECHNOLOGY AND SOFTWARE EVOLVE QUICKLY, CHANGING WITH GREAT SPEED.

THESE PROGRAMS WILL SHOW POSSIBLE WAYS OF REPRESENTING VEGETATED AND LIVING WALLS WITH THE MAIN FOCUS BEING IN METHODS USED THROUGHOUT THE WHOLE PROCESS OF DESIGNING SUCH WALLS, RATHER THAN THE SPECIFIC PROGRAMS THEMSELVES.

THE FIRST PROGRAM IS ADOBE PHOTOSHOP. PHOTOSHOP ALLOWS DESIGNERS TO AUGMENT AND CREATE IMAGES AS A POST-RENDERING PROGRAM.

THE SECOND PROGRAM IS RHINOCEROS OR RHINO. RHINO ALLOWS DESIGNERS TO WORK IN 3-DIMENSIONAL SPACES TO CREATE OBJECTS. GRASSHOPPER IS THE THIRD PROGRAM OR 'PLUG-IN' FOR RHINO

GOOGLE SKETCH-UP IS THE FOURTH PROGRAM. THIS PROGRAM IS A SIMPLER AND LESS COSTLY VERSION OF RHINO AND IS A 3-DIMENSIONAL REPRESENTATION PROGRAM. DEPENDING ON THE VERSION IT IS EVEN OFFERED FOR FREE TO DOWNLOAD.

Appendix A17b: There are many programs and a few of the more commonly used ones are explained here.

START

DECISION FACTOR

CHOSEN REPRESENTATION FROM A4

CHECK DESIGN VEGETATED ASSEMBLY .... LIST OF CONSIDERATIONS

FRAMEWORK AND ANALYSIS

NO PLANT → END

THREE MAIN POINTERS TO REPRESENTATION

STANDARD ARCHITECTURAL DRAWINGS
THE PLAN, SECTION, ELEVATION, AXONOMETRIC, AND PERSPECTIVE AND THE COMBINATIONS OF

THE PURPOSE OF THE DRAWING
WHAT ARE YOU TRYING TO CONVEY TO THE VIEWER ABOUT YOUR DESIGN? IF THE DRAWING DOES NOT CONVEY THIS YOU CANNOT TALK ABOUT WHAT IS NOT PRESENT

PERSONAL METHOD
THIS IS CRITICAL. WHY IS THE DRAWING YOURS AND NOT ANOTHER'S? WHAT DO YOU BRING TO THE DRAWING? WHAT IS YOUR PROCESS?

ITERATE DESIGN TO COME TO A CHOSEN VERSION .... LIST OF CONSIDERATIONS

IMPLEMENT IN DESIGN
ITERATE WITH MAIN FRAMEWORK

CRITERIA TO CONSIDER

METHODS + SELECTION CRITERIA

REMEMBER PERSONAL MASTERY OF A TECHNIQUE IS A PERSONAL DECISION IN DESIGN AND REPRESENTATION:

THIS IS PERHAPS THE MOST DIFFICULT AREA TO GIVE A GENERIC ANSWER TO WHAT REPRESENTATION IS, ESPECIALLY IN ARCHITECTURE.

THERE IS SIMPLY NOT A CORRECT OR RIGHT ANSWER. THE DESIGN PROJECT COMBINED WITH YOUR OWN PERSONAL TECHNICAL SKILL WILL YIELD YOUR REPRESENTATIONAL STYLE AND METHODS.

OFTEN THERE IS A SPIRIT OF THE TIMES TO THE METHOD OF REPRESENTATION. CALLED A ZEITGEIST, IT IS YOU CHOICE TO EMULATE OR DEVIATE FROM THE CURRENT DESIGN NORM.

HOWEVER WHILE THE IMPLEMENTATION AND RESULTING REPRESENTATION IS UNIQUE, TECHNIQUES AND PROGRAMS IMPLEMENTED ARE MORE STANDARD.

BOTH DIGITAL AND ANALOG TECHNIQUES WILL HELP US TO REPRESENT DESIGNS, HOWEVER IT IS THE UNIQUE DESIGN IMPLEMENTATION THAT WILL YIELD YOUR REPRESENTATION (A16, A17)

CONSIDER TYPE OF PRESENTATION
   DISTANCE AND DETAIL

CONSIDER THE AUDIENCE
   WHOM AND WHY THIS DESIGN

USEFUL LITERATURE:
EXAMPLES FROM YOUR FAVORITE ARCHITECTS. PERSONALLY,

GLEN MURCUTT, FRANK LLOYD WRIGHT, RENZO PIANO, SHIGERU BAN AND TADAO ANDO

Appendix A18: Representation is something that is born out of tradition, but solidified through experience. Sometimes it is influenced by the times and sometimes it breaks or deviates from the norm.

START

DECISION FACTOR

CHOSEN
PROMPT CRITERIA
FROM A4

CHECK DESIGN VEGETATED ASSEMBLY

LIST OF CONSIDERATIONS

FRAMEWORK AND ANALYSIS

NO PLANT

END

METHODS + SELECTION CRITERIA

REMEMBER PERSONAL MASTERY OF A TECHNIQUE IS A PERSONAL DECISION IN DESIGN AND REPRESENTATION:

A BASIC FRAMEWORK TO GET STARTED CAN BE SEEN BELOW. MY SUGGESTION IS TO QUICKLY MAKE AND UNDERSTAND YOUR OWN DESIGN PROCESS BY INFUSING THE PROMPT CRITERIA SUGGESTIONS THAT COMPRISE YOUR PERSONAL ARCHITECTURE

PROMPT CRITERIA SUGGESTIONS

CONSIDER THE SITE
LOOK AROUND AND SEE AND UNDERSTAND THE SITE. OFTEN THERE ARE QUALITIES TO BRING FORWARD IN THE DESIGNED RESPONSE

IGNORE THE FULL PROGRAM AT FIRST
DO NOT USE A PROMPT OF PROGRAM AS A CHECKLIST. INSTEAD WHAT IS THE TYPOLOGY OF THE BUILDING TO BE DESIGNED (OFFICE, AUDITORIUM, SCHOOL, ETC) AND TYPE TO CAPTURE ITS PURPOSE.

WHAT IS YOUR DESIGN THESIS?
WHAT ARE YOUR CONSIDERATIONS YOU ALWAYS BRING TO A DESIGN? MINE ARE RECLAIMED MATERIALS, A MODULE, AND VEGETATION

FRAMEWORK

IDEATION
DEFINE PROJECT

CHARACTERISTIC COLLECTION

PROJECT CRITERIA

REPRESENTATION

ITERATION

EVALUATE ITERATIONS

CHOOSE ITERATION

DECISION + IMPLEMENTATION

ITERATE DESIGN TO COME TO A CHOSEN VERSION

LIST OF CONSIDERATIONS

IMPLEMENT IN DESIGN
ITERATE WITH MAIN FRAMEWORK

CRITERIA TO CONSIDER

Appendix A19: How do the requirements of the prompt influence your work? I suggest seeing how the idea can give life to rather mundane programmatic elements often found in design. Instead of what is it, look to what it ought, should, or could be.

START

DECISION FACTOR

MASONRY MATERIAL
CONSIDERATIONS
WITH PLANTS

CHECK DESIGN VEGETATED
ASSEMBLY

LIST OF CONSIDERATIONS

FRAMEWORK
AND
ANALYSIS

NO PLANT   END

MASONRY MATERIAL CRITERIA

THERE ARE THREE MAIN KINDS OF MA-
SONRY INCLUDING BRICKS, CONCRETE
MASONRY UNITS, AND STONE.

THESE TWO ARE DIFFERENT IN THAT A
BRICK IS TYPICALLY FIRED CLAY, WHILE A
STONE IS CUT TO SHAPE.

BOTH FUNCTION IN A SIMILAR MANNER
FOR THE PURPOSES OF THE VEGETATED
WALL.

THESE WALLS CAN HAVE VEGETATION DI-
RECTLY APPLIED, HOWEVER THEY MUST
BE MAINTAINED WELL. THIS MEANS MOR-
TAR AND OTHER JOINTS ARE NOT EROD-
ED, GIVING ROOTLETS OTHER PLACES TO
ATTACH OTHER THEN THE MAIN SURFACE.

ROOTLETS ARE THE MOST AGGRESSIVE
METHOD OF ATTACHMENT THAT VINES CAN
HAVE ON WALLS. HOWEVER, FULL VEGE-
TATED WALLS WITH MEDIUM ARE A SEP-
ARATE LAYER FROM THE MAIN BUILDING
ENVELOPE AND HAVE INTERNAL LAYERS
THAT PROTECT THE WALL.

THERE ARE TWO MAIN TYPES OF WALLS:
VINES ON WALLS IN THE TRADITIONAL
SENSE AND CONTEMPORARY WALLS WITH
MANY LAYERS AND FORM DISTINCT WALL
ASSEMBLIES

WALLS SHOULD ALSO CONSIDER:

STRUCTURE
METHOD OF CLIMBING
MOISTURE
ORIENTATION
TYPE OF VEGETATED WALL
TYPE OF MASONRY WALL
LOAD BEARING, DRY-STACKED OR VE-
NEER MASONRY WALLS
MAINTENANCE

TOPICS ON MASONRY MATERIAL

PLANT SPECIES / CLIMBING MECHANISM
HOLDFASTS, TENDRILS AND ROOTLET PLANTS CAN BE APPLIED
DIRECTLY, TWINNING VINES NEED SECONDARY STRUCTURE

CONDITION OF THE WALL
POORLY MAINTAINED MASONRY WILL BE AT RISK WITH ANY KIND OF
MATERIAL NEAR OR ON THE WALL. ALL MASONRY AND SPECIFICALLY THE
MORTAR JOINTS MUST BE IN WELL REPAIR AND PLANTS GROOMED

ORIENTATION OF THE WALL
SPECIES PERFORM BETTER BASED ON THE TYPE OF SUN OR
SHADE DEPENDING IF THIS IS IN THE MORNING OR AFTERNOON

MASONRY MATERIAL
USAGE IN THE
DESIGN OR NOT

LIST OF CONSIDERATIONS

IMPLEMENT IN
DESIGN
ITERATE WITH MAIN
FRAMEWORK

CRITERIA TO CONSIDER

Appendix A20: The materials and building aspects will inform the plants and subsequently the colors that will be available to make compositions. It is important to also consider the species of the plant while designing a structure or selecting its materials.

Appendix A21: The materials and building aspects inform the plants and subsequently the colors that will be available to make compositions. It is important to consider the species of the plant while designing a structure or selecting its materials.

START

DECISION FACTOR

PLANTS AS DEC-
ORATION BEFORE
PERFORMANCE

CHECK DESIGN VEGETATED
ASSEMBLY　　　LIST OF CONSIDERATIONS

FRAMEWORK
AND
ANALYSIS

NO PLANT　　END

TOPICS FOR DECORATION

LOCATION:
INTERIOR OR THE EXTERIOR OF THE BUILDING OR OTHER
STRUCTURE CAN LEND ITSELF TO A TYPE OF USE

USAGE:
INTERIOR USES ARE OFTEN MORE FOR DECORATION, AS THE MAIN
PERFORMANCE-BASED FUNCTIONS OF A VEGETATED SYSTEM ARE FOUND
IN STORMWATER RETENTION AND SHADING OF THE BUILDING

MAINTENANCE:
DECORATIVE PLANTS OFTEN NEED MORE PRUNING AND
WATERING THAN PERFORMANCE SPECIES. THIS IS SPECIES BASED

CHOOSE WALL
TYPE AND PLANT
SPECIE(S)　　LIST OF CONSIDERATIONS

IMPLEMENT IN
DESIGN
ITERATE WITH MAIN
FRAMEWORK

CRITERIA TO CONSIDER

DECORATION CRITERIA

THESE CRITERIA ARE NOT MEANT TO BE
A DECIDING FACTOR. INSTEAD UNDER-
STANDING THE PURPOSE OF THE VEGE-
TATED WALL CAN HELP TO INFORM DESIGN
DECISIONS.

FOR EXAMPLE:

A DECORATIVE WALL CAN BE MORE VAR-
IED IN ITS PLACEMENT AND PLANT SPE-
CIES. THESE WALLS ARE NOT NECESSAR-
ILY MEANT TO BE LOW MAINTENANCE OR
BE STORMWATER CATCHMENT.

THIS CAN MAKE THE WALL A MORE ABOUT
A SERIES OF LAYERS.

HOWEVER THE VEGETATED WALL NEEDS
TO BE CONSIDERED AS A PART OF AN IN-
TEGRATED BUILDING ENVELOPE. IF THE
WALL IS CONSIDERED AND ADD-ON IF THE
MONEY IS THERE, THEN THE WALL WILL
NOT BE AS SUCCESSFUL.

THIS IS THE DIFFERENCE BETWEEN DEC-
ORATION AND DECORATIVE. DECORATION
IS AN ADDITIVE ELEMENT AFTER THE
FACT. DECORATIVE IS IN ITS INTENT TO
BE INTEGRAL TO THE DESIGN, BUT IS NOT
NECESSARILY STRUCTURAL.

IN ARCHITECTURE THIS IS CONSIDERED
AS ORNAMENT. THIS CONCEPT OF MORE
OR LESS ORNAMENT IS WHAT CONTRIB-
UTED TO ENTIRE MOVEMENTS OF ARCHI-
TECTURE. THIS CAN LEAD INTO WHAT IS
CALLED TECTONICS.

THESE TECTONICS ARE OFTEN CLEAR
AND ORDERED, BEING CONSISTENT IN
IDEA, AND ORGANIZATION. IN THIS SENSE,
WHAT COULD BE THE ARCHITECTONICS OF
THE VEGETATED WALL?

Appendix A22: What is the vegetated assembly being used for? What could it be used for? Why is it used that way? Is it the only way it could be used? These are general questions into aesthetic and decorative functions of these assemblies.

START

DECISION FACTOR

PLANTS AS PER-
FORMANCE BEFORE
DECORATION

CHECK DESIGN VEGETATED
ASSEMBLY

LIST OF CONSIDERATIONS

FRAMEWORK
AND
ANALYSIS

NO PLANT

END

TOPICS FOR PERFORMANCE

LOCATION:
INTERIOR OR THE EXTERIOR OF THE BUILDING OR OTHER
STRUCTURE CAN LEND ITSELF TO A TYPE OF USE

USAGE:
THE MAIN PERFORMANCE-BASED FUNCTIONS OF A VEGETATED SYSTEM
ARE FOUND IN STORMWATER RETENTION AND SHADING OF THE BUILDING.
INTERIOR USES ARE OFTEN MORE FOR DECORATION.

MAINTENANCE:
THIS IS SPECIES BASED. PERFORMANCE SPECIES OFTEN HAVE
LESS MAINTENANCE THAN DECORATIVE PLANTS.

CHOOSE WALL
TYPE AND PLANT
SPECIE(S)

LIST OF CONSIDERATIONS

IMPLEMENT IN
DESIGN
ITERATE WITH MAIN
FRAMEWORK

CRITERIA TO CONSIDER

PERFORMANCE CRITERIA

MOVING FROM DECORATIVE AND TEC-
TONICS (A22), THERE IS PERFORMANCE.

PERFORMANCE OFTEN HAS TO DO MUCH
WITH THE PLACE OR THE SITE, CLIMATE
AND MICRO-CLIMATES

SITE CAN CHANGE THE APPROPRIATE
QUALITIES OF THE DESIGN IN TERMS OF
BOTH HUMAN AND NON-HUMAN DESIGN
FACTORS. FOR EXAMPLE ZONING RE-
QUIREMENTS CAN BEGIN TO INFLUENCE
DIFFERENT REQUIREMENTS FOR PERFOR-
MANCE.

FOR EXAMPLE ZONING CAN INCLUDE OTH-
ER CONSIDERATIONS OF VALUE SYSTEMS
SUCH AS LEED.

PERFORMANCE IS NOT TIED TO THESE
REQUIREMENTS, BUT INSTEAD SHOULD BE
BEYOND THEM, TREATING THEM AS MET-
RICS AND CRITERIA, BUT NOT DECIDING
PROCESSES FOR DESIGN.

THESE QUESTIONS OF PERFORMANCE
CAN BE BEGIN TO INFLUENCE TECTONICS
AS A VERNACULAR OR AS LOCAL MATERI-
ALS THAT BECOME A PART OF THE BUILD-
ING ENVELOPE.

MORE PRAGMATIC QUESTION OF PERFOR-
MANCE IS THE COST OF A VEGETATED
WALLS. THIS OFTEN DRIVES THE PROJ-
ECT, HOWEVER THE LEVEL OF VEGETAT-
ED WALL CAN DRASTICALLY CHANGE THIS
QUESTION.

THE POINT IS THAT PERFORMANCE
SHOULD BE BALANCED WITH DECORATION
AS MUCH AS POSSIBLE.

Appendix A23: What is the vegetated assembly being used for? What could it be used for? Why is it used that way? Is it the only way it could be used? These are general questions into aesthetic and performative functions of these assemblies.

START

DECISION FACTOR

SITE DESIGN IN
TERMS OF
DESIGN

CHECK DESIGN VEGETATED ASSEMBLY　　　　LIST OF CONSIDERATIONS

FRAMEWORK AND ANALYSIS

NO PLANT　　　**END**

TOPICS FOR SITE ANALYSIS

PERFORMED WITH PRE-DESIGN
QUALITIES OF THE PHYSICAL SITE SHOULD ALWAYS BE DONE WITH
RESEARCH WORK IN PRE-DESIGN AS EACH INFORMS THE OTHER

CONSIDER DESIGN CONSTRAINTS
USE THE PROMPT OR CLIENT DESIRES TO BEGIN LIMITING THE DESIGN,
THIS CONTEXTUALIZES THE PROBLEM AND ALLOWS FOR IDEAS TO BE
FOUND IN THE BOUNDARIES OF THESE CONDITIONS AND LIMITS

CONTEXT:
SURROUNDINGS, CLIMATE, TIME, HISTORICAL CONTEXT, AND
OTHER TOPICS CAN BEGIN TO CONTEXTUALIZE THE SITE

CHOOSE WALL
TYPE AND PLANT
SPECIE(S)　　　　LIST OF CONSIDERATIONS

IMPLEMENT IN
DESIGN
ITERATE WITH MAIN
FRAMEWORK

CRITERIA TO CONSIDER

SITE ANALYSIS CRITERIA

WHERE DOES THE SITE END?

THE SITE IS A COMBINATION OF A NUMBER OF FACTORS AND SHOULD NOT BE LIMITED BY THE PHYSICAL VIEWS OR CONSTRAINTS OF THE SITE.

THESE NON-PHYSICAL CONSIDERATIONS ARE PLACES THAT INSPIRATION CAN BE DRAWN FROM TO CREATE ORDER OR ORIENTATION WITHIN THE SITE WHILE MAINTAIN A REFERENCE TO A LARGER ARCHITECTURAL FABRIC.

CLIMATIC CONCERNS

THE SITE HAS LOCAL CONDITIONS THAT DESIGNS NEED TO RESPOND TO BE A MORE COMPLETE DESIGN.

CLIMATE AND WEATHER ALSO HELP TO DETERMINE WHICH SPECIES AND TYPES OF PLANTS THAT WOULD BE PICKED FOR VEGETATED ROOFS AND WALLS

THE DESIGNED RESPONSE

THESE TWO THINGS COMBINED MAKE THE DESIGNED RESPONSE.

THE DESIGNED RESPONSE REFLECTS THE PLACE THAT THE PROJECT WAS DESIGNED FOR RATHER THAN ATTEMPTING TO BE SOME UNIVERSAL ANSWER TO A VERY SPECIFIC PLACE.

THE DESIGNED RESPONSE IS REFLECTIVE OF THE ENVIRONMENT IN WHICH IT IS DESIGNED FOR AND SUBSEQUENTLY PLACED.

Appendix AB: The site is a critical part of the design. The site gives context and understanding for the project and a place to begin to inform our design. This can be cultural, but also climatic in nature.
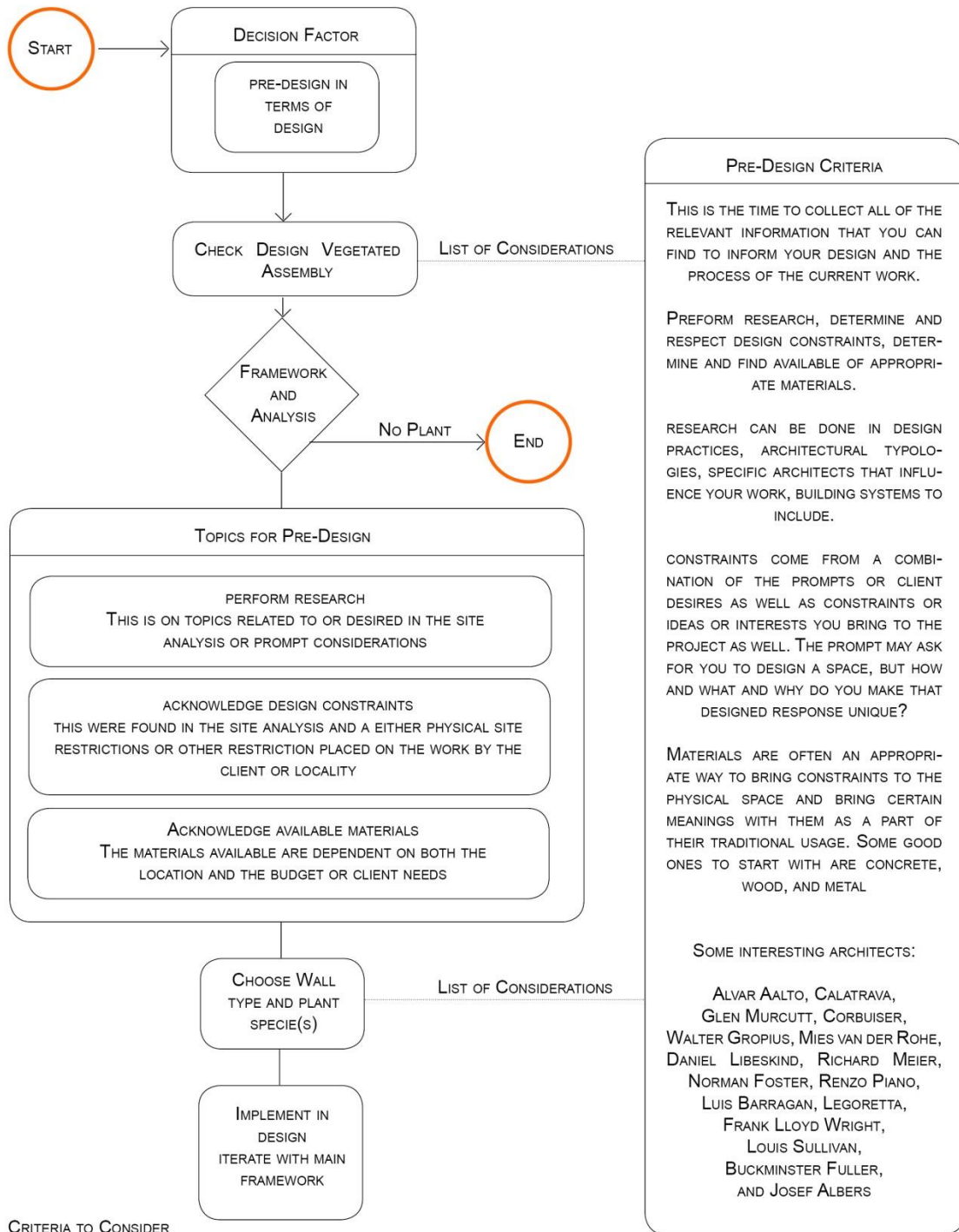
Appendix AC: Pre-Design is where the site analysis meets the need for information. For example using the framework presented here would most likely fall into this part of the design process, but can be used at any time as a reference.

START

DECISION FACTOR

SCHEMATIC DESIGN
IN TERMS OF
DESIGN

CHECK DESIGN VEGETATED
ASSEMBLY

LIST OF CONSIDERATIONS

FRAMEWORK
AND
ANALYSIS

NO PLANT   END

TOPICS FOR SCHEMATIC DESIGN

USES THE NEXT THREE TOPICS JOINTLY:
IDEATION, CHARACTERISTIC COLLECTION, AND REPRESENTATION
TO MAKE THE FOURTH: ITERATIONS

EXPLORATION BY DOING
SKETCHES, DRAWINGS, (PLAN, SECTION, ELEVATION), CONSTRUCTED
DRAWINGS, ISOMETRICS, MODELS (BOTH MASSING AND STRUCTURAL), OF
DIFFERENT VERSIONS OR ITERATIONS

QUESTIONS:
THESE DRAWINGS, MODELS AND METHODS AS QUESTIONS OF THE
DESIGN TO UNDERSTAND AND ARE NOT REPLICAS OF A FINAL

CHOOSE WALL
TYPE AND PLANT
SPECIE(S)

LIST OF CONSIDERATIONS

IMPLEMENT IN
DESIGN
ITERATE WITH MAIN
FRAMEWORK

CRITERIA TO CONSIDER

SCHEMATIC DESIGN CRITERIA

SCHEMATIC DESIGN IS THE METHOD OF
TAKING INFORMATION AND BEGINNING TO
MAKE A DESIGNED RESPONSE TO THE
SITE ANALYSIS AND PRE-DESIGN INFOR-
MATION GATHERING.

THIS MEANS SYNTHESIZING INFORMATION
AND USING EXPERIENCE, OR INTUITION,
ALONG WITH REFERENCES TO MAKE AN
ARCHITECTURAL INTERVENTION INTO A
SITE.

THIS PROCESS OF SCHEMATIC DESIGN
USES FOUR MAJOR TECHNIQUES TO
MAINTAIN A SYSTEMATIC APPROACH TO
EXPLORING AND UNDERSTANDING A PER-
SONAL INTERACTION WITH ARCHITECTURE

DIAGRAMMING
IS OFTEN TRANSLATING IDEAS INTO SIM-
PLE REPRESENTATIONS ON PAPER. THESE
CAN BE REFINED OF NOT, BUT ARE USED
TO GET AN IDEA OUT AND BEGIN TO EN-
GAGE IT ON PAPER

SKETCHING
IS NOT ABOUT LITERALLY RECORDING
WHAT IS PRESENT ON A SITE OR THOUGHT,
BUT IS ABOUT CAPTURING THE ESSENCE
OF WHAT AN IDEA IS IN A MORE DETAILED
MANNER THAN A DIAGRAM. THESE ARE
OFTEN DONE IN A SKETCHBOOK

DRAWING
IS HOW WE AS STUDENTS OF ARCHITEC-
TURE WORK THROUGH MORE AND MORE
LAYER OF COMPLEXITY. DRAWINGS ARE
A SET OF STANDARD TYPES THAT HELP
OTHERS TO UNDERSTAND OUR IDEAS AT
CERTAIN SCALES.

MODELING
IS DONE CONCURRENTLY WITH ALL OF THE
OTHER TYPES OF 2 DIMENSIONAL REPRE-
SENTATION AND ARE USED TO EXPLORE
QUESTIONS THAT ARE NOT PRESENT IN
DRAWINGS

Appendix AD: Schematic Design is the first step of working out a designed response to the site and its conditions. In architecture it takes the form of sketching to get ideas out. This process is often referred to as ideation.

START

DECISION FACTOR

PROCESS OF
IDEATION IN TERMS
OF DESIGN

IDEATION DESIGN CRITERIA

IDEAS CAN COME FROM A VARIETY OF
SOURCES; HOWEVER I HAVE FOUND THAT
IDEAS ARE OFTEN ROOTED IN PAST EXPE-
RIENCES.

THESE PAST EXPERIENCES REVEAL TOP-
ICS THAT WE HAVE BEEN INTERESTED IN
BEFORE, BUT THEN NEW OR INTRIGUING
IDEAS CAN COME FROM THE INTERSEC-
TION OF DIFFERENT TOPICS.

CHECK DESIGN VEGETATED
ASSEMBLY

LIST OF CONSIDERATIONS

FRAMEWORK
AND
ANALYSIS

NO PLANT   END

WE USE THESE EXPERIENCES, BOTH
PHYSICAL AND METAPHYSICAL TO UNDER-
STAND THE WORLD AROUND US.

THIS IS WHY VISITING YOUR SITE, OR
TALKING TO CLIENTS AND OTHERS WHO
ARE FAMILIAR WITH SIMILAR WORK IS
CRITICAL TO THE DESIGN PROCESS.
GATHERING INSPIRATION FROM MULTI-
PLE SOURCES: INTERNET, OTHER PEO-
PLE WITH VEGETATED WALL ASSEMBLIES,
BUILDINGS WITH VEGETATED WALLS

TOPICS FOR IDEATION

IDEAS:
GATHER IDEAS FROM THE BOUNDARIES OF OTHER TOPICS AS THE
OVERLAPS MAKE INTERESTING QUESTIONS FOR IDEAS

PRINCIPLES:
DECIDE ON PRIMARY AND SECONDARY DESIGN DECISIONS AND PRINCI-
PLES. WHAT DRIVES THE DESIGN AND WHAT ARE SUPPORTING FEATURES
THAT WILL GIVE WAY TO THE MAIN IDEA?

METHODS:
DO NOT LIMIT IDEAS FOR FEASIBILITY. UNPLAUSIBLE IDEAS CAN
BE MADE PLAUSIBLE WITH REFINEMENT THROUGH THE PROCESS

THESE PAST EXPERIENCES WILL REVEAL
THE PRINCIPLES THAT ARE USED TO OR-
GANIZE AND PROVIDE GUIDANCE FOR
PROJECTS. THESE EXPERIENCES ARE
ROOTED IN INTERESTS OR OTHER THAT
ARE THEN APPLIED LINES OF INQUIRY TO
THE LARGER PROFESSION

PERSONALLY THIS TRANSLATED TO VEGE-
TATED ARCHITECTURE AS I HAVE ALWAYS
FOUND PLANTS AND NATURE AS AN IN-
TERESTING PART OF OUR LIVES. THEN
COLOR THEORY WAS USED TO ORGANIZE
THE INQUIRY INTO THESE PLANTS.

CHOOSE WALL
TYPE AND PLANT
SPECIE(S)

LIST OF CONSIDERATIONS

THESE THEN ARE APPLIED TO AN AREA OF
ARCHITECTURE: THE BUILDING ENVELOPE
AND HOW THESE INTERACT WITH OUR EX-
PERIENCE OF ARCHITECTURE, RESULTING
IN THE STUDY OF VEGETATED ASSEMBLIES
SUCH AS GREEN WALLS AND ROOFS

IMPLEMENT IN
DESIGN
ITERATE WITH MAIN
FRAMEWORK

CRITERIA TO CONSIDER

Appendix AE: Ideation is making ideas, the stuff that thoughts are made of. These come from a variety of sources such as interests in the discipline or past experiences.

Appendix AF: If we have little experience with then we need to collect information. This is a part of schematic design [Appendix AD] and pre-design [appendix AC] and responds to certain desires of the designer. Characteristic collection is often done in conjunction with the project criteria [appendix AG].

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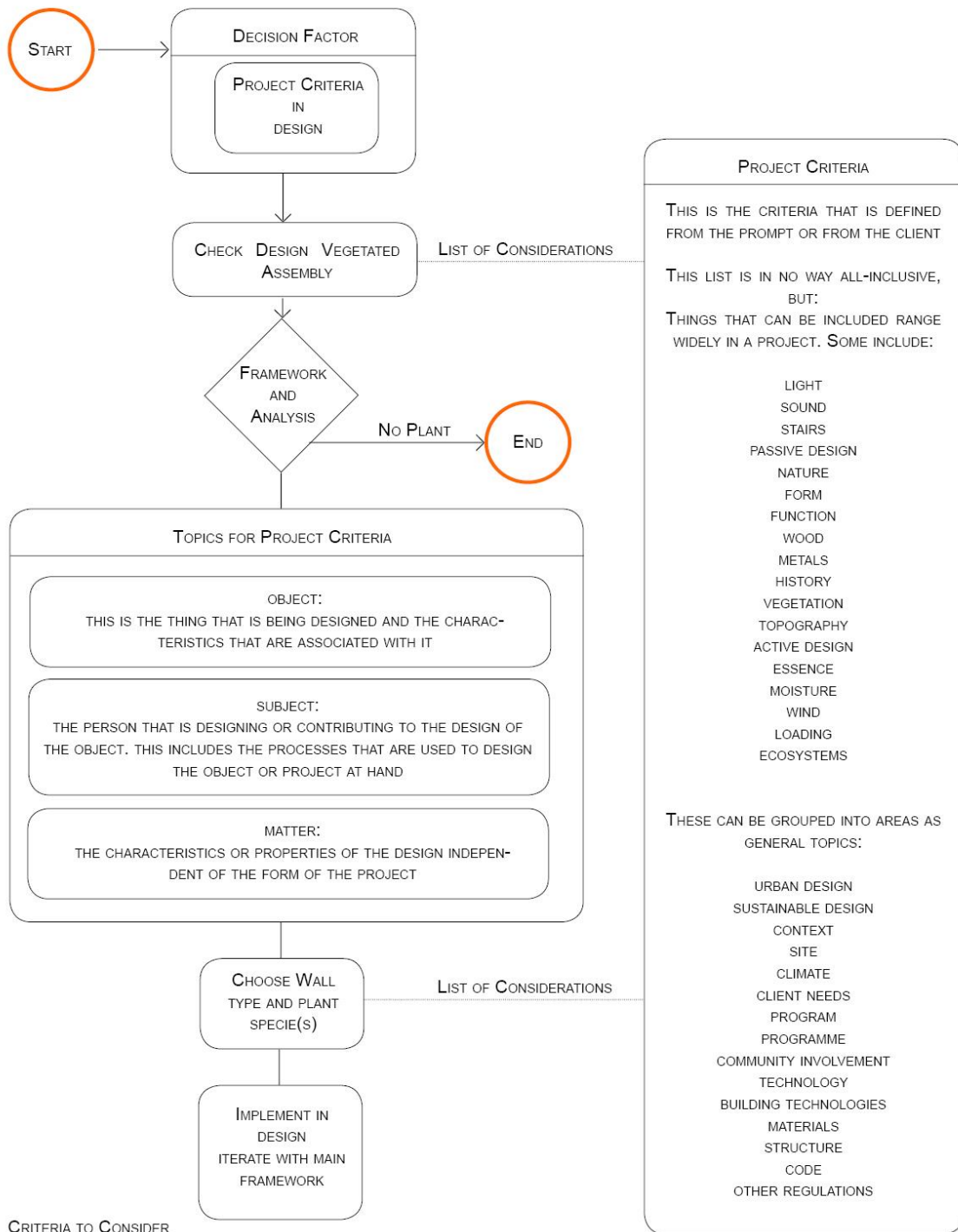
Appendix AG: These criteria are directly from the prompt, or the object at hand. This is best understood with pre-design [appendix AC] and characteristic collection [appendix AF].

Appendix AH: This is one of the major concepts in design and architecture: how to show or explain ideas to others. Quite frankly this is something that needs to be considered during all of the phases of design.

START

DECISION FACTOR

ITERATION
IN
DESIGN

CHECK DESIGN VEGETATED
ASSEMBLY

LIST OF CONSIDERATIONS

FRAMEWORK
AND
ANALYSIS

NO PLANT

END

TOPICS FOR ITERATION

VISUALIZATION
RAPIDLY CREATE MODELS AND SKETCHES TO HELP VISUALIZE THE
PROJECT AND OBJECT OF DESIGN

REFINEMENT
REFINE SKETCHES AND MODEL MAKING, WHILE CONSIDERING DESIGN
ELEMENTS AND FACTORS COMPLETED IN THE SITE ANALYSIS AND
PRE-DESIGN PHASES

ITERATION
ITERATE ON STRONGER IDEAS BY COMBINING IDEAS AS FOUND
APPROPRIATE

CHOOSE WALL
TYPE AND PLANT
SPECIE(S)

LIST OF CONSIDERATIONS

IMPLEMENT IN
DESIGN
ITERATE WITH MAIN
FRAMEWORK

CRITERIA TO CONSIDER

ITERATION CRITERIA

ITERATIONS ARE VARIANTS OF IDEAS THAT CAN BE BASED ON SIMILAR IDEAS, BUT HAVE DIFFERENT METHODS OF EXPRESSION. NOT ALL BUILDING, CARS, EVEN PENS, LOOK THE SAME.

THESE SYSTEMATIC CHANGES TO A DESIGN IN RESPONSE TO DIFFERENT CRITERIA MAKE OUR SERIES OF ITERATIONS.

THE PROCESS OF ITERATING IS CRITICAL TO THE DESIGN PROCESS.
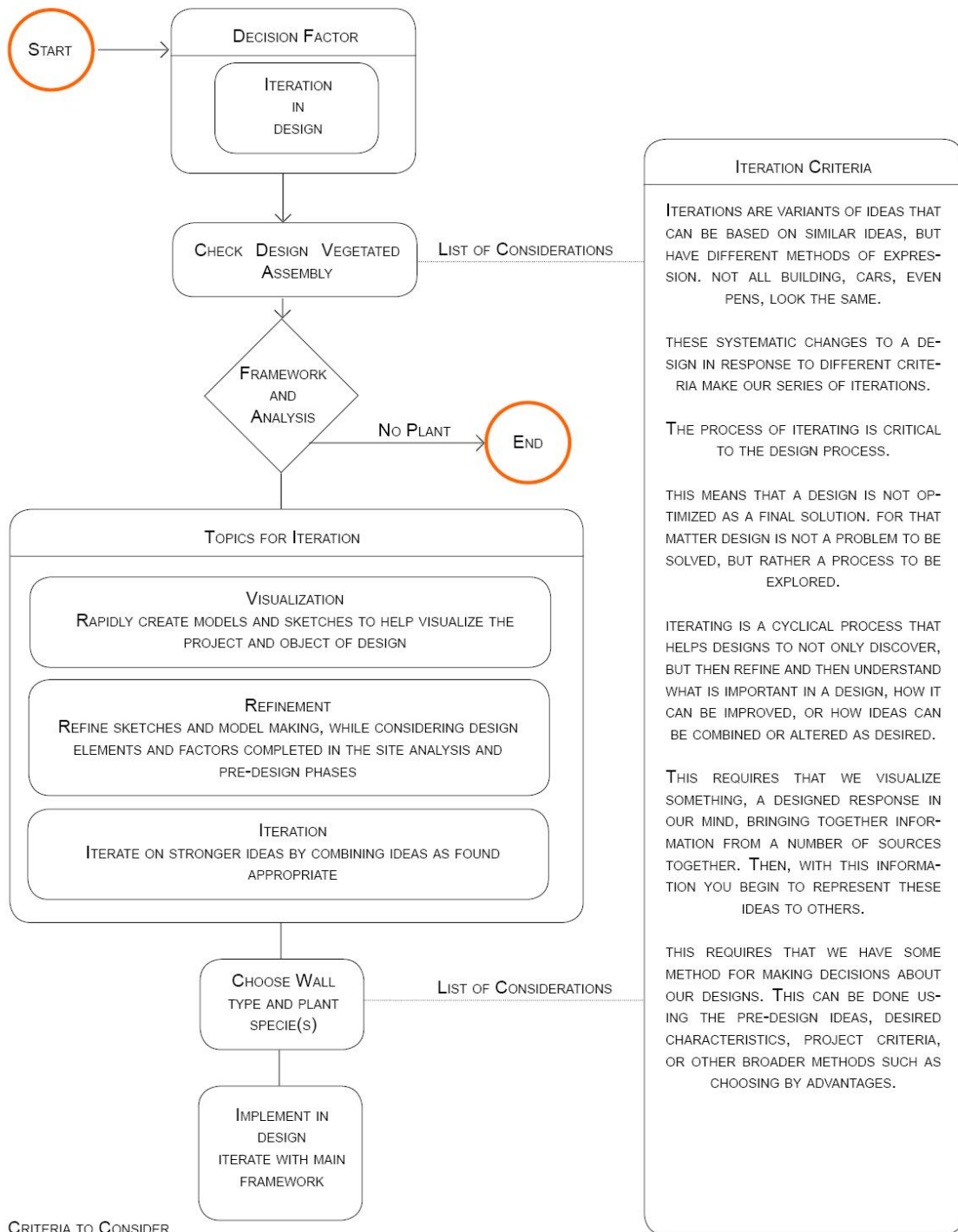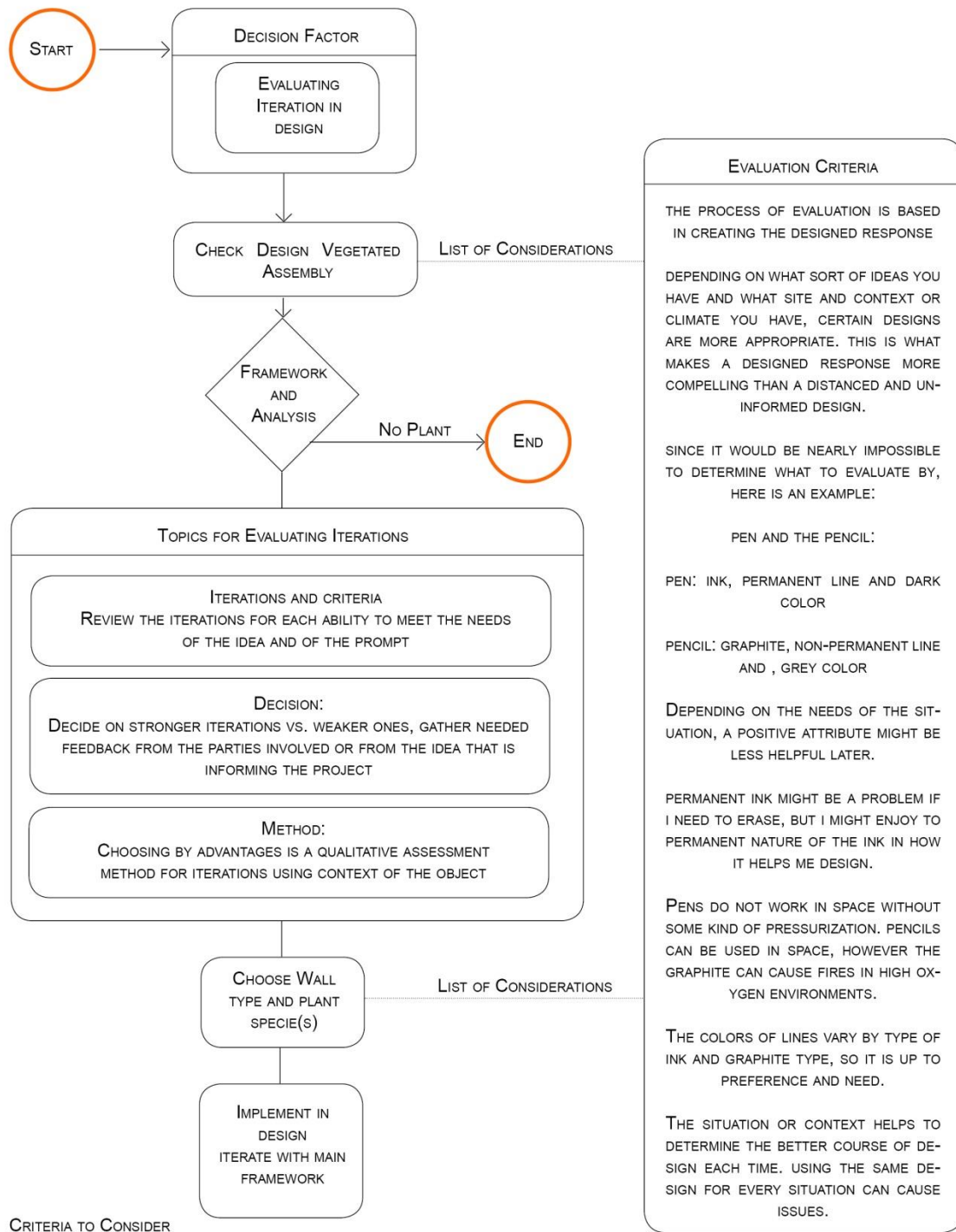
THIS MEANS THAT A DESIGN IS NOT OPTIMIZED AS A FINAL SOLUTION. FOR THAT MATTER DESIGN IS NOT A PROBLEM TO BE SOLVED, BUT RATHER A PROCESS TO BE EXPLORED.

ITERATING IS A CYCLICAL PROCESS THAT HELPS DESIGNS TO NOT ONLY DISCOVER, BUT THEN REFINE AND THEN UNDERSTAND WHAT IS IMPORTANT IN A DESIGN, HOW IT CAN BE IMPROVED, OR HOW IDEAS CAN BE COMBINED OR ALTERED AS DESIRED.

THIS REQUIRES THAT WE VISUALIZE SOMETHING, A DESIGNED RESPONSE IN OUR MIND, BRINGING TOGETHER INFORMATION FROM A NUMBER OF SOURCES TOGETHER. THEN, WITH THIS INFORMATION YOU BEGIN TO REPRESENT THESE IDEAS TO OTHERS.

THIS REQUIRES THAT WE HAVE SOME METHOD FOR MAKING DECISIONS ABOUT OUR DESIGNS. THIS CAN BE DONE USING THE PRE-DESIGN IDEAS, DESIRED CHARACTERISTICS, PROJECT CRITERIA, OR OTHER BROADER METHODS SUCH AS CHOOSING BY ADVANTAGES.

Appendix AI: Iteration is doing a process more than once. It asks the designer to look at the same design question and answer it from different core ideas or perspectives. It boils down to having different options to choose from that might be fundamentally different.

Appendix AJ: After you have multiple iterations it is good to revisit the core idea that the designer intended, for example the project needs and the site analysis. Does it meet the issues presented? Do this with Choosing By Advantages [Appendix AM].
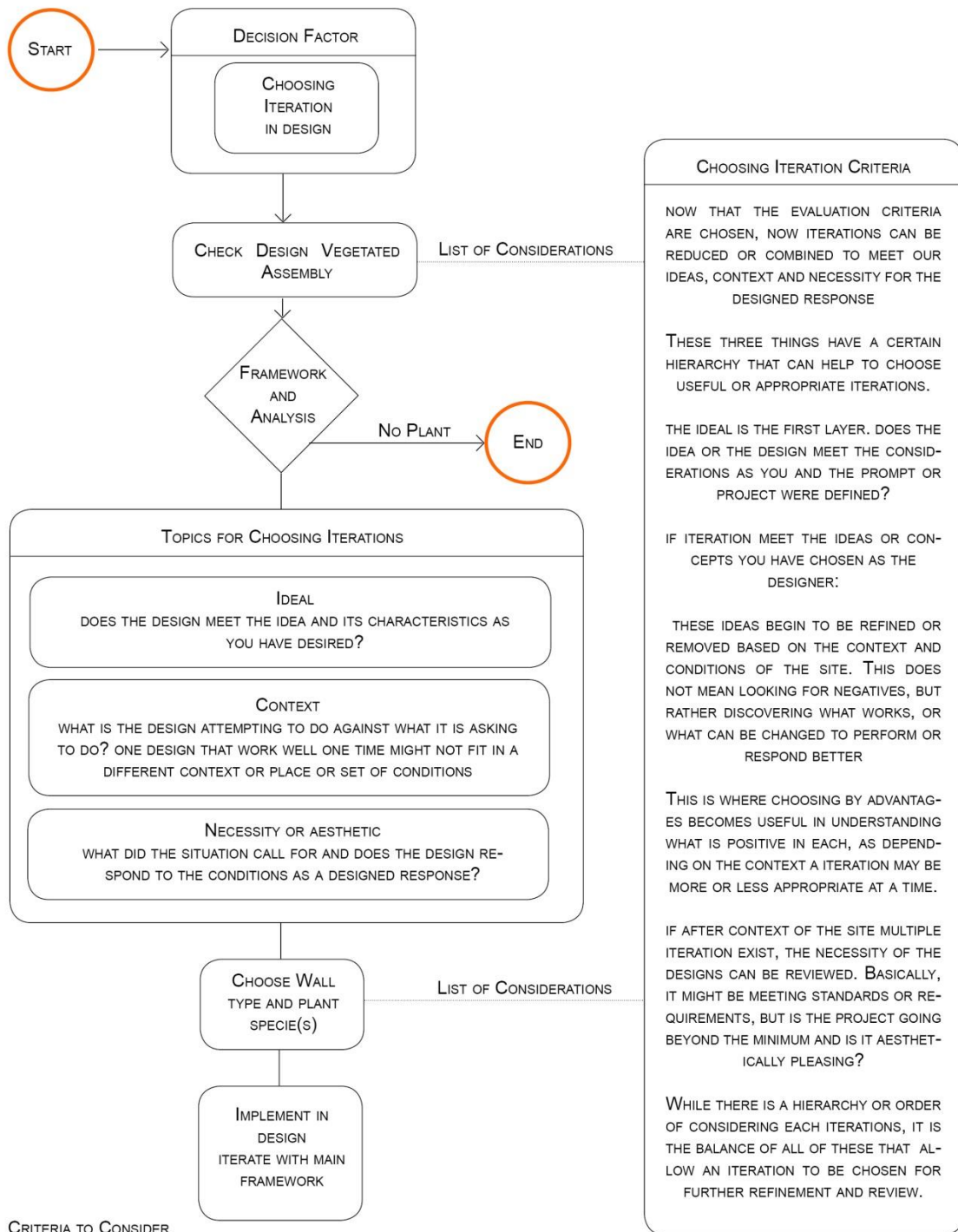
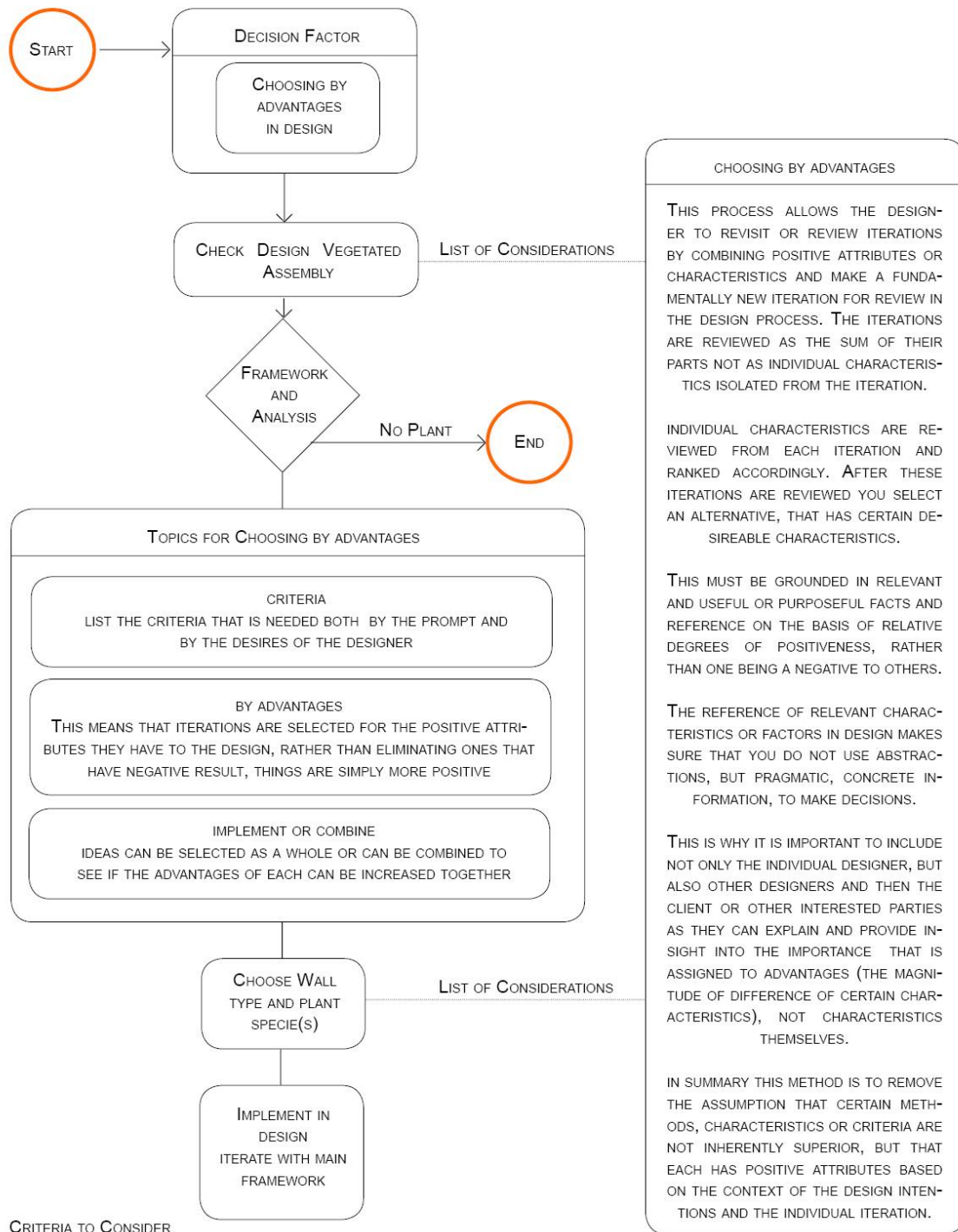**Appendix AK:** After the iterations are evaluated, next comes choosing iterations. This is not a zero-sum game. Parts of iterations might be combined or none are chosen and the process starts over, or parts of all the iterations are used. It depends on the designer, the project, and the process of architecture developed. This is good to do in conjunction with Choosing By Advantages [Appendix AM].

START

DECISION FACTOR

IMPLEMENTATION
IN DESIGN

CHECK DESIGN VEGETATED ASSEMBLY — LIST OF CONSIDERATIONS

FRAMEWORK AND ANALYSIS

NO PLANT → END

TOPICS FOR IMPLEMENTATION

MODEL:
MAKE LOW FIDELITY PROTOTYPES, IN ORDER TO CONSIDER FORM IN THREE DIMENSIONS

CIRCULAR PROCESS:
CONSIDER ITERATION PHASE AGAIN AFTER GATHERING MORE INFORMATION FROM BUILDING MODELS. THIS ALLOWS FOR THE REFINEMENT OF IDEAS

RE-CONSIDER
CONSIDER ORIGINAL DESIGN DECISIONS AND PRINCIPLES, AND SEE IF THEY ARE CONSISTENT OR HAVE CHANGED THEN BUILD IT

CHOOSE WALL
TYPE AND PLANT SPECIE(S) — LIST OF CONSIDERATIONS

IMPLEMENT IN DESIGN
ITERATE WITH MAIN FRAMEWORK

CRITERIA TO CONSIDER

IMPLEMENTATION CRITERIA

IMPLEMENTATION IS NOT MINDLESSLY PRODUCING DRAWINGS OR OTHER REPRESENTATIONS. THE IDEAS ARE STILL BEING REVIEWED AND REFINED.

TOPICS OF THE PROJECT ARE BUILDING ON EACH OTHER DURING THE WHOLE PROCESS, WHILE STILL LOOKING FOR FUTHER REFINEMENT.

WHILE DRAWING IS CRITICAL TO THE REPRESENTATION AND DESIGN PROCESS, TWO DIMENSIONAL REPRESENTATION MUST BE COUPLED WITH THE THIRD DIMENSION, THUS MODELING.

THESE MODELS ASK A QUESTION OF THE PROJECT AND ARE NOT MADE TO SIMPLY PRESENT CONDITIONS. THESE MODELS LOOK AT CONNECTIONS AND THE VOLUME OF SPACE TO GAIN GREATER UNDERSTANDING OF A DESIGN

THIS PROCESS USES THE INTERACTION OF DRAWING AND MODELING INFORM EACH OTHER AND TO FIND AREAS FOR IMPROVEMENT.

OVER TIME, THESE DIFFERENT MODELS AND DRAWINGS BECOME MORE REFINED AS EACH ARE INFORMED BY THE OTHER BY USING EACH FOR THIER RESPECTIVE STRENGTHS

AFTER RE-CONSIDERING THE DESIGN INDIVIDUALLY, PEER REVIEW AND CLIENT REVIEW ARE USED TO DEFINE AND REFINE THE DESIGNED RESPONSE AND REPRESENTATIONS

FROM THESE CRITIQUES, ONCE A PROJECT IS COMPLETE OR IT IS TIME TO PRESENT, MODELS AND REPRESENTATIONS ARE MADE OF THE REFINED AND IMPLEMENTED ITERATION.

Appendix AL: After you choose iterations the designs must be implemented either in more developed drawings, models, or other forms of representation. This is good to do with Choosing By Advantages [Appendix AM] in mind.

Appendix AM: Depending on the context iterations and ideas can be the most positive or advantageous when designed. Though Choosing By Advantages is detailed in the appendices, it has not been used in the dissertation as an example and was selected after the different questionnaires and design exercises were completed as a method to strengthen the decision support system.
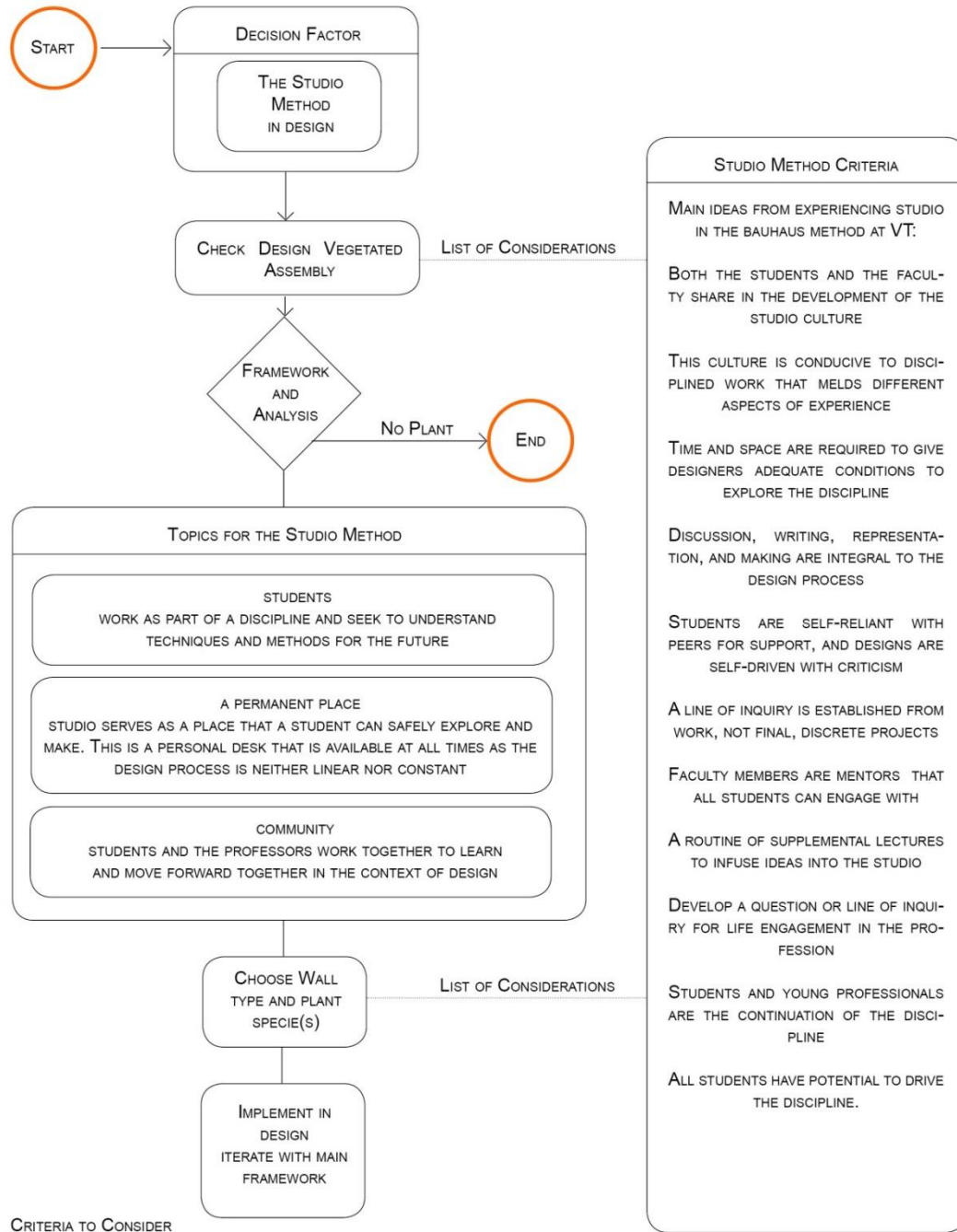
Appendix AN: In the end it comes down to the environment you are working in. If it is stressful or not conducive to design, the design process will be more difficult to implement and its results will vary widely. This is specific to architecture, but it can be used to develop other lab, or studio-based work environments. Since most of my experience is with Virginia Tech our major studio community atmosphere tenets are reflected.

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