# Fusion of teaching and research: Design support tools and vegetated walls

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ABSTRACT: Architectural 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). With the continued and increasing use of computers and digital representation, the design process should not become prescriptive or formulaic. Technology, such as computers, has given students many opportunities to design previously not available, for example, Adobe Photoshop, Grasshopper, and Google SketchUp. Will their method of representation be by hand, digital, or both?

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 in relation to 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.

The purpose was to see what and how students design when using vegetated assemblies and what tools or technologies they chose to represent ideas and make decisions. This was done to confirm that the targeted programs for use in a future prototype tool were in fact the programs students used. 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.

The envisioned tool will help inform designers, but not make decisions for them. This initial research refined assumptions made about programs to target in the prototype tool, and confirmed a self-identified student need for a tool. A larger study is aimed at changing the way buildings are designed by creating a prototype tool for the representation of vegetated walls focusing on color theory.

KEYWORDS: Architecture, Design Research, Research, Student Research, Vegetated Assemblies

## INTRODUCTION

This paper focuses on lessons learned from a pilot two-week project in a second-year architectural design studio with a view toward the future creation of a prototype tool to aid the design of vegetated walls. This two-week project provided insight for a future larger and longer studio and a new design support process, which will provide a framework to help novice students and designers to make decisions. The students targeted for the subsequent semester-long studio will most likely be fourth-year students. These fourth year students will help to determine how designers (students) currently address the process of representation and decision-making as it relates to vegetated assemblies. From this understanding of the current process employed by students, a framework for a design support process (DSP) will be created with the intent of developing a prototype tool. The prototype tool would be a computer program to help in the representation of vegetated assemblies, most likely in the form of a computer program combined with cross-checking databases. After the development of the DSP, a second studio with fourth-year students will be implemented to include the use of the DSP and the prototype tool. This second studio will serve to validate both the DSP and the corresponding prototype tool for vegetated wall systems as students employ it in their design work.

## 1.0 BACKGROUND

### 1.1. Areas of inquiry for the new prototype tool

The study has four main concepts: aesthetics, decision theory, color theory, and plant biology. This study will engage aesthetics from a phenomenological view. This philosophical view is concerned with the study of consciousness from personal observations. The critical experience of phenomena is in considering the content or meaning given to an object in light of our own notions and thinking.

First, aesthetics can be defined as a strain of philosophy dealing with the nature of beauty, and encompassing questions of, for example, proportion or composition. However, there are many different kinds of interpretations of aesthetic beauty. Immanuel Kant believed aesthetics to be a subjective experience of beauty, universal in function only when disinterested (Kant and Walker 2008). To Friedrich Schiller, aesthetic appreciation of beauty was the most perfect reconciliation of the sensual and rational parts of human nature (Schiller and Snell 2004). As expected, methods of thinking or expression that are subjective in nature, such as architectural design, have many different aesthetic definitions or processes.

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. The design support structure that will become the prototype representation tool in this research will help designers make decisions, but not make decisions for them.

Finally, color theory, according to Goethe, is a guide to the nature of colors and how these colors are perceived by humans (Steiner, Goethe, and Barnes 2000). His understanding of color centered on how the phenomena of color are perceived and was less concerned with analytic properties. However, this is only one view of color theory and this concept is interpreted in many ways. Color theory in this study is used as one of the criteria for selecting plants in the future framework and prototype tool. Color in plant biology can influence the appearance and representation of a vegetated assembly over the course of the seasons.

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. Plant biology is useful in determining plant species since vegetated walls use plants as a main component and their color can vary widely. This research engages questions students may have, but not know where to find answers to, such as: What kinds of plants are adaptable to vegetated assemblies in the southwestern Virginia climate zone?; Are there compatibility issues between types of plants selected in assemblies?; and What are possible implementation issues for plants that are adaptable in vegetated walls?

But beyond this, this study begins to investigate reasons why people find plants and nature desirable. According to Edward O. Wilson, this desire, called biophilia, is an appreciation of life and the living world (Kellert and Wilson 1993). The research aims to discover how plant biology and the practicalities of incorporating vegetation on the envelope of a building can be combined with color theory in the design of vegetated building assemblies.

## 2.0 METHODOLOGY

### 2.1. The as-is process in studio and the studio prompt

In this preliminary study, a group of students were given a two-week project in a second year studio with the requirement to use vegetated assemblies. Their work was reviewed in relation to what types of design representation and methods were chosen and how they were used in support of their design decision-making process, which was termed the “as-is” process. The purpose of the current study was to see not only what the students designed when using vegetated assemblies, but how they designed. The study documented the tools and technologies the students chose to represent their ideas and to help them to make decisions. This was done to determine whether or not the targeted or anticipated programs planned to accept 3D models in the new prototype tool were in fact the programs students or would use.

This first project used the teaching method of the second year studio and a two-week project module to determine how students interacted with a project based on previous experiences. The studio used a series of two-week projects to keep the students in an iterative mindset and to make decisions about projects quickly, within the constraints provided by the brief and site. This project was a learning experience for the lead author, as he was the teaching assistant, and the professor, Mario Cortes, reviewed and approved the project. It was 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 tool. The following was the studio prompt for the two-week project involving an amphitheater near the Duck-pond on Virginia Tech’s campus. The project was designed to get the students

thinking about a larger site context rather than a singular location when implementing vegetated facades. The prompt given to the students read as follows.

> *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 at the site. This project has the opportunity to serve as a place to entertain and showcase performance arts such as theatre and cinema. Treat the project as an extension of the surrounding area, including the President's ability to entertain guests.*
>
> *Some important 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. 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 page presented at the end of the project period.*

**Figure 1:** Prompt for the studio to the students

### 2.2. Reviewing the as-is process after project completion

After the completion of the vegetated wall and amphitheater studio project, a survey was given to the students in an attempt to discover their desire or need for a design tool, and how this related to the expertise of the individual. The survey included the following questions and statements.

03: Have you used vegetated assemblies in a project before?
04: What kind of drawing techniques did you use? (You can select digital and/or hand-drawn)
05: What kinds of techniques did you use during the project?
06: What kinds of pens of pencils or paper for hand-drawing, or what programs for computers?
07: I understand the considerations involved in designing vegetated assemblies.
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.
11: I understand how I can design vegetated assemblies in studio.
12: Building users provide valuable insight into the design of vegetated assemblies.
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.
14b: What were some of the projects?
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.
18: I understand the difference between the various types of vegetated assemblies.
19: I understand the major obstacles to implementing vegetated assemblies.
20: Vegetated assembly suppliers provide valuable insight into vegetated assembly design.

From this initial exploration of the process undertaken by each student to design their project, the new prototype tool can reflect the nature of the design process. This future tool will be introduced back into a studio environment to see how the design process was influenced and assisted by the addition of the tool.

## 3.0 RESULTS

### 3.1. Results of the as-is process survey

As shown in Table 1, which addresses questions 3 through 6, 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. Figures 2 through 4 show the range of media used in the design studio.

**Table 1**: Number of students in relation to experience and method used in vegetated assemblies

| 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 |

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. For example, the framework and the prototype tool would need to be able to take scanned images as well as exported files from Rhinoceros, Photoshop, Illustrator, and Google SketchUp for use in the tool. Illustrator was a program that had been overlooked initially, but will also be included as it is the vector-based version of the Adobe software often used in conjunction with Adobe Photoshop. Adobe InDesign was mainly used to design layout of presentation materials for the projects, rather than design development. 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).

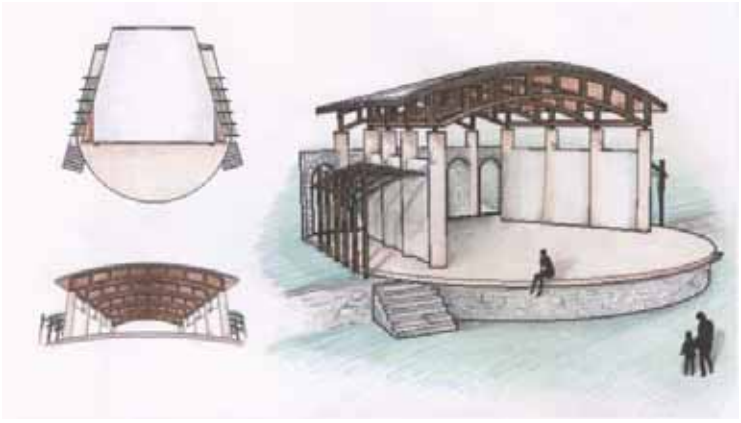
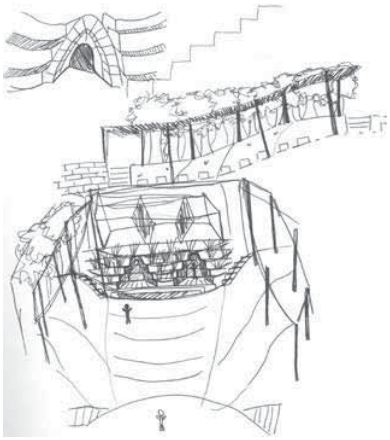


**Figure 2**: One student's amphitheater, using hand renderings of a google sketchup computer model

**Figure 3**: Another student's amphitheater, hand drawn and hand rendered

**Figure 4.1:** A third student's amphitheater, digitally rendered in google sketchup

The students were asked to keep a journal or sketchbook as a record of their initial design process and thoughts on the project. One of the topics that showed up consistently were notes on the site conditions and initial impressions of the space framed at the site and how this would be incorporated into their design process. Some examples were: the wind through the trees, sunlight shimmering in the leaves, either developing a sense of seclusion or invitation, amplifying sounds, or using the topography. The images below are from the sketchbook of the same student who proposed the space in figure 4.1, above. This particular student explored both of the categories (hand drawn and computer-aided) during the project period.



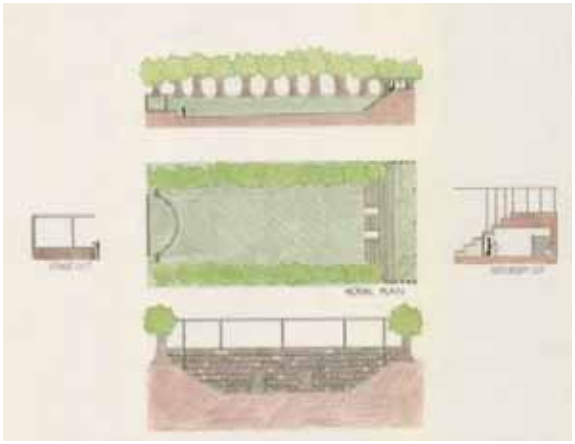


**Figure 4.2, 4.3**: Sketchbook to hand-drawn constructed drawings, then the computer rendering in figure 4.1.

The students made a number of interesting responses to the survey. Some selected responses are shown in figure 5, and explained in detail below. The remaining questions are shown in comparison in figure 6. From the set of questions and statements listed previously, 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 Figure 5 out of 12 student responses per statement.

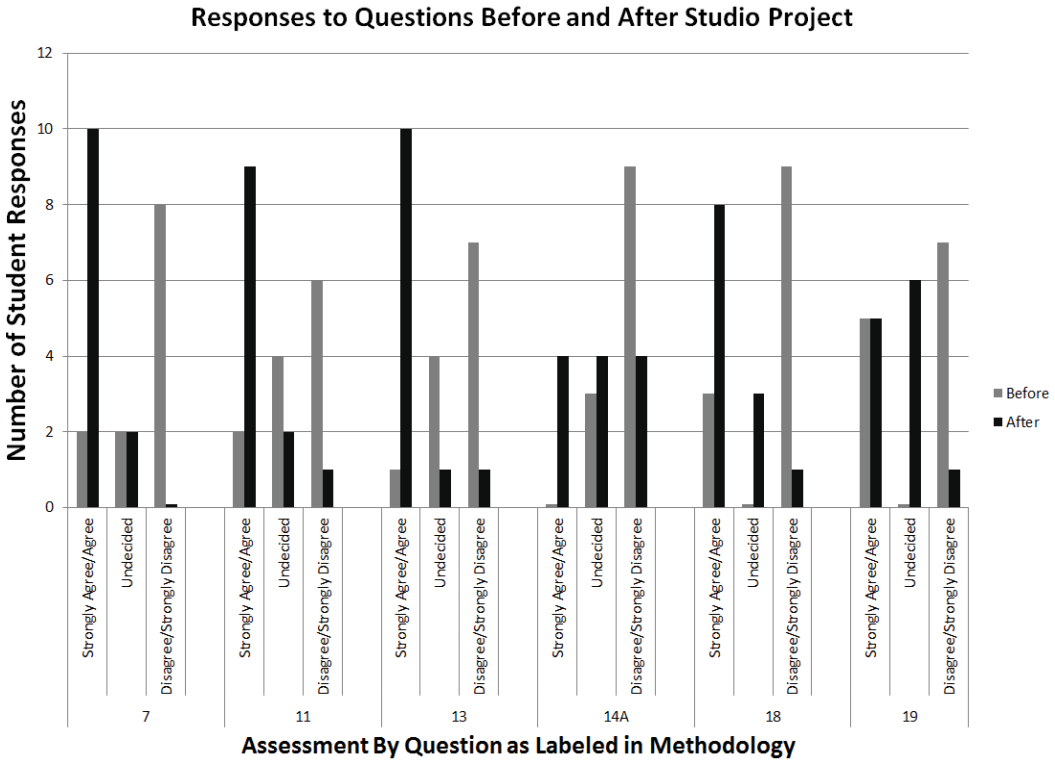



**Figure 5**: Selected responses to questions before and after studio project

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.

Figure 6 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.

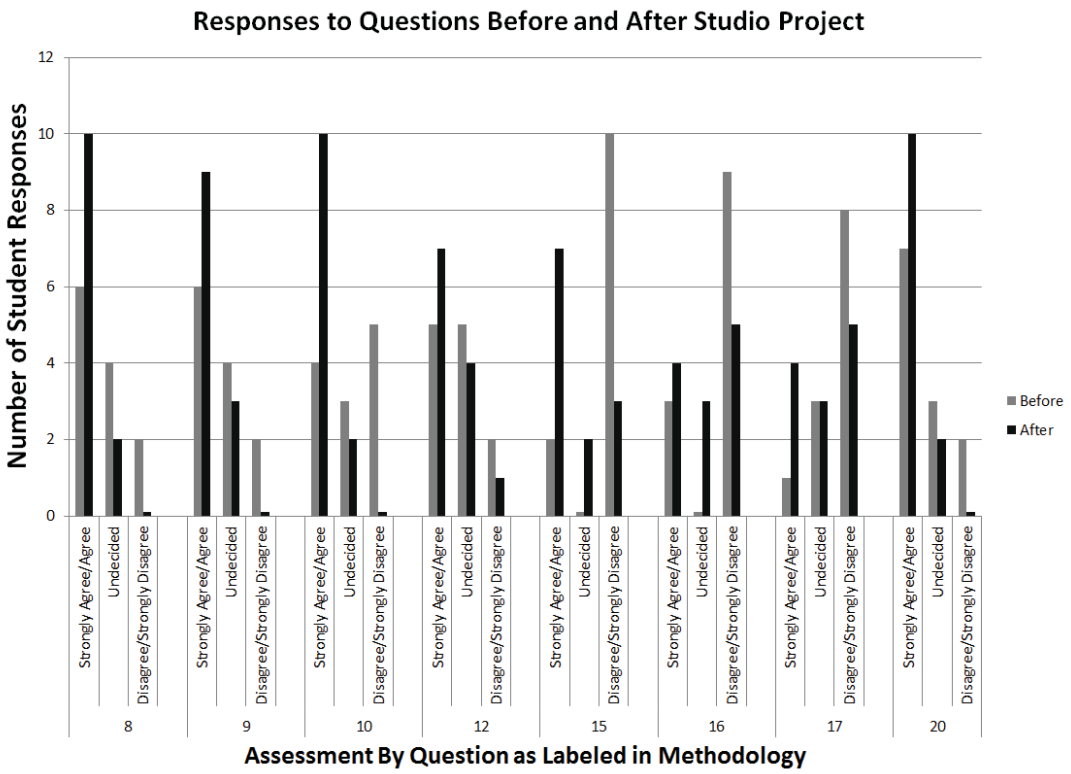



**Figure 6**: Remaining responses to questions before and after studio project

## 4.0 DISCUSSION

### 4.1. The To-Be Model in relation to the As-Is Interpretation

From these results in the survey, the method for exploring the new prototype tool was diagrammed from ideation to the tool. This served as the initial mapping of decisions that would be used in formulating the tool.

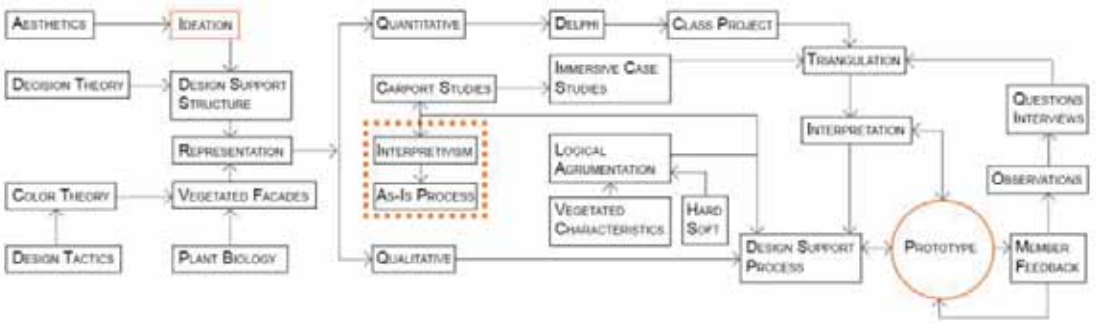



**Figure 7:** Theory map for the prototype tool methodology; the dotted rectangle shows the work of this study

The project brief using the design of an amphitheater to guide students into understanding vegetated walls was beneficial. Looking at the questions from the survey, students have a greater understanding of vegetated assemblies after having completed the design process, but still lack some major components necessary to the design of such assemblies. These include a greater understanding of plant biology and its interaction with color, where descriptions of cultivated species can be found from growers; and the obstacles of implementing vegetated assemblies in design. While some information was lacking in the survey, it provided the basis for solidifying the framework for a decision support process, and identified a need for

features that will be critical for a prototype tool, such as lists of growers, precedent studies, and color theory representations. By understanding the aesthetic characteristics and representations of vegetated assemblies, a future design support tool will integrate aesthetic design with vegetated assemblies through synthesizing vegetation/plant growth, color theory, and design decision-making in a prototype tool.

## CONCLUSIONS

This study was the first stage of a research agenda to discover the characteristics of vegetated elements in architectural design in reference to color theory and plant biology. Among other questions, designers need to consider what kinds of plants are adaptable to vegetated assemblies. They need to consider compatibility issues between types of plants selected. Finally, they need to consider possible implementation issues for plants that are adaptable in vegetated walls, such as watering, pollination, or root depth.

From the two-week pilot studio project, several observations can be made. While all of the students had the same project and parameters, a wide variety of responses were designed. The investigation into the representational styles of students in their second year of development is also important. While this project represented only the fourth architectural project in these students' academic studies as architecture students, they already had developed distinctive representational styles and methods that students employ will change and develop further. Another purpose of this study is to determine at what point in a student's development a decision support process and/or a prototype tool would be the most helpful.

The results from the survey statements show us that the professor provides a large amount of information and control in the understanding and comprehension of topics, in this case vegetated assemblies. To specifically address areas where the students reported a lack of understanding or knowledge, the prototype tool should include information that can provide examples of precedent projects as reference, a list of possible suppliers, a list of plants useable in the project's climate zones, as well as demonstrations of possible means of representing the vegetated assemblies that they design. For example, in their responses to statements 15 through17, after the project, students knew more about vegetated walls, but relatively less about vegetated roofs, suggesting that without specific instruction about vegetated walls, the students would have understood them in a similar manner to vegetated roofs. Since this is the first author's personal specialization, this also suggests that the teaching and research that either a professor or a professor and students do together can greatly influence the interest of students in particular topics from exposure to new information. Using the information presented by the prototype tool, the professor and the student/designer can then analyze proposed designs in light of the real constraints of vegetated systems.

## CONTINUATION

This study was the beginning of a much larger study into the representation of vegetated assemblies. By confirming what methods and programs students use for representing vegetated assemblies, we can begin to target these programs for use with the future prototype tool for design support. If the students are familiar with programs and the prototype tool in their formal education, then these programs and methods can be used to conduct research into not only vegetated assemblies, but other aspects of architecture throughout their careers. The ultimate goal of this longer study is to determine a useful prototype tool for the future conductors of design research: our students. Finally, the software used by students in this pilot study will be reviewed in both academic and professional settings for use in the prototype tool.

## ACKNOWLEDGEMENTS

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