

# Virtual Sketching: Instructional Low Resolution Virtual Reality Simulations

■ Antonieta Angulo

Ball State University  
aangulo@bsu.edu

■ Guillermo Vásquez de Velasco

Ball State University  
guillermo@bsu.edu

## Abstract

*This research paper describes the implementation of virtual reality immersive simulation studios in academia, facilitated by the use of the "Virtual Sketching Method" (VSM). The VSM allows the basic expression of architectural forms and the perceptual experience of interior and exterior spaces. It fosters simulations based on render-less (low resolution) visualization in contrast to other simulation workflows based on render-more (high resolution) visualization techniques. It bridges between different types of media and supports iterative cycles of formulation, prototyping, and assessment. The paper reports on students' learning outcomes and their qualitative correlation with the VSM usability and effectiveness in design learning.*

**Keywords:** Virtual Reality, Immersive Simulation, Spatial Design, Virtual Sketching, Design Instruction

## Introduction

Our previous research and teaching efforts have been dedicated to implementing virtual reality (VR) immersive simulation studios that would permit novice students to undertake spatial design (Angulo & Vasquez de Velasco, 2014). The main objective has been to expand the limited and mistaken notion that regards architectural objects as simple artifacts with merely formal exterior appeal. Our objective has been to reinforce the concept that architectural objects may provide us with multiple perceptions of inner and outer cohesive formal expressions. Spatial design considerations may induce the student to switch focus from the outside to the inside and vice versa on a cyclical basis. We have used the CAP VR Environment at the College of Architecture and Planning (CAP) in Ball State University as a tool that students may use to visualize exterior volumetric shapes but also their corresponding interior spaces. The CAP VR Environment has been used to simulate real spaces, projects for final presentation, and projects at different stages of elaboration with varied levels of detail. The CAP VR Environment supports simulation of layout options and movement inside spaces. It has been also used to simulate visual aspects of interior spaces with the explicit purpose of making the affective appraisal of interior architecture possible. In this paper we report on the latest implementation of the CAP VR Environment that was aimed to support design learning during the actual design

process in academic environments. The use of the CAP VR Environment as a learning tool demands a clear method to provide efficient and timely support during any stage of the design process, but most especially during conceptual stages. The Virtual Sketching Method (VSM) has been developed to provide such a support and was implemented for the first time during the 2015 academic spring semester. Based on the results of our first experience, we are currently implementing an improved version of the VR immersive simulation studio using the VSM during the 2015 fall semester.

## Virtual Sketching Method

The act of traditional sketching has been related to the execution of graphic work that might record something that the artist sees, it might record or develop an idea for later use or it might be used as a quick way of graphically demonstrating an image, idea or principle (Wikipedia, n.d.). Sketching has long been embraced by architects as a versatile tool for exploratory design (Schweikardt and Gross, 1998). In virtue of the most distinctive advantages of sketching (1) the simplicity of its way, (2) the speed, and (3) the easiness to catch ideas it has been regarded as the designer's principal means of thinking (Seok-Hyung Bae et al., 2003). Sketching is part of a broader and comprehensive design process, it belongs to a continuum in which the designer re-interprets the sketches and moves on to the creation of other design

representations that are subjects of specific development, and that eventually would trigger the creation of more sketches. In this research the VSM embraces any and all means that are available to create bridges between the traditional sketching and its digital interpretation. This digital interpretation is a representation that captures the sketch's ambiguity but at the same time provides enough foundation to grow into a more refined schematic or detailed solution. Under the VSM a digital model is regarded as incomplete and ill-defined as necessary until all moving parts of the design are set into place. Ambiguity of three dimensional models is possible in different ways; some programs commonly use different levels of abstraction to reveal detail when necessary (i.e. Autodesk Revit). The level of ambiguity that the VSM encourages is concerned with the simplicity and the speed that it could provide to the novice designers when visualizing their spatial ideas in the CAP VR Environment. Ambiguity can be achieved through the following strategies: (1) using basic geometrical representations, (2) elimination of small geometrical detail, (3) using standard color maps on surfaces of models, (4) avoiding material textures, and (5) the use of default lighting.

While traditional sketching may easily help to catch ideas, its digital counterpart under the VSM would require the designer to add more information; testing of the relative validity of the emergent representation would immediately follow thus propelling the design forward. We have usually experienced that in the translation of medium from analog to digital, and vice versa, students have discovered unexpected but valid design inferences.

Studies about the role of schemata in memory of places (Mania, et al., 2006) have concluded that gross quality of the rendering (render-less) is adequate for schema related spatial information to be recalled, compared to non-schema objects that require detailed inspection (render-more) of a photorealistic scene. According to these findings, we can infer that if when performing spatial design at a very conceptual level we rely on incomplete representations it is because our memories of similar spatial configurations can help us to fill in the blanks of information not present. As our schemata helps us to interpret ambiguity, the VSM would encourage students to use the minimal rendering resolution possible for commonly known objects while selectively adding more resolution to the elements that are novel and deserve more attention during the simulation. The VSM doesn't preclude any instances under which traditional sketching may happen, in fact it encourages the students to implement hybrid methods through scanning, digital sketching on tablets, and more. The VSM fosters any modeling application that eventually uses a scanned sketch as an under-layer for the creation of vector models in three dimensions. The easiness by which the initial sketches get translated into simple models for simulation is key in the VSM. We have specified several alternative workflows that students follow to expeditiously sketch an idea, interpret it, and visualize it using the CAP VR Environment even during a single studio

afternoon session. As detail and material qualities of objects are intentionally muted, the geometrical properties dealing with spatial design, such as size, scale, proportion, position of parts, perforations, density, openness, alignment, circulation flow, among others are highlighted. The VSM also promotes the use of low resolution associated models (i.e. foliage, people, and furniture) as they can serve to emphasize human scale.

## Design Studio Implementation

During the 2015 spring semester, a sophomore design studio undertook the design of a patio addition for a well-known restaurant in Muncie, Indiana: The Damask Café. The students were distributed in teams of two members aiming to produce a finalized project in four weeks. In addition to the design of the outdoor structure/envelope sheltering the patio, the project also included the re-design of the entrance(s) and/or other adjacent features that would tie the addition with the existing building, namely: doors, windows, trellises, screens, parking lots, and landscape features as necessary. The project also included the design of interior furnishings. See figure 1 showing the location of the Damask Café with a temporal tent covering part of the area where the addition is planned to be built (Google Maps, n.d.).

The project was undertaken at conceptual and schematic levels with objectives that included: (1) appropriate tectonics (light timber structure), (2) effective layout (desired occupancy and circulation), (3) environmental performance (control over solar exposure, rain, street noise; natural ventilation), (4) seasonal use during spring and summer (dismantled during fall and winter), and (6) aesthetically pleasing (formal/spatial elegance).

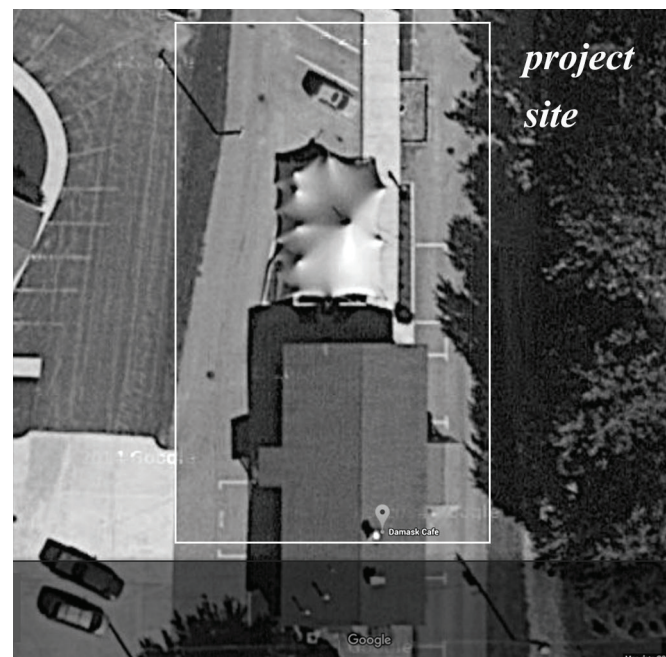


Figure 1: The project site includes the surrounding sidewalks, parking spaces, and the area currently occupied by a seasonal tent.

Consistent with the rubric of the VSM for use in the CAP VR Environment, we chose this project to be small so as to help us effectively pace and anticipate the design stages and easily observe/record the work of the students. Despite its small size, we ensured that the design problem was infused with enough qualitative elements so the students could regard the design of the patio addition as the design of a signature space (Angulo, 2013). Signature spaces convey meaningful information about significance; they can even express the character of what the building is going to be known for. Thus, we expected that the future addition to the Damask Café could convey the image and the branding of the restaurant.

The VSM was described and explained to the students as part of a suggested design process. The process included the following general steps:

#### Survey of the site:

During a field trip to the project site pictures were taken and sketches were produced inside and outside of the existing building. Measurements and qualitative annotations were also taken as part of the survey.

#### Introduction to the CAP VR Environment:

We have used the CAP VR Environment since 2012. It is a head mounted display (HMD) VR solution that makes use of four infrared cameras to track the presence of the viewer in a three dimensional model (WorldViz, n.d.). The quality of the system ensures an effective visualization based on efficient playback and minimal image lagging to avoid cybersickness. Our sophomore students used the CAP VR Environment for the first time to navigate inside simulations of architectural projects. The simulations were of high and low resolution. See figure 2 showing students exploring several virtual environments.



Figure 2: Sophomore students holding the remote wand and wearing the HMD tracked by four infrared cameras. The flat screen shows images of what the interactive VR viewer can see.

Navigation in the virtual reality model of the actual Damask Café was also included in this first experience. This VR model showed its four elevations and the parking lot, all surrounded by a day-lit spherical background; the interior spaces of the restaurant were not included. The Café was modeled with enough detail to simulate the experience of

approach as coming from the parking lot and to show the entrance to the Café and its spatial link to the prospective patio addition. This VR model was baked (render to texture) with photorealistic textures, using a daylight system and some artificial lights simulating a sunny summer afternoon. See figure 3 showing the VR model as seen using the VR software Vizard. The animated background and avatars are scripted additions in the program. After the navigation experience the students filled out survey #1.

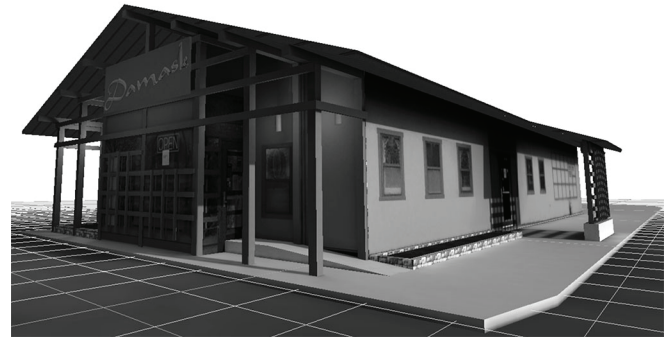


Figure 3: Virtual Damask Café as seen using the VR Vizard Inspector.

#### Briefing with the Damask Café owner:

The owner of the Damask Café, Mr. Basaam Hewani stated that that the theme of the Café made reference to the Damask fabric of Syrian origin. "Just as Damask fabric is made by the delicate interplay of colors and weaves, we at Damask Cafe believe that great food is created by the artful mixture of flavors, color and atmosphere" (Damask Café, 2014). This theme provided initial inspiration for the architectural concepts of the patio addition.

#### Formulation of ideas:

Concepts depicting intentions were formulated accompanied by not only sketches but also included small physical models. These representations illustrated the expression of the place and portrayed the essence of the Café image. In addition to the statement of individual goals concerning the overall volumetric form, the students were also prompted to state objectives about the affective perception of the interior spaces, as for instance: intimacy, familiarity, privacy, objectives that were part of the conceptual branding/ imaging of the place. Objectives and evaluators for the environmental performance, in general, and spatial design, in specific, were also stated in advance during the formulation of ideas as well as the pairing of these criteria with geometrical parameters for the assessment of the alternatives.

#### VR simulation:

Our research premise states that constant iteration between traditional sketching and the production of basic, low-resolution models for visualization in the CAP VR Environment can be a significant engine that moves the



projects forward. During the development of the projects, several visualizations were performed as the designs progressed based on constant testing and feedback. Also several cycles of traditional sketching, three-dimensional modeling, and fabrication of prototypes resulted in convincing schematic solutions.

The workflows that were used to interpret and translate sketches into basic simulations included: (1) Rhino-SketchUp-Vizard, (2) Revit-SketchUp-Vizard, and (3) 3DSMax-Vizard. These were render-less methods using only standard materials within SketchUp or 3DSMax. At this stage of the design the render-more (light-based rendering) procedures were omitted. The workflows used emphasized quick file exchange between applications and easy formatting to create Vizard-ready files for the visualization in the CAP VR Environment.

The VSM allowed the assessment of the on-going solutions as the students were able to capitalize from the quick feedback that the system provided while switching back and forth between screen representations and VR immersive walkthroughs inside and outside of the spaces of the emerging solutions. At this stage of the process the representations of the design remained sketchy and devoid of material texture; there was no need for photo-realistic texture or detail as the design focused only on a comprehensive exterior-interior shape emergence.

Students noticed that the feedback provided by three dimensional representations on flat screens was not comprehensive enough to evaluate inner spaces; important information about size, proportion, depth, density, location of components, and affective appraisal of the space would usually emerge only while navigating the VR simulations.

Among other similar intentions, we expected that the students could correlate some external mass aspects with the

corresponding inner volume perceptual experience; compare the layout configurations as seen in plans with their spatial distribution when navigating inside the VR model; and verify that the direction of views' from within were as effective as expected from the perforations they were designing in the outer building shell. Most of the students were able to complete at least two full iterations using the VSM before finalizing their designs. See figure 4 showing the images of a VR project of low resolution.

#### Project presentation:

When their designs were ready, the students were asked to produce a VR model for final review using high resolution techniques. For this particular task the students incorporated a daylight system, artificial lighting, and basic material textures. They also produced a small physical scale model, and slide presentation showcasing the overall process and the characteristics of the solution. The workflow of the render-more method included baking textures in all models and formatting as Vizard-ready files to be played back in the CAP VR Environment. It took about a week to prepare the projects under this simulation standard. Our research objective at this time was to expose the students to this laborious method that could yield very gratifying results in terms of presentation of their projects. It was important for us to know how they would compare the render-less and render-more methods in terms of usability and perception of learning. During the review the projects were evaluated by reviewers and peers. Surveys 2, 3 and 4 were also available online and filled out after the review. See figure 5 showing the same project as in figure 4 in high resolution mode. Compare the images of the VR model (left) with the renderings with V-ray and image editing (right).

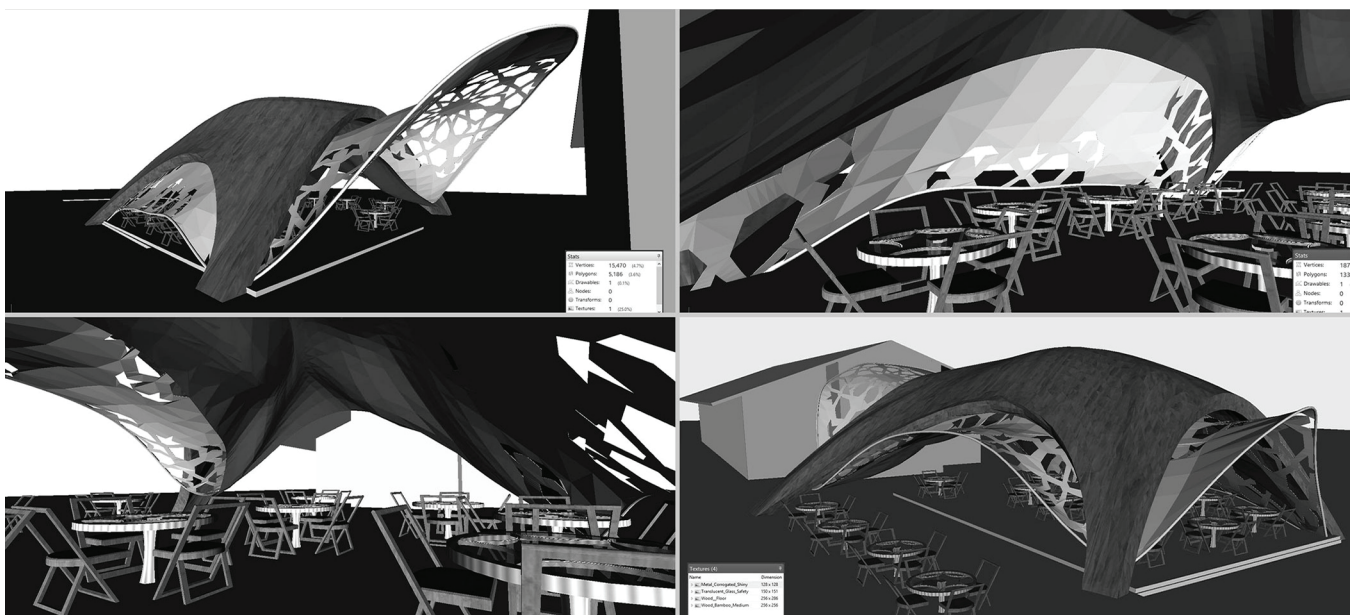


Figure 4: Render-less method using standard materials and default lighting. Project by Zack Lenza and Alayna Davidson.

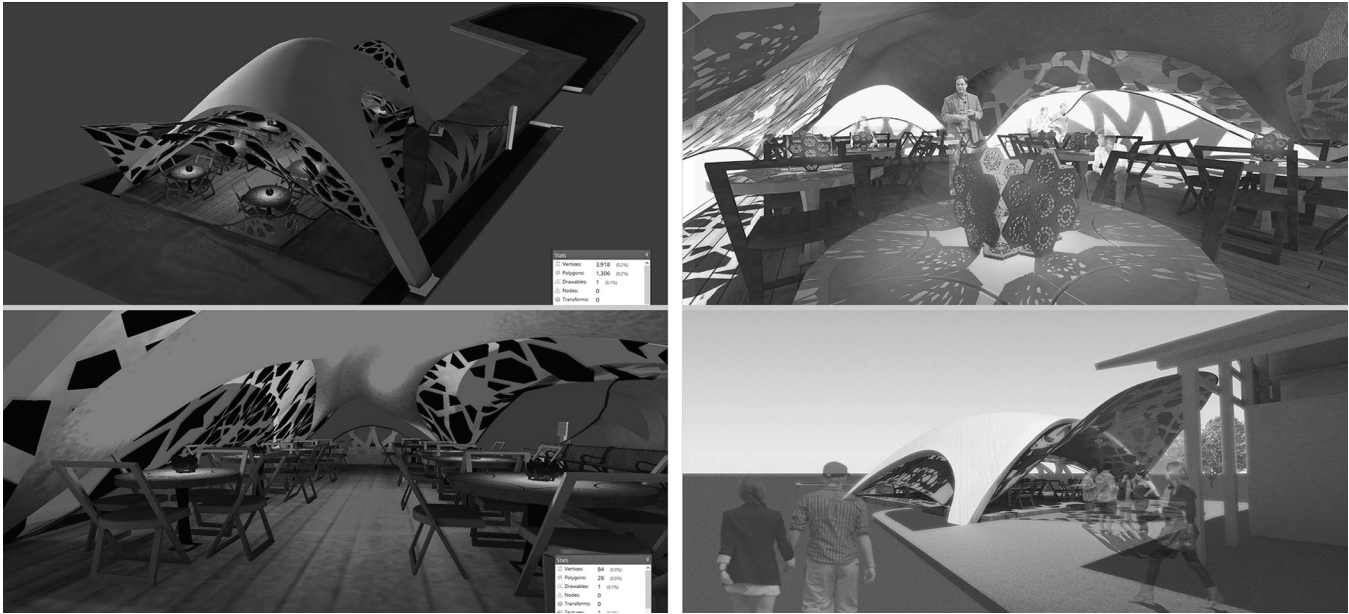


Figure 5: Render-more method using photo-realistic materials, daylight system, animated background, avatars, and artificial lighting. Project by Zack Lenza and Alayna Davidson

## Information Gathering

For the purpose of qualitative assessment, we implemented during the project four information gathering surveys, recorded personal observations during many informal, but very informative, individual review sessions, and harvested qualitative information during a formal final review session. Each student's survey responded to a particular set of topics as follows: Survey #1 addressed the VR navigation experience in the simulation of design projects; Survey #2 addressed the effectiveness of the CAP VR Environment in supporting design decisions regarding spatial design objectives, Survey #3 focused on the comparison of the two simulation methods regarding their usability and effectiveness in supporting conceptual/schematic design, and Survey #4 addressed potential improvements to the current CAP VR Environment in order to better support design processes. Information was also collected about the evaluation of the final projects on environmental performance, affective appraisal, and design communication. Expert reviewers and fellow classmates filled out the corresponding evaluation sheets during the final review of projects. As it is frequently the case due to the small size of instructional design studios, quantitative information has been used only as an indicator of potential qualitative trends. Trends have been further studied using the information harvested during individual informal reviews and the observations of the investigators during the final formal review of the studio.

## Information Assessment

Survey #1 consisted of 13 standardized questions from the Witmer-Singer Base set on factors contributing to the sense of

presence when using a VR environment (Witmer and Singer, 1998). The results from respondents indicated that 46% felt in control over the environment, 47% believed sensory aspects (i.e. visual) were well-simulated, and 65% were unconvinced of the level of realism of the VR environment. These results were consistent with the commentary harvested from informal reviews making reference to the students' awareness of the always limited depth of the simulations and the permanent need for contributions from their own imagination. In the experience of the investigators, the ability to identify information gaps in the simulation is more acute among novice designers who are challenged with the ability to be intuitive in filling those gaps. More experienced designers are less aware of those gaps because of their already acquired ability to apply past experiences to establish a higher sense of presence within the simulation.

Survey #2 consisted of a single question regarding the students' experience using the VSM for spatial design; they were also able to add comments. Results showed that 50% of students believed that using the CAP VR Environment was useful in order to obtain feedback on the spatial qualities of the design, 30% of students were undecided, and 20% disagreed. There were three main groups of comments associated to this survey, namely: comments of those completely in favor of using the VR system; comments of those in favor of the VR system but unconvinced about whether they could instead introduce some remedial measures to continue using conventional CAD applications, and comments of those who were in favor of the use of VR system only if the labor-intensive workflows of rendering to texture were omitted. The commentary has allowed us to understand that most of the students who declared to be undecided about the usefulness of the VR environment did

so in the context of a value proposition that suggested an additional learning curve, as in the case of those seeking to continue to use traditional CAD applications, or suggested an additional investment of labor, as in the case of those seeking to omit the use of textures. With that understanding in mind it is estimated that near to 80% of the students considered it is useful but would use the CAP VR Environment with certain reservations, these reservations directly attributed to additional investments of learning effort or instrumental labor. It is evident that improvements in the management of learning curves and workflows within the design process will have substantial impact on the assessment of the value proposition associate with the use of the VR environment.

Survey # 3 consisted of 24 questions on how well the design aspects were supported by the render-less and the render-more simulation methods during the project. These design aspects are part of the standard environmental performance criteria used in the evaluation of projects of this kind. The disaggregated results from respondents are shown in table 1.

|   | Method 1<br>(render-less) | Method 2<br>(render-more) | Any Method | None of Them | Method 1 + Method 2 |
|---|---------------------------|---------------------------|------------|--------------|---------------------|
| A | 24.0                      | 20.0                      | 40.0       | 10.0         | 6.0                 |
| B | 22.5                      | 5.0                       | 62.5       | 2.5          | 7.5                 |
| C | 6.0                       | 46.0                      | 22.0       | 22.0         | 4.0                 |
| D | 20.0                      | 12.5                      | 42.5       | 22.5         | 2.5                 |
| E | 12.0                      | 17.0                      | 43.0       | 7.0          | 11.0                |
| * | 16.9                      | 20.1                      | 42.0       | 12.8         | 6.2                 |

Legend:

A: Project and Context

B: Circulation & Functional Performance

C: Environmental Performance

D: Tectonics and Material Performance

E: Spatial Quality of Signature Space

\*: Weighted Average

Table 1: Comparison of the two simulation methods (percentile values) regarding their usability and effectiveness in supporting conceptual and schematic design decision-making.

In the opinion of the investigators, the most interesting and important result of this survey is that only 12.8% of the students in average considered the use of the VR environment of no particular benefit in the design process. Such a percentage is mainly attributed to the assessment of (C) Environmental Performance (sun incidence, glare, ventilation, noise, etc.) and (D) Tectonics and Material Performance (structural order, joints, fabrication, manufacturing, etc.). Other analysis programs can tackle these aspects on quantitative, less perceptual fashion. On the other hand (B) circulation and functional performance have received the highest delta

in the comparison between render-less and render-more methods. If we assume that a render-less method implies a shallower learning curve and less laborious instrumentation, such a result in survey # 3 is explained through the results previously discussed in survey #2.

Results from the survey #4 showed the students' preferences regarding aspects that may improve the capabilities of the CAP VR Environment complementing the support of the VSM. The availability of the following aspects were considered almost equally important: environmental sound, animated background, more than two animated avatars in the scene, and manipulation of objects in the scene. The following two aspects were regarded of lesser importance: implementation of force feedback and communication with other users inside the VR environment.

Results from the evaluation of the final projects are shown in figure 6. The illustration shows the comparison between students' learning achievement on environmental performance, affective appraisal, and design communication. The environmental performance was evaluated based on the same five aspects that the students handled during the design process namely, project and context; circulation and functional performance; environmental performance; tectonics and material performance; and spatial quality (See Table 1 above). Affective appraisal was used as a tool to evaluate the quality of the interior spaces from a subjective point of view. Affective appraisal can be regarded as an individual's rating of a setting on a series of adjectives highly saturated in affective but with little or no reference to objective, perceptible properties of the place described (Leather, et. al. 1993). The list of adjectives used for the affective appraisal corresponded to factors such as: general affective evaluation, utility, aesthetic value, activity, space, potency, tidiness, organization, temperature and lighting. Design communication was evaluated based on the quality of representations that effectively communicated the project. The representations included diagrams, perspectives, physical models, and a VR model. As seen in figure 6 only one team out of the six in the class barely made it to the minimum standard of 60% achievement in the affective appraisal of interior spaces. Other teams ranked above 70% with a maximum achievement of 90% for the best project. In design communication the students usually perform well, better than in other evaluation areas and as it is seen in the chart all teams achieved good to best achievement scores from 75 to 100 percent. In terms of environmental performance all projects achieved good achievement scores ranking from 75 to 90 percent. We have found out that in all projects the same specific aspects of environmental performance have had the most positive impact in the evaluation. These aspects are (1) fitting of the project in context; (2) circulation and functional performance; and (3) spatial quality. In all projects these aspects are within a range of 55% to 61% of positive impact over the total score of achievement in the environmental performance. We can correlate these aspects with the preferences that students have expressed in table 1. Students



have found it useful to use the VR environment to simulate these aspects and have also obtained high percentage values of achievement in the same aspects. This positive correlation benefit students' design learning.

## Findings and Futures

- Results from this initial study reported positive evidence in support to the use of the VSM in conceptual stages of design, when materialization and detail are intentionally left ill-defined.
- When the VSM is undertaken during the design process the students seem to defer their expectations regarding the realism of virtual environments. Low resolution and lack of realism of this kind of simulations provide enough ambiguity for novice designers to feel pushed to project their imagination and postpone the inevitability of high resolution simulated worlds. More experienced designers may be less aware of the information gaps in the renderless simulations because their schemata intuitively fills those gaps but they can equally benefit from the duality it provides in early stages of the design process.
- The final projects demonstrated a great degree of coherence between the formal exterior shape and the inner spatial shape, even when each one independently responded to different design criteria.
- Students reported strong preference for the VSM as a tool in support of recursive design processes. The high resolution method was able to provide good visualization of light and shadow effects and added some material textures to the design, however it was rejected as a good method during the conceptual design stage as it demanded long hours of preparation due to its production complexity.
- Consensus was achieved on the preference for high resolution (flat) renderings over the use of high resolution VR environments. It is not clear if future shorter workflows and shallower learning curves will alter substantially this preference. Also, future drops in the cost of VR delivery systems and their use for project presentation to clients, who do not necessarily have intuitive ability to fill in representation gaps, will alter present preferences.
- It has been evident that the VSM is efficient in providing feedback on spatial qualities, however the environmental factors (i.e. daylighting, glare control, etc.) were left ill-defined in the design. These aspects have an important effect over the affective appraisal of interior spaces. An improved VSM will seek to complement affective appraisal of spaces with environmental analysis methods.
- This research is significant because it supports the effective application of emergent VR systems within academic environments. The findings of this study imply that purposely-designed applications of VR technology can specifically support the initial stages of the design process, in contrast with conventional VR applications that are mostly limited to display the final visualization of professional-grade projects. We hope that fostering the use of VR for design in academia will gradually find its way into the generalized practice.
- Traditional sketching plays an important role in design and the VSM creates bridges between sketching and VR simulation. See Figure 7.

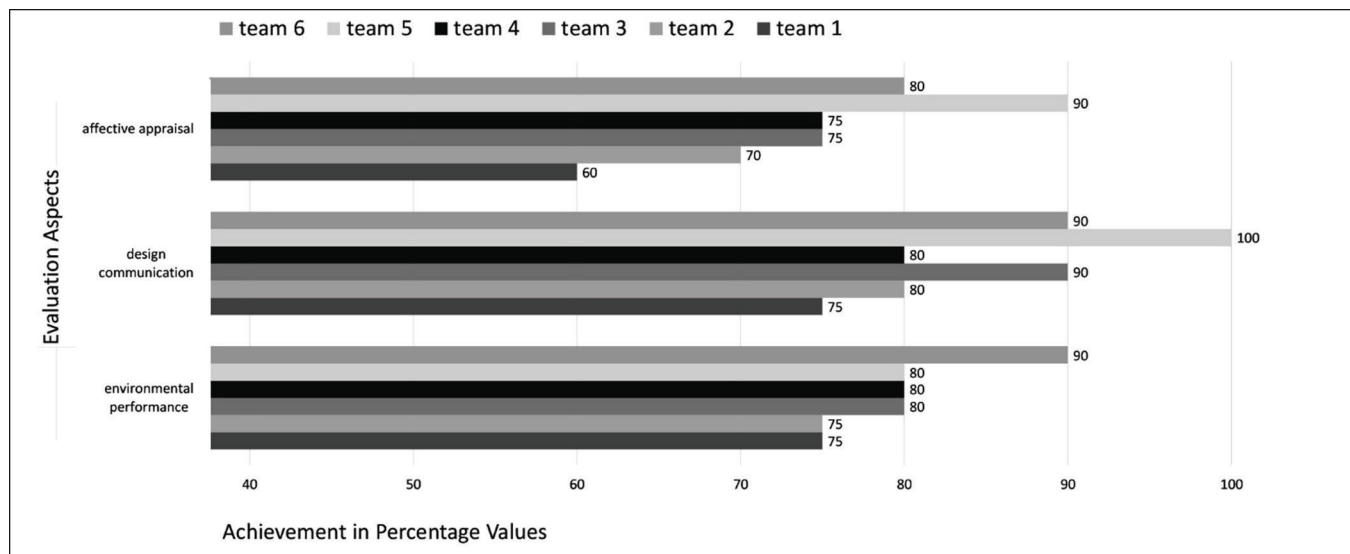


Figure 6. Comparison between students' learning achievement on environmental performance, affective appraisal, and design communication.

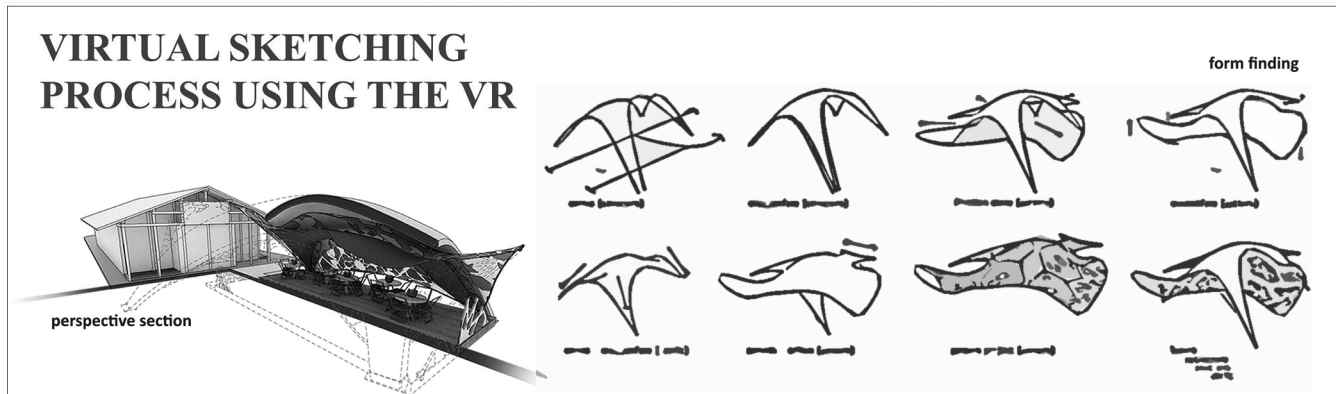


Figure 7: Project by Zack Lenza and Alayna Davidson

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