Exploring the Impact of Emerging Landscape Visualization Tools on Spatial Perception and Design Education

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1 Introduction

When the goal is to design a physical environment, the means of representation used to depict the emerging solution can have a significant impact on the evaluative process and therefore on the results of the design effort. In recent years developments in landscape visualization have provided landscape architects, architects, and urban designers with new tools to see and understand their developing ideas.

A major goal in the education of architects, landscape architects and urban designers is to develop the ability to accurately perceive scale and spatial character through design representations. Recent research at the College of Design at North Carolina State University has documented how a designer's perception of space can be effected by the visualization method. When designers viewed 3D digital models of spaces through flat screen and hemispherical VR projections their sense of scale and space was significantly different from those who developed their spatial perceptions through viewing the same spaces represented by traditional design drawings and physical models ( ). This paper builds on these earlier studies and presents the findings of a research project that explores how emerging digital media can impact the development of spatial perception skills in design students, and compares these results to the findings of earlier studies focusing on design professionals. The paper concludes by presenting a framework, based on research findings, for the integration of emerging digital landscape visualization tools into the design education process.

2 Material & Methods

2.1 Pilot Projects

This paper builds on three pilot projects conducted at North Carolina State University, College of Design and presented at the 2003 American Society of Landscape Architects Annual Conference. These projects examined the impact of the evolving technology in digital modeling and simulation on the design decision process and therefore on the results of design efforts. The focus of these pilot projects were to investigate how changing the mode of simulation affected design perception and how varying the amount of detail in a digital simulation effects a designer’s perception of the simulation as compared to their perception of the actual space. The following diagram presents the elements of static conventional media and dynamic digital media forming the framework of this research effort. A more complete discussion of these three pilot projects can be found in the Landtech Proceedings of the 2003 ASLA Conference.
This paper also includes a report on a fourth pilot project currently underway at the NCState College of Design. This project takes the findings of the first three projects and explores the impact of design media on the design education process. The project includes an analysis of spaces developed by design students using conventional hand drawn media with spaces developed using 3D digital models. The results of the comparison are placed in context with the results of the first three studies and reveal a similarity of impact on the design education process.

![Fig. 1: Research Framework Diagram](image)

### 2.2 Pilot Project One

“A Comparison of Realities: Will emerging digital representational tools change our design judgements and results?” (Holmes, Tomlinson, Rice) 2001

These research projects compared designers’ perceptions of traditional simulations to designers’ perceptions of computer generated simulations.

The goals of this project were:

1. Determine the significant differences in spatial perception related to the representational media (Traditional and computer simulations).
2. Determine if there are significant differences in spatial perception related to the mode of representation. (Overview, walk-through, and panorama)
A design of an urban campus space was presented in two different representational media to panels of professionally trained landscape architects and architects. Each panel consisted of fifteen participants. One panel of experts viewed traditional representations, at a scale of one-inch equals twenty feet including a plan, section-elevations, perspective drawings and a one thirty second inch equals a foot scale chip-board model. The other panel of experts viewed computer generated virtual reality representations of the same design.

The participants evaluated the design using three different modes of representation: "overview", "walk-through", and "panorama". The "overview" was presented through traditional representation as an overall impression of the design resulting from the viewing of traditional drawings and the physical model. This overall impression was created through computer generated representations by a bird's-eye fly over and simulated ground level views. The "walk-through" was a view from a prominent path in the design. The path was indicated in the traditional media as a series of arrows on the plan drawing. The participants were asked to mentally visualize the experience of walking along the indicated path. In the computer simulation of the walk-through the participants were shown a series of eye level views along the pathway. This series of views was presented at a consistent rate that simulated a rapid walking pace. The "panorama," a 360-degree view from a single point in the design, was indicated in the traditional representations as a viewpoint on the plan. In the computer representation a panoramic series of eye-level views were presented from the indicated point. Again, in the traditional representation participants were shown on the plan the viewing point of the panorama and asked to mentally visualize the experience of standing at that location.

The mechanism for evaluating the design from all three modes was a questionnaire composed of four sections. Section one (Design Elements) required the participant to rate the importance of specific design elements to the character of the design on a scale of one to seven. Section two (Crowding Levels) asked participants to estimate the number of individuals that could be accommodated in the design to create specific levels of crowding. Section three (Paired Adjectives) required participants to evaluate the design based on ten paired adjectives. Finally, in section four, as a means to check the completeness of the structured part of the questionnaire in a open response format, participants were asked to describe the important characteristics of the design in their own words.

The data from the completed questionnaires were analyzed to identify significant areas of agreement and divergence between the panel that viewed conventional representations and the panel that viewed computer representations. Statistical comparisons were made to determine if a particular mode of representation had a greater degree of agreement or divergence between the two panels.

A T-Test was used to analyze section one (Design Elements) and section three (Paired Adjectives) of the questionnaire. This test determines if there are significant differences in the mean responses of two groups. In section one (Design Elements) significant findings occurred in two modes of representation, walk-through and panorama. In section three (paired adjectives) two modes of representation, overall and walk-through had adjective pairs that showed significant divergence in panel ratings. The results from sections one and three showed no design element or paired adjectives were significantly different in more than one mode of representation. This supports the idea that each mode of representation
may reveal its content in a perceptually different way. In addition, it was noted that all of the design elements and paired adjectives that were perceived differently by the two groups were spatial or space defining in nature. In contrast, the two design elements that had significant agreement in response addressed design details (i.e., materials and colors).

The Mann-Whitney Confidence Interval and Test (MWCIT) was used to identify significant differences in the medians of the responses in section two (crowding levels) of the questionnaire. The section asked questions relating to the number of individuals that could be accommodated in the design to create specific levels of crowding. The walk-through was the mode of representation that produced responses that showed significant divergence. This divergence indicated that designers perceived that more people could be spatially accommodated in the computer simulation than in the conventional representations (Figure 2).

![OVERVIEW](image)

![WALK-THROUGH](image)

**Fig. 2:** Median Responses of Perception of Crowding
2.3 Pilot Project Two

“3D Immersive Simulation in Design Education: Does 3D immersive simulation provide design students with a more realistic representation of space?” (Hasenmyer) Unpublished

The purpose of this research project is to examine how two types of simulation, a scale model and the computer “walk-through” affect design students’ understanding of a space. The hypothesis was:

The computer “walk-through” will give students a more accurate sense of real spaces than conventional scale model.

Experimental Design (Pilot Project Two)

Two simulations were constructed of the space located in the courtyard of the College of Design at NC State University. One simulation was a computer-generated “walkthrough” that followed a path where the viewers enter into the space, turned around and walked out. This simulation was rendered from a 3D model that took approximately 4 hours to create. The rendered “walk-through” animation was displayed in the Elumens Vision Station. The second simulation was a hand built model constructed from mat board. This model took approximately 8 hours to complete and was built at a scale of 1/4”=1’-0”. Three groups of student participants were used to assess perceptual differences. Each student completed a questionnaire based on their impressions of the space after visiting the actual space or viewing one of the two simulations.

The three groups were composed of design student, although they varied in age and experience. The first group (Group A) walked through and evaluated the actual space. The second group (Group B) were asked to evaluate the same space by watching the animated computer “walk through” shown on the Elumens Vision Station. The third group (Group C) were asked to evaluate the same space by looking at the 1/2”=1’-0” scale model. The questionnaire contained 31-paired adjectives and only required 5-10 minutes to complete.

Results (Pilot Project Two)

The data from the completed questionnaires were analyzed to identify areas of agreement and divergence. The data was analyzed to determine which simulation method generated perceptions that were the closest to the perception of the actual site. The analysis compared mean responses to paired adjectives. This analysis revealed strong results related to paired adjectives that described spatial complexity, enclosure, and geometry. In most cases, when evaluation the paired adjectives that measured degree of spatial complexity, the responses to the computer simulation related more closely to the perception of the actual site then the responses to the physical model. In addition, in all cases when evaluation the paired adjectives that measured degree of spatial enclosure, the responses to the computer simulation also related more closely to the perception of the actual site. In most instances where paired adjectives described spatial geometry the opposite was true.
2.4 Pilot Project Three

“How Real is Real? The potential impact of virtual reality on the development of spatial visualization skills.” (Holmes, Rice, Tomlinson, Hasenmyer) Unpublished

This research project focused on the impact of the level of detail in virtual reality simulations on the ability of design students to construct an accurate mental image of a space. The two hypotheses that drove this project were:

1. That even with a minimum level of detail in a virtual reality simulation, students will be able to construct an accurate mental image of a space.
2. That by adding more detail to a virtual reality simulation, the accuracy a students of mental image of the space will improve.

Experimental Design (Pilot Project Three)

Two 3D-computer models were constructed of the College of Textiles courtyard on the NC State campus. The first model contained a low level of detail with respect to geometry, color, and lighting. The model used simplified geometric forms, four colors and only one light source with no shadow casting. The model took only five hours to construct. The second model used more complex geometric forms, unlimited colors; two light sources with shadow casting and took twelve hours to construct. The two models were used to develop computer simulations along an animated path. Three groups of student participants were used to assess differences in perception of the two computer generated simulations and the actual courtyard space. Each student answered a questionnaire based on their impressions of the place after visiting the site or viewing one of the two computer simulations. The “walk-through” representation was the only mode tested in this experiment. The computer simulations were projected on a flat screen in a classroom for viewing. The participants that visited the actual site walked along the same path as represented in the computer simulations.

The three groups of participants were comprised primarily of Landscape Architecture and Architecture students. Group A consisted of 30 participants who viewed the actual site; Group B consisted of 35 participants who viewed the low level of detail simulation; Group C consisted of 18 participants who viewed the simulation with more detail. A questionnaire was used to record the participants’ general perceptions of the site. The questionnaire contained 35 paired adjectives, which required approximately 5 minutes to fill out. This questionnaire was a simplified and refined version of the questionnaire used in the first pilot study.

Results (Pilot Project Three)

The data from the completed questionnaires were analyzed to identify significant areas of agreement and divergence between responses generated from the real space and each of the two computer simulations. Statistical comparisons were made to determine how the responses generated by each computer simulation varied from those generated from the real site. (Figure 3)
A Kruskal Wallis test was used to analyze the paired adjectives. The student responses were in line with what was expected. For example, both computer simulations were perceived to be harder and more barren than the actual site. However, the low-level simulation did result in students developing an equivalent spatial understanding of the site when compared to those viewing the more detailed simulation. In both cases 24 out of 35 of the paired adjectives showed similar medium responses to those generated by the real space however, there was variation in which pairs were similar.

Both simulations performed equivalently in the perception of scale and spatial structure but did not perform well in issues related to texture and color. The more detailed simulation showed stronger similarities to the actual site in pairs related to lighting and shading where the less detailed simulation showed stronger similarities to the actual site in pairs related to exposure and enclosure.

This test determined that eleven out of thirty five pairs had a significant difference in the median responses to the actual space when compared to median responses to the low detail simulation. When the more detailed simulation was compared to the responses to the actual space it was also found that eleven out of thirty five pairs showed significant
difference. Therefore when it came to understanding scale and spatial structure the level of
detail in the simulation did not have an effect.

3 Application to Design Education

In fall of 2001, this on going research effort began to effect introduction design education
in the Masters of Landscape Architecture Program at the NC State College of Design.
Previously, students entering the masters program without a design background began their
design education developing solutions by building physical models and using conventional
hand drawn plan, section and perspective drawings. Only after their first two semesters of
design studios were they introduced to digital modeling. This approach to design education
operated under the assumption that spatial visualization skills and design awareness could
be better developed using non-digital media and that the complexity of digital media would
hamper the development of design skills.

In that findings from the pilot projects tended to indicate that spatial visualization was more
accurate when developed from digital models, in the fall of 2001 a first attempt was made
at integrating digital spatial modeling into early design education. The idea was to have
students develop 3D walk-throughs of their preliminary designs and then use these walk-
throughs to refine and further develop their ideas. This attempt used AutoCad2000 and
confirmed the previously stated concern that the complexity of the tool would hamper
learning. Walk-throughs were generated but excessive faculty time was required to help
each student and all discussion turned to modeling and software issues and little time was
spent actually discussing design. In addition, it was very difficult to translate any spatial
insights gained from the walkthroughs into concrete design revisions and corrections.

In the fall of 2002, a second attempt was made at using 3D digital modeling in early design
education. This time three changes were made. First, a different 3D modeling program was
selected that was easier to learn and allowed for an incremental development of complexity
(FormZ). Second, students developed their designs from the beginning as a 3D digital
models. Third, students printed out a plan and an eye level view of their design prior to
each desk critique. These three changes resulted in students generating simple models of
their designs early in the idea generation phase and a rapid cycling through the design
process. Faculty critiques supported by on-screen views and walk-throughs were easily
recorded on print outs and students were then able to implement design revisions quickly.
In addition, as designs developed students were able to add detail and design refinements
after the basic structure of their designs clarified. More importantly, a preliminary review
of the resultant designs tended to indicate that the students’ ability to accurately visualize
space was developing at a faster rate.

In order to begin to develop a better understanding of the impact of this new design media
on early design education, a pilot project was begun to quantify the nature of media’s
impact on the results of student design efforts. In the first phase of this project, student
were given a basic design task, that of designing a courtyard with major and minor spaces
and entrances. Half of the students used conventional hand drawn media and half used 3D
digital modeling to develop their solutions. They were all given the same basic instructions
relative to the uses and number of people to be accommodated. Early results were very
consistent with the findings of the earlier pilot studies and indicated that both major and
minor spaces were designed, on the average, ten to twenty percent larger when students
used conventional hand drawn media.

These initial findings have prompted a much more in-depth analysis of the differences
observed and a second study that is using past records of student projects as a basis for a
much more inclusive and broader analysis. The intention is to begin to reveal the power of
our new digital design tools to further educational goals and produce a new generation of
designers who are both enriched by and in control of the new digital design media.

4 Conclusions & Outlook

Design is a process involving creation, evaluation, and modification intended to clarify,
capture, and shed light on "the dark image of the persistently constant" (Mach 1959 trans.,
Arnheim 1995). This image is the goal. As a designer modifies and develops a design the
"dark image" also evolves and becomes clearer. The intent is to both understand the
evolving image and direct the solution to it.

If time and resources were unlimited it would be possible for designers to build and rebuild
their evolving designs. In such a world, each time a design was built, designers could hold,
operate, examine, and experience the results of their efforts. After this evaluation the
designers could then rebuild portions of the design which did not fulfill expectations. This
process could continue through numerous cycles until a design sufficiently approached the
emerging "dark image" of the design intent. Unfortunately for designers as well as
scientists, both time and resources are limited and life size "tests" can not always be done
before critical decisions are made (Casti 1997). In a field such as landscape architecture,
concerned with the design of environments where people live, work and play, other means
must be developed to visualize and experience an emerging design. Our goal is to develop
a better understanding of our design and educational tools so that we can use them
appropriately and in a ways that enrich the educational process and eventually the physical
world.

At this time it is becoming clear that our new digital design media has an impact on the
designs we produce. The work reported here is just a start. Larger tests must be conducted
and specific research questions developed. It is our hope that these beginning efforts
encourage others to join our quest at understanding how our tools shape our perception and
therefore shape the world.

5 References

New York: John Wiley & Sons.