Transparency: Literal, Phenomenal, Digital

NEWTON D'SOUZA
University of Missouri

BIMAL BALAKRISHNAN
University of Missouri

JAMES DICKER
University of Wisconsin-Milwaukee

THE REFRAMING OF DIGITAL TOOLS: FROM 'TOOLS FOR DESIGN' TO 'TOOLS OF DESIGN'

A core purpose of architectural education is in the learning of visual vocabularies. This is usually initiated in the beginning studios, updated through advanced levels and developed even during professional practice. However, the advent of digital tools has fundamentally shifted this learning process. Lawson (1999) suggests that not only are digital tools non-neutral, they even encourage poor design. Lawson's grievance is not so much in the nature of digital tools, but in how they are used. Embracing this latter view, we believe that poor design occurs because of the way digital tools are framed in architectural instruction. Given that practicing architects and educators, in reality, have limited power in influencing the development of digital tools, we propose a modest reframing of these tools to bring to attention their capabilities in analyzing historic examples and generating design solutions. Hence, rather than lamenting on the disruption of visual vocabularies due to digital tools, we suggest that an opportunity has arisen to readdress this issue and by extension the core of architectural pedagogy.

Our proposal consists of a reframing of digital tools that moves away from its current usage as '*tools for design*' to '*tools of design*.' This reframing considers digital tools not as an aid to carry out a design task, rather, as '*design tools that happen to be digital*.' We feel the traditional role of digital tools such as efficiency, precision and form making, while valuable, should be balanced with intellectual core of architectural design discourse. Using one case example of visual vocabulary prominent in the architectural discourse, namely *phenomenal transparency* (Rowe and Slutzky 1963; 1971) we will demonstrate how this reframing might be possible, and how one might take advantage of the affordances of digital tools in teaching architectural history and design studios.

ARCHITECTURE AS ITS OWN DISCIPLINE

Before exploring the use of digital tools in the pedagogy of history and design, we would first like to situate architectural pedagogy within the broader context of architecture as a discipline and practice.

In questioning the role of the architectural discipline today, Leatherbarrow (2001) suggests that the subjects we have inherited in traditional discourse must be rethought in our times because of technological and professional changes. The real challenge in teaching, he suggests, is to set up conditions under which students can risk seeing, that is, in ways that allow architecture to be

remade metrically, spatially and qualitatively. Reflecting on the core of the discipline, Leatherbarrow further suggests that architecture does possess its own subjects and skills and that it should find its own niche in the purpose of intellectual clarity and professional responsibility.

Every discipline consists of characteristics that unambiguously reveal the nature of that specific discipline, in distinction with others (Eisenman 1980). Architecture, as a discipline is no different in this regard. One characteristic that makes architecture a distinct discipline from other applied arts or engineering is that architects rarely make buildings as artists do paintings. Rather, architects make mediating artifacts that make buildings possible. We can consider these mediating artifacts as consisting of both intrinsic and expressive content. The intrinsic content is manifested in the form of visual vocabulary that one develops for design. Choice of media and the representational structure plays a critical role in these explorations and in facilitating architectural innovation. For example, perspectival techniques of the past, emphasizing symmetry, foreground, middle ground and background, gave way to the axonometric as a means to explore ideas of unlimited space.

The expressive content on the other hand includes artifacts in the form of drawings, physical and virtual models, and animations among others. These artifacts eventually manifest itself in the built form. Much of the developments in digital tools have focused on the development of these artifacts based on efficiency and precision in construction management and co-ordination through building information modeling (BIM) tools. One can argue that these developments have shifted the emphasis from intrinsic content of the architecture to its expressive content.

Recognizing that the digital tools currently used in architecture were not born within the discipline, but in other areas such as mechanical engineering and film, it is understandable that these tools are quiet divorced from the intellectual discourse of architecture. These tools approach architecture through the lens of descriptive geometry, i.e. as a geometric array of co-ordinates and information parameters rather than form and space.

We argue that the core of architecture rests on a strong intrinsic content because unlike artists or engineers who handle the medium and its construction, architects handle mainly representations. As Leatherbarrow (2001) suggests, architects handle drawings and models, not bricks and mortar. Of course, architectural representations can be seen as artistic painting, but it not their only purpose or primary purpose. The plan, section and details of a building are rarely significant in a pictorial way because they are rarely intelligible individually. Architectural understanding means grasping of a network, a weave, or a matrix of figures, each partially, but all mutually dependent on each other. If expressive content such as fabrication and manufacturing exists, it exists because of the intrinsic content rather than despite it.

DESIGN MEDIA AFFORDANCES AND THE PEDAGOGY OF ARCHITECTURAL HISTORY

Despite the changing nature of architecture discipline, the teaching and learning of architectural history has hardly evolved. Architectural history has been traditionally taught through different ordering systems. The primary ordering system has been chronological, based on dominant cultures (Egyptian. Greek etc.). Other ordering systems include paradigmatic groupings based on stylistic notions (modernism, post-modernism etc.) In this case the learning of history sometimes succumbs to explicit name-branding (for e.g. the Barcelona chair, the De Stijl movement).

While these are valid approaches in their own right, the knowledge from architectural history can also be considered as transcending time and place. As students of architecture begin to develop their personal visual vocabularies - rather than the categorization of styles - what will be more important is to understand how different cultures have solved recurring problems over time. This lends a problem-solving and applied approach to history, based on cross-comparison, rather than the accumulation of explicit knowledge.

The teaching and learning of architectural history also needs to be considered in the context of the changing nature of architectural profession. In Vitruvian time, and up until modern architecture, architects operated primarily as master-builders, responsible from conception to execution. It would be reasonable to assume that the study of architectural history served as a guide for individualistic exploration. One can refer to La Tourette as a case ex-

ample of Le Corbusier's exploration of the Dionysiou monastery. Today, however, as Barrow (2000) has pointed out, architects work with a dynamically networked team of consultants in the design process. This means architects have transformed into 'integrators' of various fragments of knowledge. The role of architectural history in this context now needs to be available for shared and collective scrutiny.

The problem-solving approach to history along with its need for general scrutiny, demands a cross-comparative approach where hitherto unknown connections can be made and hidden elements can be revealed. Digital tools with its replicability, speed of search operations and the affordance of recording large corpus of knowledge can be used as a vehicle to explore history for this purpose. Moreover, computing speed has made it possible to record and analyze historic examples in terms of architectural fundamentals such as proportion, hierarchy etc., in a faster and more structured way. In other words computing has accelerated the mathematical approaches to architecture prevalent in the historical discourses of Alberti, Palladio, Brunelleschi and others. If one approaches architectural history in this way, the teaching of architectural history and teaching of computing can be seen as two sides of the same coin.

Designers often look to history for precedents to address contemporary design problems. Most of the references take the shape of photographs and 2-dimensional drawings. These references provide designers with vignettes rather than the whole. Three-dimensional models of precedents when coupled with interactive capabilities of digital tools provide more opportunities to encourage exploration and uncover hidden spatial relationships.

Experiential and analytical sketches of spatial composition have always been an important part of architectural education. Visual vocabularies such as phenomenal transparency (Rowe and Slutzky 1963; 1971) is useful for design analysis to reveal hidden design strategies (e.g. analysis of Villa Garches) as well as for design ideation as shown by Hoesli (1997) in his design studios. Interactive section planes (See villa Hariri, figure-5), ability to manage information complexity through visibility controls and the affordance to take perspective views from any point of view or exploded axonometric views all encourage exploration. In an urban infill project for example, the geometric relationships that are extracted often act as starting points for generating design alternatives. Digital tools can improve the analysis-ideation process, by making it easier and faster to reveal hidden relationships as well as to explore more design alternatives. While explorations into shape grammars (Stiny 1980) focused on computational analysis of architectural typologies, current parametric modeling tools enable rapid generation of design variations.

With increasing reliance of digital tools for design ideation, architectural history provides an interesting opportunity to train students in the use of digital media. At University of Missouri, in the introductory course on 3-d computer graphics, the visualization exercises rely on reconstructing buildings of historic importance. Students are encouraged to explore the experiential aspects of the spaces by paying attention to spatial proportions, lighting qualities and materiality. This encourages students to go beyond exploration of form. Within the constraints of time, students are encouraged to explore "what-if" scenarios during the visualization process and follow their curiosity, by exploring alternative proportions or choice of materials before accurately recreating the building. These richly detailed 3-d models also provide opportunity for interactive analysis during the lecture course in history of modern architecture.

FROM HISTORY TO DESIGN STUDIO – THE ROLE OF DIGITAL MEDIA

In the design studio, the artifacts and representations used by architects start as more abstract and speculative representations and become more concrete as the design develops. Most CAD tools are primarily aimed at the latter stages of the design, though recent tools like Google SketchUp and AutoDesSys Bonsai3d are starting address designer's needs better during the early stages. Given that architects work in the subjunctive (not nominative), each drawing or model is an 'as if' (Summers 1991). Most digital tools therefore need to be subverted to be effective in the early design stages. Within this context, it is important that we make a distinction between representation and presentation, a boundary that is increasingly blurred in the digital domain. When using manual tools, based on one's selection of medium, it is easy to distinguish between representations for ideation (freehand sketching) and presentations for design communi-

cation (precise drawings done in ink using technical pens). In the digital realm, the same medium is used for both representation and presentation. In fact, on several occasions we use these terms interchangeably, adding to further confusion. This lack of distinction between ideation and communication is also prevalent in the area of information visualization and visual analytics.

Carpendale and Montagnese (2001; p.61) define representation as the act of creating an image that corresponds to the information. Thus representation involves developing a mapping from the information to a structure that can be displayed visually. Representations are primarily a visualization tool to aid reasoning and creative process. Presentation is the act of displaying this image, emphasizing and organizing areas of interest (Carpendale and Montagnese, 2001; p.61). This distinction is important especially when the users are not trained in the representational conventions of the designer.

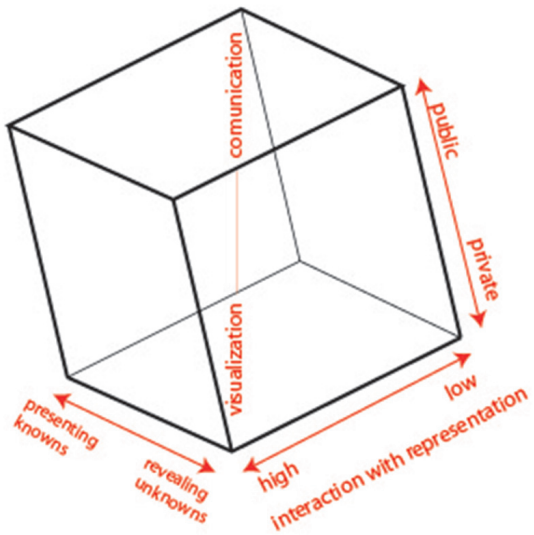

Figure 1. *representation – presentation cubic space*

This distinction becomes further muddled while representations are thought of as lying in a continuum. This is analogous to MacEachren's (1995; p. 358) depiction of cartography as a cubic map-use space with visualization and communication occupying opposite poles. In the design process and communication, representation and presentation can be respectively mapped on to the visualization – communication poles [See figure –1]. This also will help to clarify distinctions between the two such as the level of interaction or engagement (high for representation, low for presentation), purpose (exploration of unknown, communicating known) and intended domain (private, public) (MacEachren 1995; p. 358).

Changes in representations directly influence the nature of the artifact under design whereas changes in presentation primarily affect how it is viewed or perceived. For the same information or representation, the presentation strategies can vary depending on the type of task, nature of information and skills of the user (Carpendale and Montagnese 2001). This distinction will allow us to explore the presentation space independent of information specification. Chi and Riedl (1998) sums up the difference succinctly – representations involve value operations, whereas presentations involve view operations. In early stages of design, designers frame problems as means to reduce the complexity of the problem so that one can launch with conviction a creative and intellectually stimulating solution rather than arriving at a precise and optimum solution.

This is the primary reason why parametric modeling and building information modeling tools like Autodesk Revit while important for design practice are ill-suited for design ideation, particularly with respect to exploration of spatial experience. However, many affordances of current digital media tools like layer manipulation features (e.g. masking and blend modes in Photoshop), interactive section planes in Google SketchUp offers new opportunities for design ideation when seen through the lens of transparency.

REVISITING TRANSPARENCY: FROM PHENOMENAL TO DIGITAL

We see an opportunity to reframe digital media tools for design by revisiting ideas of transparency proposed by Rowe and Slutzky (1963; 1971) for architectural analysis and further advanced by Hoesli (1997) in the design studio. We seek to extend the idea of literal/phenomenal transparency to reframe how we approach digital tools for architectural design and analysis of historic exemplars.

Deriving from Gestalt psychology and analytical cubism, phenomenal transparency is a visual device that creates simultaneous perception of different spatial locations in which space fluctuates in a continuous activity and pleasures the spatial experience. For example, if one sees two or more

figures overlapping one another, and each of them claims for itself the common overlapped part, then one is confronted with a contradiction of spatial dimensions without destroying the overall optical character of the individual figures. The resultant state of flux is termed as phenomenal transparency and is distinguished from literal transparency which is just the static experience of using transparent materials such as a glazed opening or a wire mesh. Learning and teaching phenomenal transparency hence requires rigorous experimentation of understanding and play of various layers and planes in architectural design.

Unlike static layers or the classical perspectival views of foreground, middle ground and background, phenomenal transparency thrives in the interpenetration of these spaces. Instead of clarity there is possibility and indication. The spatial stratification imposes an instant blurring and brings into attention multiple readings. Space not only recedes but fluctuates in a continuous activity. The position of transparent figures has equivocal meaning as one sees each figure now as the closer, now as the further. Non-stability replaces absolute regularity allowing and facilitating simultaneity, superimposition, and ambivalence.

Such a spatial stratification can be illustrated in an example of Mondrian's painting, figure 2. (Dicker and Snyder 2005). One can view Mondrian's painting as a continuous cutting of planes through which subsequent layers are revealed. For example, in the figure below (read in rows from left to right), one could start with a yellow layer over which a red layer is placed. One could then cut open the red plane to reveal the yellow layer underneath. Now both the yellow and red layer can be seen simultaneously and in a dynamic fluctuation between the yellow and red plane. Next, one can place a blue layer over the red/yellow layer to create another spatial stratification. These layers could be consecutively overlaid until the Mondrian's painting is complete. The final work shows a stratification of 5 different planes (red, yellow, blue, gray and white). Carrying this analogy to architectural buildings, Rowe and Slutzky (1963; 1971), in their classic works introduced the idea of phenomenal transparency in the works of well-known architects such as Le Corbusier.

For example, in the Villa Garches, several of these layers are revealed. First layer consists of the plane

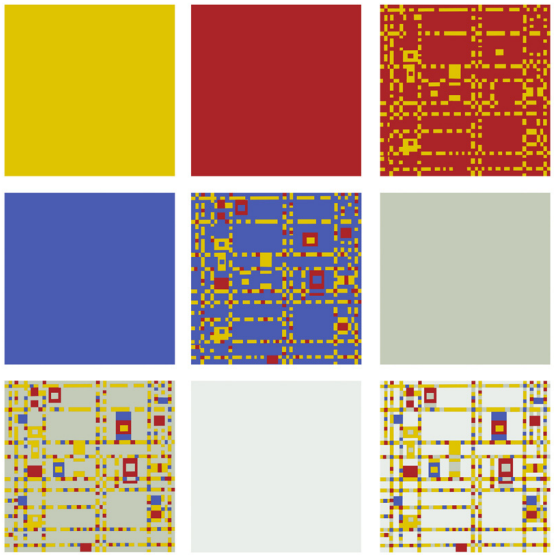

Figure 2. study of Mondrian paintings based on phenomenal transparency (Dicker and Snyder 2005)

of the front façade starting at the second floor and cantilevered from the ground floor plane, second, the plane connecting the ground floor wall and redefined on the roof by the two free standing walls of the terrace as well as the termination of second floor windows on the side elevation, third, the plane connecting the parapet of the garden stairs and the terrace and the second floor balcony, fourth, the plane defining the rear wall of the terrace and the front wall of the penthouse, and fifth, the rearmost wall of the terrace as well as the walls below. In essence, the real surfaces work with the imagined surfaces creating a continuous dialectic between fact and implication enforcing a reading after reading. Each of the planes is incomplete in itself or even fragmentary, yet with strategic visual points of reference one can complete a gestalt of spatial stratification. Similar planes can also be revealed in the horizontal axis with the three floor slabs and the roof. These five vertical planes and the four horizontal planes create a gridding of space resulting in continuous fluctuation of interpretation.

DIGITAL TOOLS THROUGH THE LENS OF TRANSPARENCY

This exploration of transparency can be reinforced using digital tools through specific operations that most afford. These operations can include additive or subtractive ones in which planes are either im-

posed upon or subtracted from a basic datum. Similarly, operations in which planes can be cut open and depth is inserted in the ensuing slot. Or even, when new planes are added to older planes to make it seemingly bulge forward. In essence the planes overlap, dovetail and exclude each other. The challenge in using digital media is that most operations involving computers involve accuracy and precision, both ill-suited for ideation. Ambiguity has an important role in the design exploration and must be regained. A number of features of various digital tools lend itself to the idea of transparency, literal and phenomenal. Some of those features and their possibilities for both historic analysis as well as use in design are explored here.Literal transparency

Many digital modeling tools now provide an "x-ray" mode of representation. Though this feature may be aimed at achieving precision and accuracy, it offers the simplest opportunity to explore the idea of literal transparency during design ideation. This feature is an improvement over the "wireframe" representational mode by providing an enhanced idea of space while still providing visual connection between the interior and exterior. This feature allows one to explore impact of transformations of form on space and vice versa. It also allows one to see traces of the plan and section simultaneously.

Phenomenal Transparency

A number of digital tools, particularly image editing tools now afford the opportunity to explore the idea of phenomenal transparency. Layer manipulations using the masking feature or blend modes in Photoshop allows the designer to explore multiple readings of possible spatial relationships. Since these manipulations in the digital media are much faster than in using analog tools, one can explore many more alternatives in a short span of time. This can be easily illustrated with a simple Mondrian composition. The following series of variations on the Mondrian painting was explored using the layer masking tools in Photoshop. Though we have used the simple example of Mondrian painting, one can extend the power of these imaging tools to treat solid and void as complementary aspects of space and explore what-if games (See figure – 3).

The analogy of Mondrian paintings in the digital media can be extended to the spatial analysis of Villa Garches. For example, if one constructs the digital model of Villa Garches in software such as Sketchup, it takes very little effort to create sectional planes

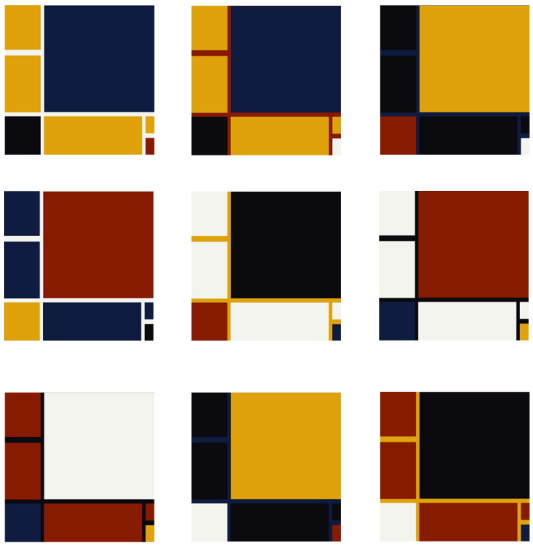

Figure 3. variations of Mondrian compositions explored using layer manipulation features in Photoshop

and deconstruct the poche both in longitudinal and transverse planes (see figure – 4). In the Villa Garches example one can observe the complexity of the sectional planes revealed and displayed in consecutive layers. One could change the viewports and explore these planes at different angles to ma-

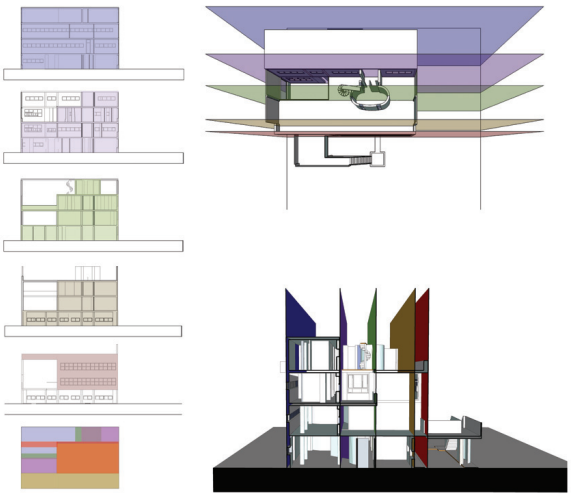

Figure 4. analyzing the spatial stratification of Villa Garches using digital tools

nipulate them. Moreover, one could view the plans, sections and axonometric views of these planes almost instantaneously and the resulting manipulation of one drawing could help in further exploration of another. It is also possible to move from a planar analysis to a more spatial analysis with solid modeling tools, or even an experiential analysis using interactive digital tools. In summary, because of the power of quick replication and the ability to infinitely experiment without consuming physical resources makes it possible to push the boundaries of intellectual explorations in architecture.

Void Modeling and Boolean Operations

One can extend the above idea to the realm of digital tools for 3-d visualization, especially since most of them afford Boolean operations (union, difference and intersection) in a 3-d context. Instead of teaching these tools as means to describe geometry, one might look at these tools as facilitating the spatial vocabulary. Most visualization tools are primarily conceptualized from a solid modeling point of view. This limits opportunities for spatial exploration for architecture where solid and void are complementary aspects of space and they need to be dealt with intelligently. Tools like Form.Z from AutoDesDys which is built around the concept of void modeling where the contained part and the container can behave independently when undergoing a Boolean operation (Yessios 1987). Students can use these tools to experiment and explore fundamental gestalts of transparency where space can be additive or subtractive and various Boolean operations could be used to explore appropriate aesthetic effects. One can take these exploratory exercises further to play 'what-if' games to learn from existing exponents of phenomenal transparency. One might use the example of Villa Garches upon which new forms might be added to enhance the existing transparency. Because there is no right starting point to such an exercise, students might see different fluctuating patterns and end up with very different solution, and yet having its own merit. One might even create basic walkthroughs to experience the spatial stratification from different vantage points and to explore the idea of phenomenal transparency at a more micro-level.

Section Planes and Multiple Viewports

Digital tools offer new opportunities for analysis of historic exemplars for design. Most schools now offer courses or at least basic training in 3-d modeling and visualization. In addition to training students, these courses provide opportunities for creating a repository of historic exemplars in 3-d. Tools such as SketchUp have features like the interactive section planes, which are helpful for design analysis and to reveal phenomenal transparencies. The section plane can be used to reveal the changes in volume and space in works such as the villa by Gisue and Mojgan Hariri at The Hague, as shown in figure – 5. Students in our design communication class construct 3-d models of exemplars from architectural history. This exercise over the next few years will create a library of 3-d models, which can be re-used in architectural history lectures as well as stored in a repository in our immersive visualization lab (iLab) for exploration by undergraduate students in, stereoscopic 3-d. This will provide an opportunity for our students to explore how phenomenal transparency is used by masters of modern architecture as a design tool. Simultaneously, they will be able to explore the experiential qualities of the design decisions in an immersive environment.

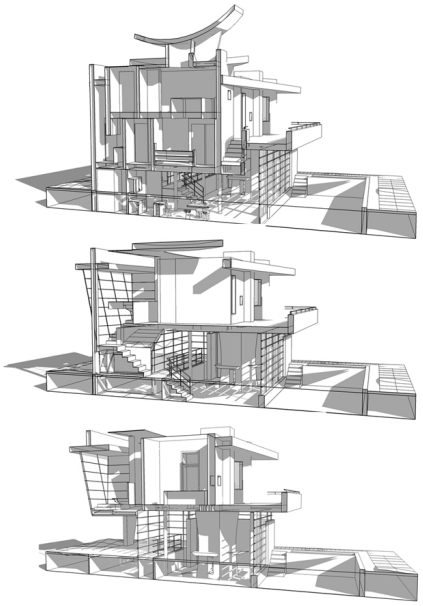

Figure 5. Villa Hariri – modeled by Karen Tobin, used with permission

THE ROLE OF DIGITAL MEDIA IN REFRAMING HISTORY AND DESIGN

Louridass (1999) describes that the uniqueness of a designer is that, a good designer is able to see things

in different ways, to determine their meanings, to organize them in a structured whole, and to re-organize them depending on the result. As demonstrated in the few examples in this paper, digital tools have the capacity to facilitate these reorganizations.

The exploratory examples in the previous section show that architectural history can be seen more as a problem-solving exercise, one in which the analysis process is important. Digital media, by its very nature, allows one to dissect the process in different ways facilitating conjectures and exploration with minimum cost and labor. In short, they provide an enormous variety of virtual learning materials that do not break or wear out (Bricken 1990). As Bricken has pointed out, digital tools facilitate the experiential learning ideas which consists of "Try experiments, safely. Experience consequences, then choose from knowledge." (Bricken 1990, p2).

Once analytical exercises are explored then one can use it to create 'what-if' scenarios for design. In their study of phenomenal transparency Hoesli and his students have shown that one can carry over the knowledge gained from history directly into design. Digital tools aaccelerates this process by providing a shared, holistic, structured and replicable environment, which allows for reflection.

Unlike analog explorations, where concepts and ideas might get lost in translation between the instructor and the student, digital models are helpful precisely because they structure the imagination better than working models and are useful because they provide a legible structure to the otherwise ambiguous nature of manual tools (Goldschmidt 1991). In other words, digital media provides a neutral medium for general scrutiny and a level playing ground between the instructor and the student.

With the advent of digital tools, architectural pedagogy has fundamentally shifted the learning and teaching of visual vocabularies, and has brought into question the core of architecture discipline in itself. In making a distinction between 'real' and 'fake' creativity, Lawson (1999) observes that because it is possible to produce a certain kind of three dimensional form in a digital package, the design student does so by bypassing the visual editing critical faculty we try to inculcate in design schools. Because digital media makes it easier to complex shapes based on ellipsoidal sections, rotations of curved parabolic forms and so on, the design student mistakes it for being more creative.

While the ability of digital media to create complex geometric shapes has many advantages, we have proposed that reframing digital tools as 'tools of design' rather than 'tools for design' frees the designer to go beyond the superficial construction to a more rigorous exploration of visual vocabularies. Both geometric precision as well as exploratory flexibility can then be used in complementary terms for a more unified approach to architectural designing. This reframing will strengthen the history-design studio axis. Digital tools will then function as a as a mediator shifting the focus from extrinsic to intrinsic content and allowing the designer to launch with conviction creative and intellectually stimulating design scenarios.

REFERENCES

Barrow, Larry R. 2000. "Cybernetic Architecture, Process and Form: The Impact of Information Technology." PhD diss., Harvard University.

Bricken, Meredith. 1991. "Virtual Reality Learning Environments: Potential and Challenges". *Computer Graphics* 25(3): 178-184. Accessed September 1, 2011. http://doi.acm.org/10.1145/126640.126657.

Carpendale, M.S.T., and Catherine Montagnese. 2001. "A Framework for Unifying Presentation Space." Paper presented at the annual ACM symposium on User Interface Software and Technology, Orlando, Florida, November 11-14.

Chi, Ed Huai-hsin, and John Riedl. 1998. "An Operator Interaction Framework for Visualization Systems." In Proceedings of the IEEE Conference on Information Visualization, Research Triangle Park, North Carolina, October 19-25.

Rowe, Colin, and Robert Slutzky. 1963. "Transparency: Literal and Phenomenal," *Perspecta*, 8: 45-54.

Rowe, Colin, and Robert Slutzky. 1971. "Transparency: Literal and Phenomenal…Part II," *Perspecta*, 13/14: 287-301.

Dicker, James, and Gill Snyder. 2005. Personal communication. Dicker and Snyder teach a beginning studio using phenomenal transparency at the University of Wisconsin-Milwaukee, School of Architecture.

Eisenman, Peter. 1980. "In my father's house are many mansions." In *Seven Houses* (Catalogue 12), edited by John Hejduk, 8-20. New York: IAUS.

Goldshmidt, Gabriela. 1991. "The Dialectics of Sketching," *Creativity Research Journal*, 4(2):123-143

Hoesli, Bernhard. 1997. Addendum in *Transparency* by Colin Rowe and Robert Slutzky,85-119, Basel: Birkhauser.

Lawson, Bryan. 1999. "'"Fake" and "Real" Creativity using Computer Aided Design: Some Lessons from Herman Hertzberger." In Proceedings of the 3rd conference on Creativity and Cognition. Loughborough, UK, October 11-13.

Leatherbarrow, David. 2001."Architecture Is Its Own Discipline", in *The Discipline of Architecture*, edited by Andrzej Piotrowski and Julia Williams Robinson, 83-102. Minneapolis: University of Minnesota Press.

Louridas, Panagiotis. 1999. "Design as Bricolage: Anthropology meets design thinking," *Design Studies* 20 (6): 517-535.

MacEachren, Alan. M. 1995. *How maps work: Representation, Visualization, and Design*. New York: The Guilford Press.

Stiny, George Nicholas. 1980. "Introduction to Shape and Shape Grammars," *Environment and Planning B*, 7:343-351.

Yessios, Chris. 1987."The Computability of Void Architectural Modeling." In *Principles of Computer-Aided Design: Computability of Design*, edited by Yehuda Kalay, 141-172. NY: John Wiley & Sons.