# Virtual and Material Realities Transformed by an Architecture of Information: A Web-Based Construction Document

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## INTRODUCTION

The value of this paper is that it presents research on a construction information system that breaks with the tradition of two-dimensional hand or computer drafted documents. The paper outlines a structure to an online information experience that suggest using computer network technology as a construction document. This is important because this sense of structure mediates the information by giving it a field of perceptive references in what might be an otherwise random pattern of interactions. This means visual organization (as an architecture) informs the orderly transfer of technical information by giving that information its own sense of space and time. Significant is that this research uses computer technology as a medium and not an isolated "tool" to support an individual user. What this means is that this online document is not only "an organized body of information" (Horton 94), but also a forum for interaction among design team members. As a medium, the document intends to capture and direct the flow of communications between clients, consultants, contractors, and project administrators to facilitate interaction and direct the social construction of values and meanings established during the design development process.

The weight of the jargon in this introductory paragraph needs clarification before we can begin. First, because this paper sketches the ideas of early research that remains highly experimental. As such, it is the subject of several parallel hypothetical investigations, any of which could easily redefine the results presented in this paper. Second, as most of those working with the Internet know, the market perception of this technology is far from the reality of its actual performance (especially with the World Wide Web). In fact, the complexity of the myths and capitalistic pretense of the computer industry and the Internet may be its greatest threat (McGrath 96). Third, it is important to remember that software evolves, and market demand (or lack of it) drives the direction of this evolution, sometimes without logic, but often with a good deal of hyperbole that needs to be picked through with skepticism (Gram 97). This means that much of this research is perched in a precarious position. As an example, this work began as a hyperlinked graphic document on a modified version of MacPaint running on an early Macintosh 128. Since then, its progress has been awkward, temperamental, and unpredictable, with software that has been consistently frustrating, overstated, and often abandoned by the original programmers. The best of these programs support this research, but only in so far as their next release, or the next coded innovation by another imaginative manufacturer. The fourth reason for clarification is that the possibility of a practical working example of an immersive construction document like the one presented in this paper remains at least a year away. In other words, current versions of this document are a patch of a variety of Hypercard stacks, implementations on different web-sites, and human "agents" supplanting XCMD sequences that have yet to be written (and may never need to be). This includes dealing with often erratic operating systems for both the Mac and PC platforms, consistently slow MODEM speeds, once at 300 bps, now commonly at 28,800bps and higher, that cannot keep up with the demand for increased bandwidth, and the Internet itself, overloaded and often said to be reaching its own breaking point (Fenton 97)

In other words, take these parenthetic clarifications as a hint of the state of both this research and the technology it is attempting to use. Far from the so-called cutting edge, this is the bleeding edge of computer documentation theory. This paper suggests a prototype that remains open to almost constant reevaluation. As such, it attaches itself to the tail of a comet and does not pretend to control its direction or predict the resulting destination. The goal of this paper is to share the underlying protocol and general status of this work with the precaution that all of this remains far from a viable, working, and contractible document that can be used (immediately) in the design and construction industry.

## COMMUNICATING NOT ILLUSTRATING

A fundamental premise of this work is that design and construction drawings are communication devices and not illustrations drawn in a social or technical void. This means that these documents are not produced for their own sake, but to communicate ideas in an exchange of ideas that occurs in the course of actual practice. Construction drawings are really conjectures, subject to tests and criticism (refutations) by clients, consultants, or anyone else involved in the design or construction process. As they are resolved, verified, checked, corrected, and accepted, they congeal as evidence of agreements that solidify meaning and value in this exchange. This includes sketches, schematics, construction drawings, renderings, and physical or computer models. When successfully drawn, they are the result of a communications process and not simply an isolated illustrative technique. For example, an idea might begin as a scribble on the back of an envelope. The scribbles become rough sketches that test the original concept in discussions with associates back at the office. These sketches lead to more sketches that are then evaluated and redrawn before they are prepared as a schematic for a client's input (and authorization to continue providing services). This piecemeal process of concept, perceptualization, discussion, presentation, and further modification or approval, continues throughout a design's development as a set of preliminaries and then construction documents — and often into the construction phase as change orders and clarifications.

What this means is architectural drawings are objects of knowledge that evolve in conversations, as the products of interaction and communication (Wiggins 91). Each phase of the design's development is the result of a set of technical transactions that occur in the process that transforms a vague design concept into a working construction document. In this way, an idea matures and information grows as the direct result of thousands of interrelated communications. The specifications, drawings, notes, and schedules that we see as the final document are therefore the derivative of social and technical interactivity. They are the reification of information, formed in the gradual process of the design's development, evidence of the congealed consensus that was (or was not) resolved as the sum of these interactions.

This is an important premise because it underscores the fact that drawings, as plans and specifications, facilitate the communication of the construction details of a building during the design development process. This means these documents are an integral part of a conversation because they are the "subjects" of the exchange. As such, they contain symbols, signs, and graphic representations, what Foucault might have called the "statements" of the discourse itself. These statements record the evolving consensus of the members of a design team. In this way, the construction document can be seen as a media of communication. They are not so much illustrations, but graphical hypotheses resolved through agreement as social constructions of meaning and values.

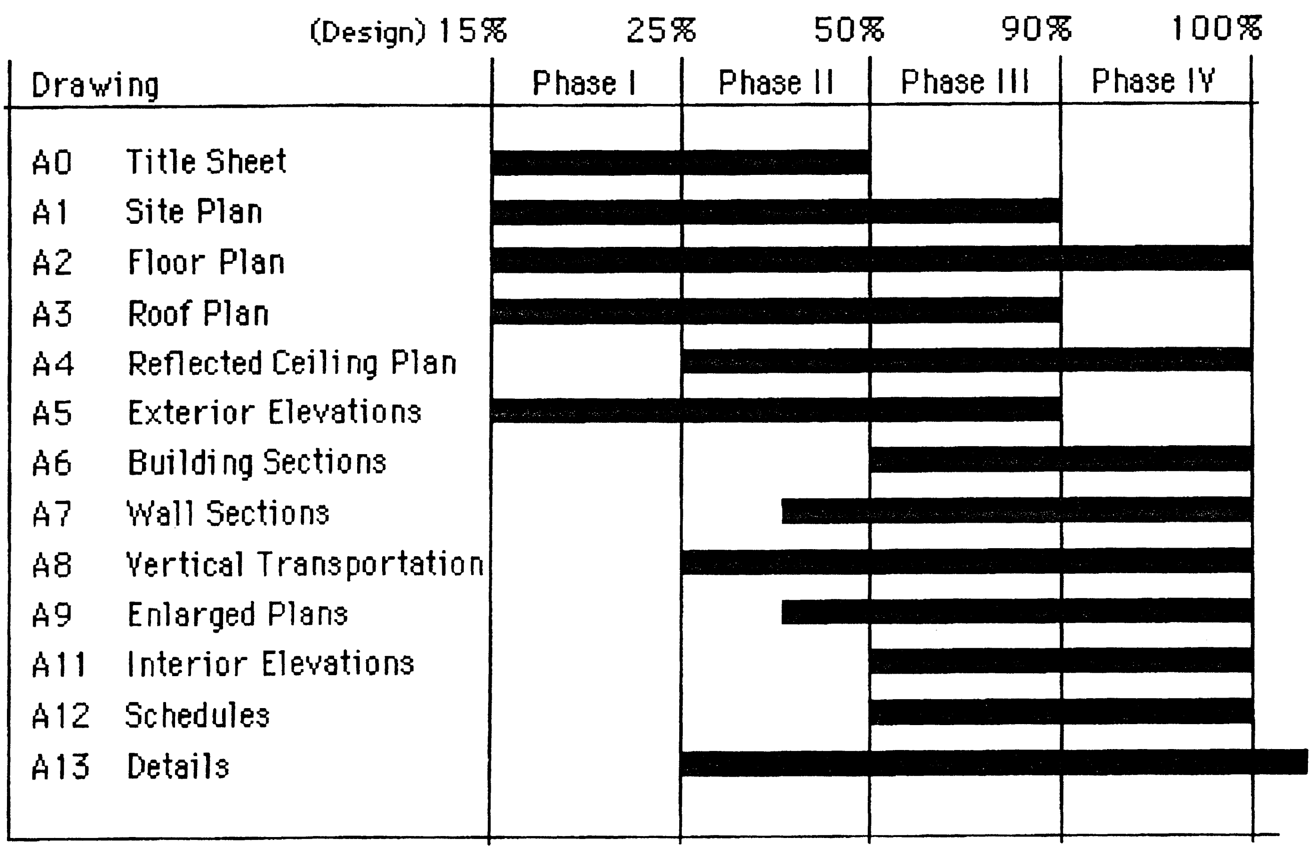


Fig. 1. Phase development of typical construction drawings indicate evolution of the documents Wiggins

## SOCIAL CONSTRUCTION OF MEANING

There is a good deal of literature to support the idea of social construction. In fact, the line of this literature can probably be drawn through many philosophers, but it is most strongly represented in the phenomenological thinking of Immanuel Kant. This is clearly articulated in Robert Schutz's work on phenomenological societies (Schutz 62). The general theme is that meaning systems are constructed through social interaction. This interaction assigns meanings and values through sensory inputs and the experience of these inputs guide our relationships and construct certain truths that we then maintain in further interactions. Eventually these subjective interpretations become consistent enough to be held as common knowledge among a group of people. Though never fixed, these ideas are consensual in that they are localized in the cultural context of a particular group. These groups have been labeled as paradigms (incorrectly), cults, disciplines, and social formations and are held together by what Foucault calls "history" (Foucault 89) and Popper refers to as an "evolutionary tree" (Popper 69).

The general theme of the phenomenological theory of social construction is that meaning systems are constructed through interaction with others. This interaction assigns meanings and values through inputs that evolve in the exchange, and the experience of these exchanges guide our relationships, constructing certain truths that are then maintained in further interactions (Jones 96). Eventually these subjective interpretations become consistent enough to be held as common knowledge among a group of people. Though never completely fixed, these ideas are consensual in that they are localized in the cultural context of that particular group. For example, a beam might be suggested as a feature in a preliminary drawing even though the beam itself may not have been visualized in early schematics. The beam is sized and its supports are resolved, first through a series of tentative alternatives (different sizes, materials, finishes, etc), then as calculations that finalize the beams position and visual characteristics. In the process, memos are exchanged, along with copies of various drawings that illustrate these ideas, each of these drawings supersede earlier versions of the beam. When we see these versions as hypotheses, resolved through critical analysis, what remains in the end are solutions that responded to conjectures and criticisms as compromises that became the basis of further design development. The exact details of the beam are thereby fixed by the social interaction and each of the drawings record the evolution of the original concept.

In summary, these drawings are only the most visible part of a communication process. They are snapshots of the stages of the development of meaning and value and not an end in themselves. If it were possible to animate this process, we could see the growth of meaning as it occurred during a project's development. And if one could see this animation in real-time, in other words, be immersed in the scenes that record the process as it was occurring, visibly witnessing one's actions in the context of the design team and able to archive the interactivity, one might thereby be better able to predict and control the outcomes (meanings) that are produced. In other words, given that these documents are the result of a social process, the process from which they evolve must be critical to the quality of the final product (the building). Communications (as text, sketching, telephone, drawings, fax, models, e-mail, etc.) is therefore the medium of the interaction and the framework for the information that evolves. If the flow of this interaction can be controlled, directed, and represented, according to carefully regulated relationships, meaning itself might be shaped by the mediated communications process.

## COMPUTER MEDIATED COMMUNICATIONS

It follows then, as a second premise in this research, that computer technology can play an important role in these mediated communications. The power of the computer to mediate communications and establish consensus in controlled interactions is fairly well documented (Turkle 90). Computers mediate exchanges in ways that are difficult to develop in face-to-face conversations (Santori 95). They breakdown barriers and encourage uninhibited interaction (Jones 95). Edward Barret defines this as "sociomedia" and believes that this ability to eliminate social boundaries is an important aspect of computer technology (Barret 91). His thesis is that the ultimate value of these machines is as a mediator for "social" purposes. He points out that they "objectify, exchange and collaborate, invoke, comment upon, modify, and remember thoughts and ideas" as an extension of our social interactions.

The power of computers to transfer information in this communications process is probably most obvious in recent developments of educational psychology. For example, collaborative learning has long been shown to be an effective method of teaching because it builds on group thought and social interaction (Johnson 89, Brown 89, Johnson 94). Some educators apply these methods to student design problems in engineering (Gal 91). The results suggest improved retention and deeper understanding of the application of design theory (Smith 95). Several scholars have shown that the computer works to improve communication within these collaborations (Lawley 95, Berge 95). For example, disabled and place-bound students can be drawn into conversations with their peers using e-mail (Pemberton 95). Scholars can quickly express ideas and publish the results of research using list-servers and electronic journals (Harrison 96, Muns 95). Usenet and chat-groups prove to be effective in overcoming barriers that often interfere with social interaction (Kinner 95). And a virtual space, as an electronic classroom, has been found to suspend time and facilitates student to student and student to teacher interaction (Barret 95).

In each of these examples, a series of focused interactions suspends real-time and produces information as a result of computer mediated communications. The computer mitigates the variability of external exchanges driven by a clock-on-the-wall and replaces them with internal interactions regulated by the representation of data in a machine. In this process, time "passes" as modifications are made to the database. Each posting attaches new information to a thread of communication saved to computer memory. Changes in the data structure mark the completion of some new event in virtual-time. This means coordination of the interaction of the design-team is a matter of calibrating the data modifications of individuals and producing a graphic representation of the result. The idea quantifies the performance of the individuals. This is important because within a virtual data environment, time and the evolution of meaning can be said to stop if no changes occur to the computer's data structure. Simultaneously, information can be said to be growing, as ongoing changes to the data cause it to mature into its final and (most stable) form.

## MEANING AND VALUE CONSTRUCTED THROUGH COMPUTER COMMUNICATIONS

It remains then to combine the theory of social construction with the communicative power of the computer in ways that control the transfer and construction of information. To do this we draw on the work of educators who use social construction to build learner-centered relationships between their students (Jones 96, Johnson 89, Harrison 96, Smith 89). In this research, the learner (as user) is seen as a participant in the construction of meanings and values as lessons that evolve out of an interactive process. Termed "constructivism," the pedagogical thesis of these researchers is roughly paraphrased as "meanings (that) are socially constructed through interactions with others....shaped by the categories and relationships embedded in everyday language, activities and values....learning (as information transfer) occurs when anomalous events raise questions" (Jones 95). Understanding the context of computer mediated communications as it relates to constructivism is important because it can be fundamental to developing motivation and interest in the subjects that are important to students (DeBoer 91). It is generally agreed that critical problem-solving ability is improved by knowledge of the concepts that are relevant to the area under investigation. In this way, the process of building structured knowledge (as information) is integral with its application. This is the main premise of constructivist educational theories. These theories stem from Socratic dialogs (White 76), Kantian architectonics of constructions and reconstructions of knowledge through hypothesis and testing (Werkmeister 80), the progressive schools of John Dewey (Dewey 63), Kuhn's notion of paradigms (Kuhn 62), and the cognitive studies of Jean Piaget (Phillips 71).

These constructivists ideas set up the potential for social construction in a controlled interactive environment and introduce parameters (into a learning process) that involves context and practice. This can inform our teaching, but it can be even more significant as the basis of research into an architecture of information. If we substitute the constructivist learner for the social user (client, consultant, political authority), and think of learning, constructed through activity and interaction, as the transfer of information within a controlled technical correspondence, we may be able to redefine the meaning of practice using the structure of a computer interface to control the interaction of a design team.

## THE RESEARCH HYPOTHESIS AND METHODOLOGY

Taking the constructivist's notion of context and activity, where learning (as new information) emerges from interaction and communication as social construction, it seems logical that computer mediated communications may offer an opportunity to literally "define" the design development process. This means if information can be controlled, directed, and represented according to a perceptual order of relationships, meaning might be shaped by the environment that contains the data experience. In other words, when we look at a computer program, and recognize that it is a sophisticated information environment that stimulates interaction and creates meaning through that interaction, the power of networked technologies, as a forum for communications, seems clear. Given the underlying structure of computer mediated exchanges, and the social constructions of meanings that emerge, perhaps we can capture the force of the perceptive associations built into the directed interaction — not as a natural formation of ideas, but as a purposeful association of virtual spaces that direct our understandings of those ideas.

The hypothesis, therefore, is that an architecture of information, perhaps shaped by designers themselves, might effectively control the development of socially (and technically) constructed meanings, if this architecture shapes the interaction itself. This points to a user-centered model of information-transfer that suggests the potential for greater control of the design and construction process. The idea is to create an information landscape where space is ordered by virtual form. In this space, information simulates the object to be constructed and information, not illustration, regains its strength in the construction process.

The methodology used to test this hypothesis uses associative visual relationships to orient the user to the information (Loftus 76, Bedard 89, Kojonen 84) within a virtual environment. This means movement is user-centered and data-links are associated with visual elements in the information landscape. Users therefore remain in control of their movement and build perceptive relationships with the information. These perceptual references build on the biological structure of the brain and how it reinforces memory and learning through patterns and textures (Johnson 91).

## A PIECE-BASED INFORMATION SYSTEM (PCIS)

This hypothesis is being tested as the construction document necessary to assemble an erectable trainer. The combination of a virtual information system and a physically erectable trainer is called the Erectable Hypergraphic Trainer (EHT). The EHT is a pedagogical research tool designed to test the hypothesis and evaluate the effectiveness of various configurations of the construction information system. This is a piece-based construction information system (PCIS) and the immersive virtual environment of the EHT. PCIS is a network-based document that describes the construction of an object according to the information relationships of its pieces rather than diagrams of spatial relationships that must be interpreted for construction. The methodology studies how changes in the perceptive organization of PCIS affect the performance of student's engaged in the EHT's construction. The objective is to understand the potential of the computer to control the transfer of technical knowledge (as construction information). As discussed above, the organization of this transfer shapes the social construction of technical meaning defined in the interactive process as the construction documents.

For the purpose of this paper, the physical trainer, and the constructivists lessons embedded in its design, will not be discussed (See Fukai 96).

Immersion into the PCIS site begins as the interface opens with a sequence of transformations that draw the user toward a matrix of cubes that act as a gateway to the data files of the information system. This orientation sequence is critical to providing the illusion of immersion for the data experience. It sets up the sense of scale and attempts to focus the user on the experience of the virtual space.

A click on one of the cubes shifts the user to the information environment defined by that particular file. The cube pops open and expands as its sides tumble outward to form the main data-theater. The extended sides of the original cube partition the data into separate perceptual formations. At the center of the main data-theater sits an orthographic simulation of the object to be constructed from the PCIS document. Various configurations of the data-partitions lead to sub-simulations that contain models of the plumbing, electrical, and HVAC systems. Design-team members "enter" these chambers to coordinate the document's development, review progress, and make changes to the information system.

A navigator compass gives users access to two realms of information. The first centers around the array of orthographic simulations that provide the scaled details of the EHT. In this realm, the partitions display projections of horizontal and vertical slices taken through the object. Below a horizontal reference plane are hypergraphic projections of slices through floor framing, foundation, excavation, utilities and soils. Above this plane are projections of roof framing, fixtures, ceilings, and roof penetrations; and to the sides of a vertical plane are slices that define framing cuts, finishes, and elevations.

Details on these slices are hypergraphic. This means a mouse click on one of the projections leads to more information about the construction. This includes piece-oriented links that open to data threads that extend into the supporting database — past simple manufacturer URL's and specifications to the underlying science of the materials themselves. The slices can be sorted and animated to show the sequence of construction for any part of the total assembly. These animations are scaled isometrics "played" from the data structure of the piece-based information system. Piece-based data means that the objects represented on the slices can be recombined to show different stages of assembly.

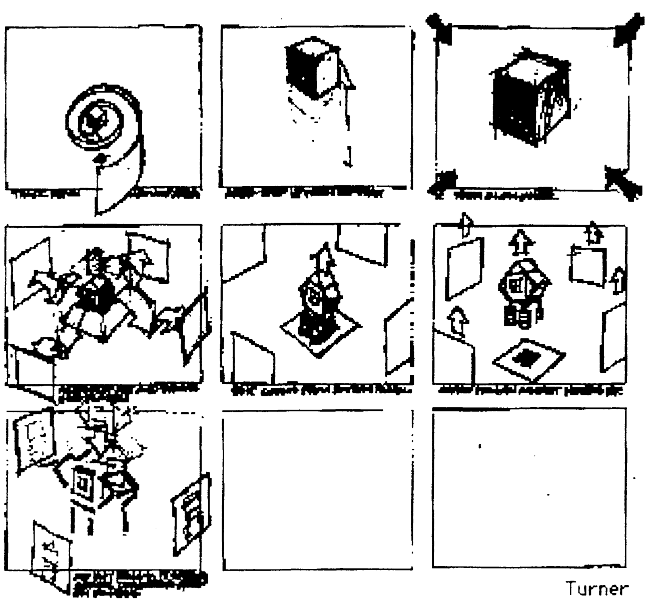


Fig. 2. A cube transforms into a data-theater of the object to be constructed

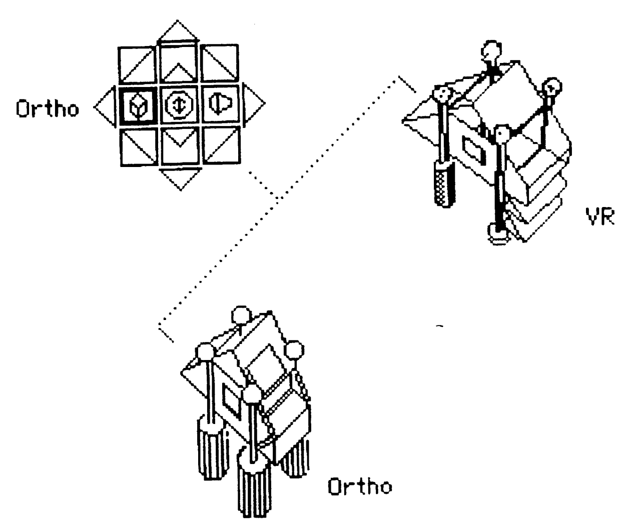


Fig. 3. The navigator compass switches between the Orthographic and VRML environments

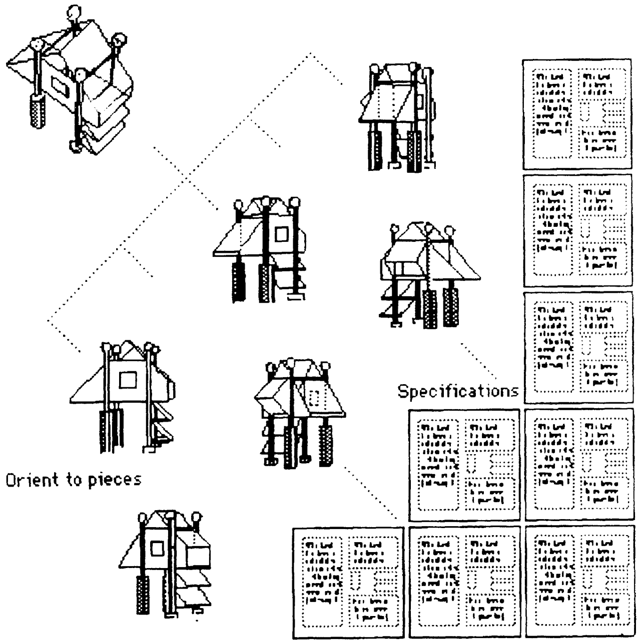


Fig. 4. The virtual environment has links from the pieces of the object to data pages.

This means it is possible to sort the graphic data to simulate the construction process in many different ways. It also means that the resources and value of that data is available for evaluation and compilation.

A button on the navigator compass switches the user from these scaled orthographic simulations to a second, parallel realm of free-flowing virtual realities. In this environment the user is free to examine the object at different angles and distances. The partitions remain, but they are now available as maps to information about each of the pieces of the EHT. Hypergraphic links from these pieces extend deeply into a network of data underlying the information system. This includes specifications of base materials, code issues, client preferences, geographic constraints, and other information that would be difficult to include in a printed construction document.

## VIRTUAL AND MATERIAL REALITIES TRANSFORMED BY AN ARCHITECTURE OF INFORMATION

This immersive information environment shifts the focus of the tradition of this design development process by embracing the notion of the computer as a tool that changes our perception of space and time (Smith 71, Gibson 84). Important is that this addresses not the illustrations of design, but the communication of information that occurs during its production (as a building). Though we often forget to remind our students, this process is where the "meaning" of a building is defined in actual practice. It is here that ideas are suggested, criticisms and corrections exchanged, and values established. Control of this interaction, centered on the information necessary for the construction of the building, is the main objective of the research.

PCIS is a computer document where graphic information finds an architectural form that defines the construction of an object in both space and time. This suggests that the interface between virtual and material realities might be transformed by a computer mediated experience that is controlled by the structure of the technical information exchanged. The architecture of this information is thought to increase the perceptibility of the user of the construction document, thereby increasing the efficiency of the design and construction team. This improves communications and helps build partnered-relationships because users have equal access to all the factors driving the final design. The result is a document that contains living information that guides the design and construction process, bridging the gap between virtual and material realities. This breaks with the notion of a hand or computer-drafted document and suggests a broader focus for the use of computers in the control of the design and construction process. It provides users with the means to shape their own information experience and gives them the opportunity to participate in an interactive process that will ultimately shape the final construction. The value of this idea is that it suggests an increasing relevance for our students in the design and construction process — one that could give their designs the strength to survive in the competitive relationships that they will face in the now prevalent, information age.

## BIBLIOGRAPHY

Barret, Edward. 1992. Sociomedia. MIT Press.

Berge, Zane L. And Mauri P. Collins. 1995. *Computer Mediated Communication and the Online Classroom*. Volumes 1, 2, 3. Hampton Press..

Bedard, Michael David. *Structures Housing Knowledge and the Memory of Experiences*. 1989.

Brown, John Seely, Allan Collins, and Paul Duguid. January-February 1995. Situated Cognition and the Culture of Learning. In *Education Researcher*.

DeBoer, George. *A History of Ideas in Science Education*. Teachers College, Columbia University. 1991.

Dewey, J. *Experience and Education*. Holt, 1963.

Fenton, Brian. "Death of the Internet" *Popular Mechanics*, January 1997, pp40-6.

Foucault, Michel. 1972. *The Archaeology of Knowledge and the Discourse On Language*. Pantheon Books.

Fukai, Dennis. "Real-World, Real-Time, Real-Fast: Using a trainer in a computer mediated classroom" A presentation as a fellow to the Materials and Technology Institute of the Association of Collegiate Schools of Architecture, Berkeley, CA, 1996.

Gal, Shahaf. 1992. "Computers and Design Activities: Their Mediating Role in Engineering Education." In *Sociomedia*, ed. Edward Barret. MIT Press.

Gibson, William. *Neuromancer*. Ace Books, 1984.

Gram, Bill. "Online Services: Good News...Bad News." *Microtimes*, #160, January 1, 1997, pp178-84

Harrison, Teresa M. 1996. *Computer Networking and Scholarly Communication in the Twenty-First Century*. State University of New York Press.

Horton, William. 1994. *Designing and Writing Online Documentation*, 2nd Edition. John Wiley & Sons, Inc.

Jones, Byrd L. and Robert W. Maloy. *Schools for the Information Age: Reconstructing foundations for learning and teaching.* Praeger Publishing, 1996.

Jones, Steven G. 1995. *Cybersociety: Computer-Mediated Communication And Community.* Sage Publications.

Johnson, David and Roger Johnson. 1989. *Cooperation and Competition: Theory and Practice.* Interaction Book Company.

Johnson, David and Roger Johnson. 1994. "An Overview of Cooperative Learning." In *Creativity and Collaborative Learning*, ed. Thousand, Jacqueline, Richard Villa and Ann Nevin. Prentice-Hall.

Johnson, George. *In the Palaces of Memory: How we build the worlds inside our heads.* Alfred A Knoff, 1991.

Kinner, Joseph. 1995. "Computer Access for Students with Special Needs." In *Computer Mediated Communication and the Online Classroom: Overview and Perspectives*, ed. Zane Berge and Mauri Collins, Volume 1. Hampton Press.

Kojonen, Teuvo. *Self-Organization of Associative Memory*, 3rd Ed. Springer Verlag, 1989.

Kuhn, Thomas S. *The Structure of Scientific Revolutions.* University of Chicago Press, 1962.

Lawley, Elizabeth Lane. 1995. *Discourse and Distortion in Computer Mediated Communication.* School of Library and Information Science, University of Alabama.

Loftus, Geoffrey R. *Human Memory: the processing of information.* John Wiley, 1976.

Mc Grath, Charles. "The Internet's Arrested Development." *New York Times Magzine*, December 8, 1996, pp 80-5.

Muns, Raleigh. 1995. "Online Scholarly Discussion Groups." In *Computer Mediated Communication and the Online Classroom: Overview and Perspectives*, ed. Zane Berge and Mauri Collins, Volume 1. Hampton Press.

Pemberton, Anne. 1995. "CMC and the Educationally Disabled Students." In *Computer Mediated Communication and the Online Classroom: Overview and Perspectives*, ed. Zane Berge and Mauri Collins, Volume 1. Hampton Press.

Phillips, John L. *Piaget's Theory, a Primer.* W. H. Freeman, 1981.

Popper, Karl. 1986. *The Poverty of Historicism.* Ark Paperbacks.

Santoro, Gerald M. 1995. "What is Computer Mediated Communications." In *Computer Mediated Communication and the Online Classroom: Overview and Perspectives*, ed. Zane Berge and Mauri Collins, Volume 1. Hampton Press.

Schutz, Alfred. 1967. *The Phenomenology of the Social World.* Northwestern University Press.

Smith, Karl A. 1989. "Cooperative Learning and Problem Solving." In *Cooperative Learning and College Teaching*, Volume 3, Number 2.

Smith, Karl A. "Cooperative Learning: Effective Teamwork for Engineering Classrooms." IEEE Education Society Newsletter, April 1995.

Turkle, Sherry and Seymour Papert. 1990. "Epistemological Pluralism: Styles and voices within the computer culture." *Signs: Journal of Women in Culture and Society* 16.

Werkmeister, W. H. *Kant, The Architectonic and Development of his Philosophy.* Open Court, 1980.

White, Nicholas P. *Plato on Knowledge and Reality.* Hackett Pub. Co., 1976.

Wiggins, Glenn E. 1989. *A Manual of Construction Documents.* Whitney Library of Design.