A Cyber-Enabled Collaborative Design Studio

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The research project investigates the use of a network-enabled platform involving a combination of technologies. As a preliminary report on a proof-of-concept design studio conducted in 2007 between Carleton University and Pennsylvania State University, the paper first describes the implementation of this network-centric collaborative design platform. The report articulates the "staging" of the conditions of possibility for a dynamic interplay between technological mediation and the reality of making, then compares the use of high bandwidth technology with customized symmetrical toolsets in the telecollaborative environment, versus commercial toolsets deployed over moderate bandwidth connections. In each setting, the collaborative environment is assessed according to issues encountered by students and design outcomes. The effectiveness of the digitally mediated collaborative studio is also gauged in terms of student reaction to the learning process via feedback surveys and questionnaires.

1. Introduction

The process of making building is a highly collaborative intense, intimate, and simultaneously creative and technical endeavor that involves a variety of disciplines and specialists. As we increasingly look toward sustainable building and planning practices, even more disciplines are contributing to the process. Typically, this process relies heavily on visual communication through a wide range of digital and analog assets. Increasingly, participants are spatially segregated, relying on a variety of digitally mediated and extremely large data sets, creating a rich but heterogeneous work environment. Geographically distributed and digitally mediated work environments exacerbate the complexity of the design process but simultaneously provide immense opportunities. Recent improvements in visualization and communication technologies challenge traditional location-dependent partnerships and open up new possibilities for rich modes of creative activity and collaboration. Several questions are immediately suggested by these technological innovations, regarding their potential implications for how we create, communicate and represent designs collaboratively:

- What new modes of creative collaboration are enabled by digital mediation that traditional, location-dependent teamwork might not offer?
- How do we define the substance, qualities and boundaries of a digitally mediated environment?
- How do we shape this environment to meet the conditions of possibility for a creative design process?

During the spring semester of 2007, student teams in two locations participated in a collaborative digital architecture studio, between the Immersive Environment Laboratory (IEL) at The Pennsylvania State University (PSU) and the Carleton Immersive Media Studio (CIMS) at Carleton University (CU), Canada. The experimental design studio investigated the use of a tele-collaborative educational environment in which broadband data networks; high-performance rendering and visualization resources, immersive visualization systems, and supporting multimedia applications were integrated into the design workflow. The objective of the tele-collaborative environment was to create an immersive, information and communications rich environment for dialogue, group problem solving and the shared experience of participatory design. The research agenda is to build upon previous research conducted at the IEL and in CIMS on advanced networks, broadband video, visualization technologies, middleware and interface design, and to investigate how digitally mediated design can facilitate the collaborative design process in 'real-world scenarios'.

This "proof-of-concept" and "capacity building" phase of the Participatory Design Studio (PDS), was implemented through a series of collaborative design environments, each of which comprised a loose assemblage of geographically distributed platforms (or "scenes"), including traditional architecture studios at both PSU and CU, immersive media labs, multiple communication and visualization technologies, and a web based Network Enabled Platform (NEP). The efficacy of the new collaborative environment is governed by how technology and its formal features may shape user interaction, processing and perception of mediated content. Thus, we approached each collaborative design environment as a "staging" – choreographing of a palette of digitally mediated tools, from digital sketching, 3D parametric modeling to simulation within a NEP – in order to evaluate unique conditions for a dynamic interplay between technological mediation and making.

2. Background on digitally mediated collaborative design studio

The notion of the technologically mediated collaboration has been around since the mid-1990s as communication technologies evolved and became readily available. The Media Spaces experiment at Xerox PARC [1] utilized video cameras in collaborator's locations to create a shared virtual workplace. The first example of the digitally mediated collaborative design studio experiment, entitled 'Distant Collaboration', was attempted in 1992 between the University of British Columbia (UBC) and Harvard University. Since W. Mitchell coined the term 'Virtual Design Studio' (VDS) in 1993 [2], many Architecture schools have conducted various experiments on VDS [3] in collaboration with other schools of architecture, including Harvard, Cornell, MIT, Washington University and Hong Kong University [4-5]. Due to the lack of available collaboration technologies, they had to rely heavily on asynchronous communications such as email, message bulletin boards ("digital pinup boards"), FTP, and the still developing Internet. With insufficiently powerful and crudely coordinated tools, collaboration was primarily in an asynchronous, task-based working process that did not allow for full participation by members of the design teams [6]. As a result, participation was reduced to "simply submitting and giving oneself over" [7] to the process and other participants.

Since then, various attempts were made (Cornell University, ETH Zurich, MIT, UBC, National University of Singapore and the University of Sydney, Brisbane and Tasmania, ETH, HKU, UW, UBC, and Bauhaus University Weimer in 1997, 1998 and 1999, etc.), and numerous terms have been coined to indicate such endeavors: participatory design, collaborative design, multi-disciplinary design, co-operative design [8]. Kvan described the requirements of collaborative design and differentiated between collaboration and cooperation. He claimed that while collaboration implies that the members of the design team share a common goal, cooperation, though similar in context, implies only that the design team works together. He illustrated three types of collaboration- mutual, exclusive and dictator [9]. A European workshop called ACCOLADE (ArChitectural COLlAborative DEsign) was also conducted with similar goals in mind around 2001 [10]. Many authors such as Achten [11], Klercker [12], Maver and Petric [13] along with over 25 researchers from 12 universities researched on the underlying principles in collaborative design for the future. They discussed the important qualities of collaboration, and the hindrances in simultaneous and multidisciplinary design process to figure out the aspects to be developed for future.

Schnabel and Kvan [14] also conducted the first virtual design studio in Australia that was conducted solely in a virtual environment. From 2000 onwards, Maher [15] carried out a lot of studies related to analyzing the tools required for VDS including usability studies and protocol analysis of tools. Virtual design studio has implications on the way design decisions are made and designs are documented. According to Maher et al. [16], very little is understood about the phenomenon of collaboration within a distributed computernetworked environment and there is need for appropriate computer representation for design development and documentation.

The digitally mediated collaborative design studio has become an established part of teaching design within the digital realm [16]. They vary in configuration ranging from primarily 2-D and text-based to include various forms of interactive synchronous or asynchronous collaborative function, but the emphasis of most research has been primarily on information exchange during the design process.

A steadily improving network infrastructure with higher bandwidth, lower latency connections and effective media technologies now offers us the possibility for greatly enhanced ways to communicate, contribute and collaborate, allowing real-time interactivity and rich media experiences amongst participants with quality and reliability. Although the recent development of synthesized networking and media technologies has led to significant progress in enhancing collaborative environments in academic settings (Stanford University, University of Strathclyde, University of Sydney, MIT Media Lab, U.C. Berkeley, etc.), truly collaborative work is still rare. The transformative nature of these technologies has barely been tapped in design fields and little research has investigated how these latest developments in visualization and communications technologies might play out over long-term use in real-world settings [17]. There is hardly any research done to speculate on how such a paradigm shift in the world of architecture brought by the most up-to-date development in visualization and communication technology opens up different modes of collaboration [13, 16]. Most prior research has studied short-term experiments mainly focusing on specific technology features. Our research project is an attempt to study the long-term setting, laying more emphasis on the traditional studio and then determining the appropriate network-centric collaborative technological mediation based on their respective affordances.

3. Mediation and collaboration

The primary goal of the PDS is to allow students at multiple locations to collaborate in real-time by sharing computational resources, geometry datasets, and multimedia content. Access to a high bandwidth Research and Education network allowed for low latencies and high-speed transfer rates to create a "next door phenomenon" thus effectively consolidated resources distributed across the two sites. Design collaboration is to 'work together in a meaningful way, not just working together efficiently, but stimulating each other to contribute to the design task...toward mutual understanding and maximizing outcomes that satisfy not only own respective goals, but also those of other participants" [8]. Thus, in order for collaboration to be successful, the environment needs to foster a sense of presence among the participants and to enable transparent conversation and use of resources, and sharing of ideas and thoughts. Our main goal was to determine effective thresholds to accomplish a phenomenologically complex participatory experience.

3.1. Facilities

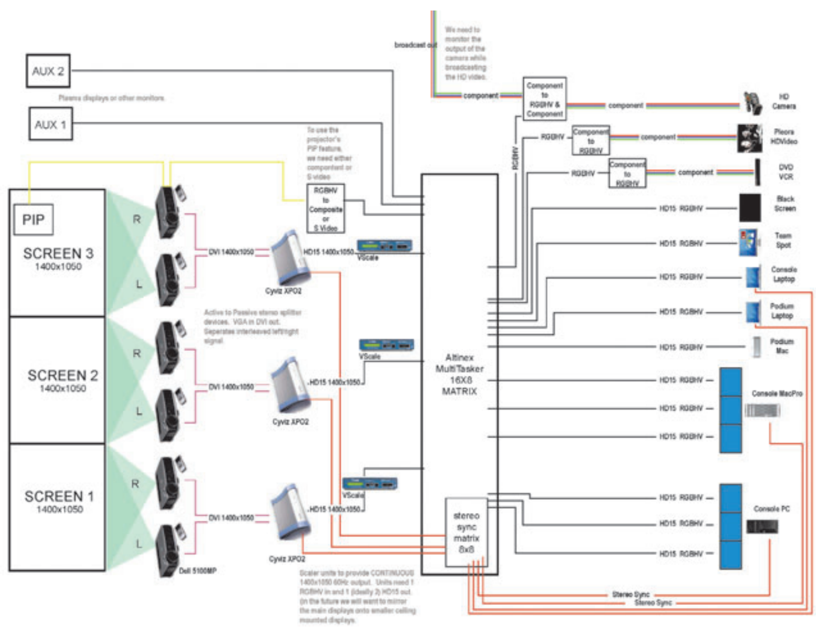
The IEL at the School of Architecture and Landscape Architecture at PSU offers a three six-by-eight-foot, panoramic, passive stereoscopic VR display and is supported by multi-platform graphics workstations and software to allow VR-like display of student designs. Conceived as a lower-cost VR alternative to then first-generation CAVE and like systems, the IEL has evolved to support and reflect student work habits, in which VR capabilities often are used with other modeling, multi-media or presentation applications within an immersive information environment, in addition to the intended use purely as an immersive VR display. Figure 1 shows the schematic diagram of the IEL equipment. (For more information, please refer to the IEL website [18].) The IEL is also equipped with the same Standard-Definition (SD) tele-presence system and is connected to the APN and its associated resources through a 1Gb/s layer 3 PacketNet connection to CIMS. The user pattern at CIMS and IEL suggested that an integrated multimodal platform would best serve at the evaluative stage during the design process, especially in a collaborative setting [19]. Current specification of the IEL, specifically related to this research includes:

- Windows Workstation: IBM Intellistation A Pro workstation, nVidia Quadro FX 4500 PCI Express video adapter, 2x AMD Opteron 256 3.0GHz processors, 4GB RAM
- Projectors: 6x Dell 5100MP, 3300 lumen DLP technology, SXGA+ resolution

- Sound System: ClearOne RAV 900 conferencing system, 2x loudspeakers, 3x ambient microphones, M-Audio Audiphile Firewire external audio interface
- Video capture and processing:
  - o AcessGrid: Sony EVI-D100 remote camera, Winnov Videum 4400 video capture card
  - o Standard Definition: Sony HDR-FX1 High Definition DV camcorder, Blackmagic Multibridge Pro media bridge, Pleora Ethercast Video IP System.

CIMS at the School of Architecture at CU has at its disposal a robust configuration of network and computer resources, a range of tele-communication platforms, displays and immersive environments. Through the financial and technical support of CANARIE (Canada's broadband agency) CIMS has developed a design specific NEP to support the complex behavior involved in collaborative architectural decision making across distributed sites. The logistic complexities and configuration of the devices are made transparent to the user and virtualizes a series of workflows through a middleware "dashboard". The resources and devices include rendering and visualization clusters, storage arrays and servers, communication platforms, displays and immersive environments.

The resulting APN consolidates a variety of resources, assets, and expertise by utilizing an intelligent network that is secure, has low latencies and ultra high speeds. It has 10Gb/s connectivity utilizing User Controlled LightPath (UCLP) software for on-demand control and configuration of the optical network. Levels of connectivity (Layer 2 and 3) in 1Gb/s increments



► Figure 1. Penn State SALA Immersive Environment Lab Equipment Schematic.

can be obtained to various sites depending upon the user's requirements through UCLP configuration and control. SD (270Mb/s one way) and H323 (10-30 Mb/s) video conferencing options are available as well as High-Definition (1-1.5 Gb/s) tele-presence capability for real-time analysis of physical artifacts such as drawings and models. The specification of the CIMS set up was symmetrically to the IEL, with the exception of using two Plasma screens for a display system.

4. Defining the digitally mediated environment

We approached the "staging" of the digital collaborative environment as consisting of three primary "scenes": the IEL, the CIMS lab and, finally, the digital "scene" which, of the three, most urgently needs to be investigated and qualified. This third "scene" of the digital environment is created through a dynamic interaction between the students and the two distinct technological interfaces. None of the three primary "scenes" exists as a purely physical or purely virtual space. The IEL and CIMS labs are partially constituted by their extensions into the digital realm. Likewise, the digital "scene" requires a robust physical substrate. The virtual and the physical are interpenetrated and the boundaries between the three "scenes" are very porous. Transgression across these boundaries – the passing of data-sets and assets, but also bodily gestures, expressions and ideas - is the creative activity that actualizes the digital collaborative environment.

The digital, like any medium, is not neutral. As Don Idhe [20] argues, "the very structure of technologies is multistable, with respect to uses, to cultural embeddedness, and to politics as well… Within multistabilities there lie trajectories, not just any trajectory, but partially determined trajectories". A similar characterization of this non-neutrality of technology can be found in the writings of situated cognition theorists stating that "the culture and the use of a tool act together to determine the way practitioners see the world; and the way the world appears to them determines the culture's understanding of the world and of the tools" [21]. We must become attuned to the structural biases of a technological interface and to the cultural contingencies of the digital mediated environment. Improvements to the communications and visualizations technologies are often correlated with an increased "transparency" of the technological interface at the risk of covering over the particular biases of digital mediation.

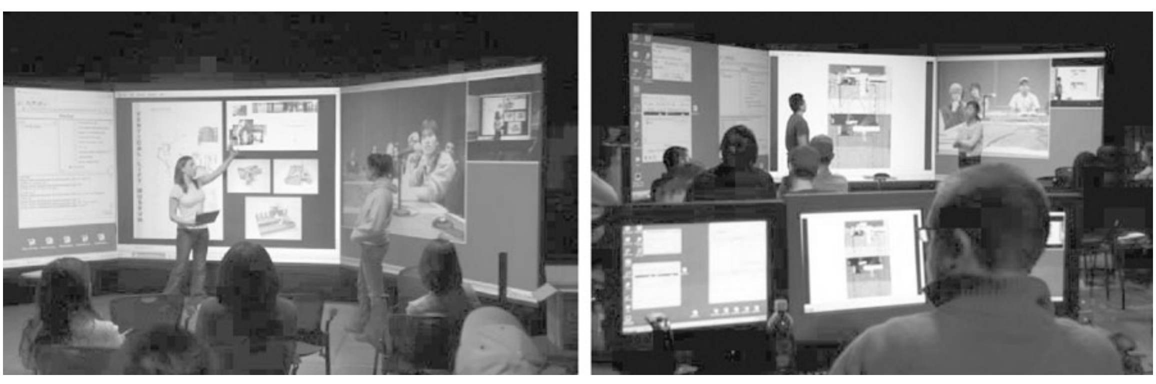
4.1. "Staging" of the Digitally Mediated Environment

In "staging" the PDS, our intention was thus not to conceal or subvert the materiality of the digital environment, rendering the technological interface more transparent, but rather to directly engage its particular behaviors and resistances, and in return to draw out its particular qualities in order to increase the "smoothness," of the digital medium. The distinction between transparency and "smoothness" suggests that technological mediation can be rendered *more* visible without constituting an obstruction. In the PDS, we found that for each major component of the digital platform, such as the broadband connection, audio quality and video feed, a critical experiential and operative threshold must be achieved. First and foremost, interaction must occur in real-time and in 3-dimensions, allowing for seamless communication, and a fluid exchange of digital artifacts and ideas. Infrastructural flexibility in the collaborative environment is paramount, so that participants can integrate new softwares, design materials and working strategies. Finally, the technological interface must be visible enough that participants can learn to work within or against its biases.

4.2. Project One (VLM – PSU local site) with AccessGrid

For the first project, students were organized into groups of 4, with 2 students from each school. Since the proposed project was located at PSU, the PSU students took responsibility for "hosting" the project, particularly in conveying the project parameters, building context and site qualities to their partners at Carleton. They transferred these assets to CU students via FTP sites. The information conveyed consisted of Form•Z digital models, pictures of existing conditions, conventional architectural drawings in PDF format (site plans, building plans, elevations and sections) and video documentation. This first staging was comprised of PSU and CU "conventional" architecture studios; tele-presence suites at CIMS Lab (Sony HDR-FX1 HD DV camcorder and UB1204FX Audio Mixer) and IEL (Sony EVI-D100 remote camera, ClearOne RAV 900 conferencing system with loudspeakers and 3 ambient microphones); a broad range of supplementary pair-to-pair communications, including instant messaging, email, phone plus a FTP site. Scheduled videoconferences were held once a week for the first three weeks and twice a week for the rest of the project. After the initial meeting session, the students communicated their design intentions via Access Grid conferences, using primarily PDF format with images from Form-Z models and scanned hand drawings, as well as some AutoCAD and other modeling software (Figure 2). The Access Grid conference was easy to operate and robust enough to serve for productive conversation and exchange of

▼ Figure 2. Left: AccessGrid Session at the IEL. Right: AccessGrid Session with the console at the IEL.



concepts and critiquing, thus contributing to the establishment of a common ground for the projects. Most of the design collaboration on the projects, however, was task-based collaboration and happened asynchronously for the duration of the project. Many PSU and CU pairs developed two parallel projects for several weeks and some groups struggled to resolve their ideas into one shared proposal.

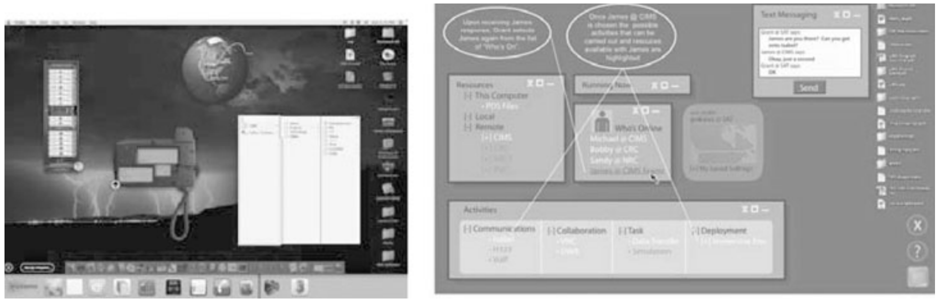
4.3. Project Two (SoA – CU local site) with National LamdaRail and CaNet*4

With the second project sited at Carleton University's School of Architecture, the PSU and CU students reversed positions, in that CU students were now responsible for communicating the unique existing conditions of a complex building, site remote to the PSU students. For this project, some groups were combined or reorganized, resulting in a variety of group sizes, with 4, 6 or 8 members. Similar to the first project, this staging included previously listed items as well as remote sketching programs (Open Canvas) and desktop sharing applications such as TeamSpot. Most significantly, the connection between IEL (Figure 3) and CIMS was switched to the 1Gb/s National LamdaRail PacketNet and CAnet4, allowing the group to deploy uncompressed SD Video using Pleora Technologies' EtherCast; PDS Web Service and Dashboard for ease of control and configuration of devices included in the APN such as the rendering farm located at CIMS and the communication platform; and DCV-RVN for real-time application sharing and high-performance visualization of assets. This PDS project is considered to be the first 'in the wild' reallife deployment of the components developed in Eucalyptus [22].

▲ Figure 3. Left: SD Videoconference Session at the CIMS. Right: SD Videoconference Session at the IEL.

PDS Web Service and Dashboard

Previously, there was no work being done to integrate and make the technology easy to use and on- demand for the end users without large support and technical staff. The PDS Web Service and Dashboard brought different tool sets that encompass and streamline almost all stages of the digitally mediated process. The Dashboard is flexible, robust and relatively "smooth" to users and will become a powerful multidisciplinary collaboration enabler as more 'Widgets' are incorporated.



► Figure 4. Left: Conceptual Diagram of the Dashboard. Right: Screen Capture of Dashboard in use.

The Dashboard is the interface in which users access and engage people, resources and tools that make up the PDS. Implemented as a web application, a user can access it from any workstation connected to the Internet (or the APN). The functions of the Dashboard are supported by a set of underlying services that are divided into two groups: task-oriented services and support/utility services. Support/utility services are generic and support the task-oriented services.

The Dashboard (Figure 4) is a flexible, customizable workspace composed of specific floating interfaces for functions such as video conferencing, file transfer or resource management, that allows each user to create the context in which s/he is working. Due to its adaptability and theoretical underpinnings, the dashboard is described as a workspace as opposed to a traditional Graphic User Interface. It functions by adding intelligence to the mediated environment and removing actions such as configuration, establishing protocols, and the logical launching of applications in a coordinated manner. Since the workspace is designed by the user and based on his/her workflow, it is an essential part of a user's practices. Once logged in, the user sees the resources, assets, and people that are located at distributed locations and that comprise his/her work environment and network.

The Dashboard is activated (and deactivated) by a hot-key set by the user. When activated, the user's desktop is dimmed and the floating interfaces come into the foreground. This type of interface operates in the depth of the screen rather than discretely or as a window (i.e. it becomes a layer over the user's current desktop). This ensures that the desktop does not compete with the other application for space, as would be the case with a taskbar, but literally runs on top of them. The graphic nature and the spatial organization of the dashboard further hides each tool's complexity from the user and becomes a contingent and responsive component in scenarios of work that are collaborative in nature – facilitating spontaneous participation and exchange [22].

"Deep Computing Visualization" RVN

The discipline of architecture is dominated by digitally mediated tools and processes that are primarily 3D and time- based, and require sharing of computational resources, large geometrical data sets and multimedia content. Although available software at this point was limited to Maya, RVN immediately became an important element in our collaborative effort. Students were able to share 3D models of projects and examine and discuss design issues together. Manipulations of 3D models from either end were flawless even though the file was fairly hefty. Again, the potential benefit of DCV in a collaborative environment was proven. CIMS and IBM are currently working on the inclusion of Form•Z.

5. Research findings

The research aspect of this proof-of-concept design studio focused on the impact of digital communication media on the design process. We captured the communication between students as well as the impact of each extended mediated communication session of the design process through journals. These journals tracked the extent of time, modality, team members who participated in a particular design session and the before and after representations of the design artifact. We also conducted focus group discussions to capture the nuances of the collaborative process as well as surveys to capture the demographics, students' computer skills as well as their sense of social presence, i.e. the extent of 'being together'. We are summarizing here our findings from the focus group discussions and our end of the semester questionnaire survey, which measured the sense of social presence and broad aspects of students' computer skills and use. Our observations from the field study during the studio and focus group session are discussed below, followed by a summary of results from the data analysis.

5.1. Observations

First staging observations

The focus-group study at the end of semester indicated that audio delay prevented team members from fully experiencing spontaneous idea exchange and generation. Poor visual quality also interfered with productive collaboration in the tele-conferences as subtle communications, such as gestures and facial expressions, could not be not clearly conveyed. This visual quality also excluded the possibility of real-time sketching within the digital environment because the resolution was not high enough to convey hand sketches or on-paper drawings. Students thus relied almost exclusively on pre-prepared Powerpoint presentations to communicate their ideas to their counterparts. Powerpoint favors the presentation of formal and apparently complete design proposals and thus did not allow participants to think and act together. The students' criticisms mirrored the findings of previous studies on remote sketching and modeling softwares [15, 16], that these computer presentations did not allow the spontaneous exchange of ideas and interpretations necessary between participants, especially in the early stages of design. Access Grid, with its low visual and audio quality and fairly rigid presentation interface, provided little opportunity for one pair to respond to their counterpart's design proposal, or to generate, represent and communicate revisions. Thus groups had difficulty concretely advancing the design proposal during the tele-conference sessions.

Second staging observations

Mitchell [6] pointed out that previous videoconferencing tools often failed to facilitate distributed discussion and negotiation, and often lead to miscommunication between participants. As Kvan [9] emphasizes, design collaboration requires a higher sense of working together in order to achieve a holistic creative result. Thus the quality of audio/video feed was crucial to the collaborative work sessions as they contribute greatly to the ways that people can relate to each other and build a foundation of shared understanding. Although we could not utilize HD Video for this experiment, SD video signal was more than sufficient for team members to even observe each other's expressions.

As students became more attuned to the constraints and possibilities of the digital "scene", they began to manipulate this environment creatively. Many students showed greater confidence in their creative appropriation of the tele-collaborative environment, as they found resourceful ways to convey ideas in realtime through physical models and hand sketches, by adjusting cameras, lighting, microphones and furniture. The increased high-quality interactivity at the videoconferences made it possible to discuss alternative approaches to their design by using physical models and even quickly sketching their ideas on paper, and to explore design issues more thoroughly. Their design adjustments became much easier and quicker as they became accustomed to the environment. The greater effectiveness of this staging is attributable not only the students' learning curve but also to improvements to the technological interface that substantially increased the "smoothness" of the digitally mediated environment.

As with every new technology, a number of difficulties had to be overcome. Although we have experimented in many different settings, the placement of the camera interfered with establishing seamless communication between distributed teams. Since a camera is not placed inside the display screen (similar to the built-in camera on an iMac), we experienced an "eye-shifting" effect. This was particularly problematic with the IEL due to its screen size, although overall its large screen size changed the videoconferencing experience for the better.

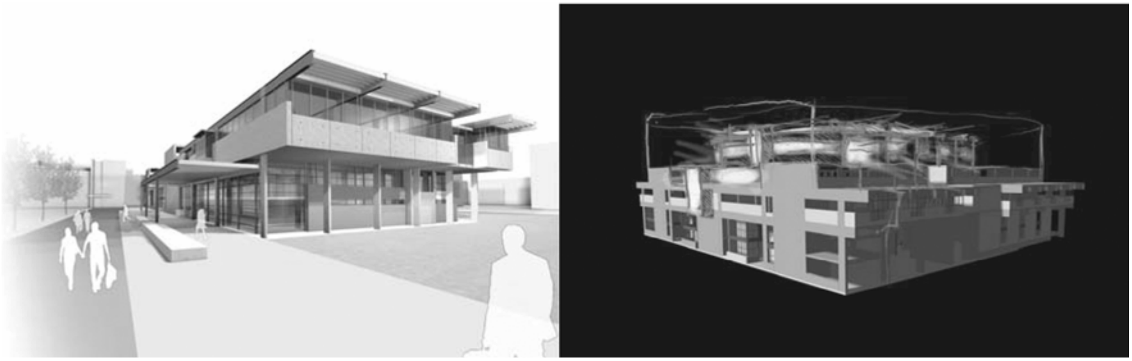
Overall observations

Collaborative design is an argumentative process in which designers create an environment for a design dialogue [23] where the project is advanced in a team environment. The focus-group study conducted at the end of semester indicated, the potential of the PDS to provide us with very effective 'collaborative work space'. Schematic implementation of the proof of concept supported a free- flowing, multi-user, participation scenario based around the presentation and manipulation of rich visual design media, and as a result projects emerged through a series of interactions between the members of the design team negotiating for a shared understanding via the aforementioned digitally mediated environment. The success of any collaborative projects is contingent on the fact that participating students can come to a mutually agreeable concept, which ideally is the summation of all ideas of the design team members. One group (Team A) had great difficulty in arriving at this shared idea. This is partially due to the fact that many students are not accustomed to working in groups or teams. Although it is getting more popular in many schools, collaboration in design studio is still rare. In contrast to the reality of practice, design activity in academia is usually considered to be an individual pursuit. By working alone on projects, many students distill a 'Fountainhead' syndrome; a creative protagonist who refuses to compromise his/her artistic visions in pursuit of an 'ideal' project. Collaborative team performance is affected by levels of mutual trust [24]. Cheng et al. [4] noted that "trust, which leads to rapport, is very critical in the germinating stages of project when directions are being formulated." Thus an introductory session or *Charrette* prior to the start of the project to build strong inter-personal relationship between distributed team members is desirable.

There are two additional factors may have contributed to Team A's unfortunate situation.

Firstly, the modes of representation, especially at the early stage of the design process are very critical to the collaborative design process. Traditionally sketching is considered to be a valuable design activity, functioning as both means of communication and generation/exploration of design concept. This 'quick and dirty' form of representation, although it is often rough, inaccurate and incomplete, is 'an essential part of the process of thinking about a design problem and developing a design solution' [25]. Contrary to sketching, computer-based presentations tend to be formal and rigid, not allowing spontaneous exchange of ideas and interpretations necessary between participants. The lack of ambiguity in most of drawings (Figure 5) Team A presented to the distributed partners did not allow other team members to conjecture, thus preventing new concepts to emerge. Team A failed to merge each other's concepts into one shared concept and their teleconferences often ended up being 'our idea' vs. 'your idea'. As we noted above, the SD teleconference somewhat overcame this issue and allowed participating students to exploit conventional sketching as a means of communication. This permitted students to instigate, evaluate and modify their project quickly in an attempt to collectively advance their project. This ability to support fast iterations is very important due to the limited conference time available to each group. Further research on how traditional tools and work processes can be transformed and integrated, and how to best harness the potentials of digital tools in the PDS, especially at early stages of the design process, is urgently needed.

▼ Figure 5. Left: Team A Project. Right: Team B project using Open Canvas.



Secondly, design decisions, both major and minor, are made all the time during design the process, quite often at the desk while working individually on project. Overall design direction was discussed and major design decisions were discussed and decided during the teleconferences. However, the review of participants' journals indicated many, often crucial, decisions were made between the teleconferences, via telephone calls, emails and instant messaging without aid of real-time shared visual materials.

▼ Table 1. Issues of Cyber enabled collaboration based on journal.

Lack of Sketching	Decision-making	Gestures and Idea exchange
Yes we should have sketches to explain to each other I wish I could just use the pen sketch tool on here, it would be so much easier	I think that we should each talk about the positive aspects of the opposite team's proposal, and then we find the right overlaps. We set ourselves down and really only work with the good things that we share in common	Can we arrange with you guys for a videoconference tomorrow? So that we can sketch things out together
skype would work right now if we were using a two way digital whiteboard	Well, it might be more useful to just compare differences and their intentional basis rather than criticisms on specific schemes	I think the problem here is just a lack of communication this past week

Miscommunication and misunderstandings are almost unavoidable in such circumstances. We will test the Dashboard's flexibility and effectiveness on one-to-one at design desk settings in the next phase of the project. Further experimentations on staging of one-to-one and one-to-many synchronous and asynchronous visual and verbal communication methods and formal and informal means of communications in each stage of design process are needed.

5.2. Measuring social presence

Successful design communication goes beyond sharing of design representations to include effective interpersonal communication. The concept of social presence, i.e. the sense of being part of a collective has been shown to predict satisfaction within a computer-mediated conferencing environment [26]. We included social presence as a variable in our research to assess its relevance to design communication in a collaborative setting. In our research, we adapted questionnaires from Nowak and Biocca [27], Schroeder et al. [28] and Basdogan et al. [29] to measure social presence. Social presence was measured using a 25-item, 7-point likert-type scale. The questionnaire also included measures of computer use for academic and leisure purposes, expertise with various software used for architectural design representation and presentation. Responses were collected from 26 students who participated in the collaborative studio of which 48% were females and their age ranged from 20 to 23 years (S.D = 1.01).

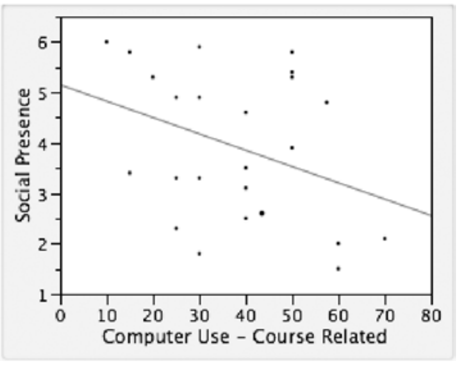
The self-reported mean computer use for all course related purposes was 37.43 hours per week (S.D. = 16.95) and leisure related activities were 11.28 hours per week (S.D. = 5.3). Form.Z (mean use of 12.98 hrs per week) and Photoshop (mean use of 15.5 hrs per week) were the most commonly used software. At the time of the survey, the students had a little over 16 months (Mean = 16.36 S.D.= 9.84) of experience with 3-d modeling software and close to 3 years of experience with 2-dimensional graphics packages (Mean = 34.8, S.D. = 11.56).

Since social presence is a multi-dimensional construct a principal component analysis was conducted to identify its underlying factors. Principal component analysis was used to analyze the dimensionality of the twenty-five items used to measure presence. Based on the scree plot, three underlying factors were identified accounting for 69.04% of the variance. On rotation using a Varimax procedure, sixteen items loaded clearly onto the three factors. The remaining nine items, which cross-loaded across the factors, were discarded from further analysis. The rotated solution yielded three factors, social presence, non-mediation and relational distance. The factor loadings are given in detail in table -2. Items that were included in the construction of final index construction and the factor under which they loaded are marked in bold in the table. Social presence index (Cronbach's alpha = 0.96) was constructed by additively combining the 10 items measuring the extent of awareness and reciprocity between distributed team members. Similarly a non-mediation index (Cronbach's alpha = 0.67) was created by additively combining the 3 items measuring the extent to which the interface seemed to vanish. The third factor, relational distance comprising of three items measuring the extent of closeness between the team members was dropped from further analysis due to low reliability (Cronbach's alpha = 0.49).

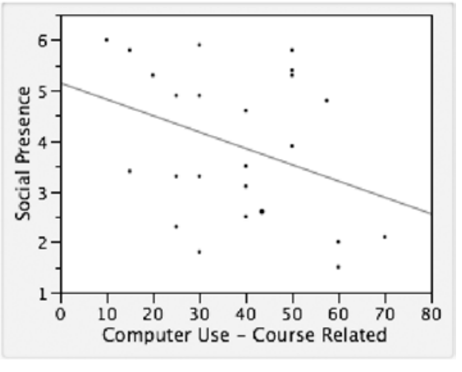
▼ Table 2. Factor Loadings.

		Item-1 Social Presence	Item-2 Relational Distance	Item-3 Non-mediation
1.	Involved in online design interactions.	0.66	0.56	0.14
2.	Design interactions stimulating	0.72	0.46	0.25
3.	Communicated coldness rather than warmth*	**0.79**	0.08	0.36
4.	Created a sense of distance between team-mates*	**0.87**	0.08	0.26
5.	Seemed detached during our design interactions*	**0.82**	0.29	0.32
6.	Unwilling to share personal information*	**0.67**	0.31	0.34
7.	Made our conversation seem intimate	**0.66**	0.19	0.01
8.	Created a sense of closeness	0.57	-0.23	0.19
9.	Appeared bored by our conversation*	**0.79**	0.33	-0.00
10.	Were interested in talking to us	**0.86**	0.28	0.09
11.	Showed enthusiasm while talking to us	**0.87**	0.21	0.01
12.	Did not want a deeper relationship with team mates*	0.20	**0.70**	0.26
13.	Wanted to maintain a sense of distance*	0.28	**0.72**	-0.07
14.	Were unwilling to share personal information*	0.16	-0.04	0.35
15.	Wanted to make the conversation more intimate*	-0.01	**0.63**	-0.04
16.	We tried to create a sense of closeness	0.46	0.46	0.45
17.	Interested in talking	0.68	0.59	-0.08
18.	Extent of collaboration	**0.90**	0,17	0.17
19.	Future design collaboration with same partners?	**0.86**	0.11	0.25
20.	Sense of being together with partners	0.01	0.39	**0.82**
21.	Sense of being in the same room	0.19	0.61	0.59
22.	Computer interface seemed to vanish feeling of directly working with the other person	0.05	0.41	**0.61**
23.	Interacting with a computer as opposed to working with another person	0.27	-0.27	**0.76**
24.	Similar to the face-to-face experience	0.74	-0.37	0.46
25.	Merely responding to some screen images as opposed to being with another person	0.69	-0.27	0.48

Since the display infrastructure at the IEL and CIMS were different, the social presence and non-mediation scores of Penn State and Carleton students were used to compare the two technologies in enabling social presence. Overall, the students indicated a somewhat moderate effect for social presence, with a mean score of 3.78 (S.D. = 1.59) on a scale of 0 to 6 and a similar effect for non-mediation with a score of 3.24 (S.D. = 1.32), again on a scale of 0 to 6. Despite the differences in the display settings of the IEL and CIMS, the differences in average social presence score of Penn State students (mean = 3.77) was not significantly different, $t(21) = -.03$; $p = 0.97$, from that of their Carleton counterparts (mean = 3.79). Similarly there was no significant difference $t(22) = .63$; $p = 0.53$ in the non- mediation score between the Carleton (mean = 3.08) and Penn State students (mean = 3.42). We also explored the impact of other variables such as gender and the extent of computer use on social presence and non-mediation. While gender is often seen as a factor affecting presence, in this case there was no significant difference, t (21) = .03; p = 0.98, between males (mean = 3.79) and females (mean = 3.77) in their social presence scores. We also did not find any significant difference, t (22) = -.35; p = 0.72, between males (mean = 3.14) and females (mean = 3.33) in their non-mediation scores. Simple linear regressions seemed to indicate that increase in use of computers for course related purposes tends to decrease social presence scores (Figure 6), but tended to increase the feeling of non-mediation (Figure 7).



◀ Figure 6. Relationship between course related computer use and feeling of social presence.



◀ Figure 7. Relationship between course related computer use and feeling of non-mediation.

6. Conclusion

Accepting the aforementioned network capability is a thing of the near future. The value of the research is in a new concept of working together. As it is acknowledged in the philosophy of technology that the way in which this environment and its tools are configured and constructed impacts the very nature of how we see, think and make architecture together. Research in 'staging' of digitally mediated environments thus will continue by acknowledging the multi-stage architectural design process: program development, schematic design, design development, contract drawings, shop drawings, and construction. Each stage necessitates various requirements and different kinds of collaboration, thus different communication scenarios needs to be studied and evaluated. Analysis on how tools are used, the ease of use and feasibility of implementing those tools in a digitally mediated environment will be performed at each stage. Many experts predict that Building Information Modeling (BIM) will revolutionize the relationship between design team members and the relationship between design and construction. However, BIM is in essence a project management tool, not a collaboration tool. It only facilitates sharing of information. The sharing of understanding is a necessary condition for any collaborative efforts. Ken Sanders [30], FAIA, observes that "the critical path isn't BIM, but rather process innovation squarely focused on people, partnerships, shared expertise, and timely decision making." Within such a context, this research is positioned to have a valuable impact on the practice of architecture for the built environment.

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