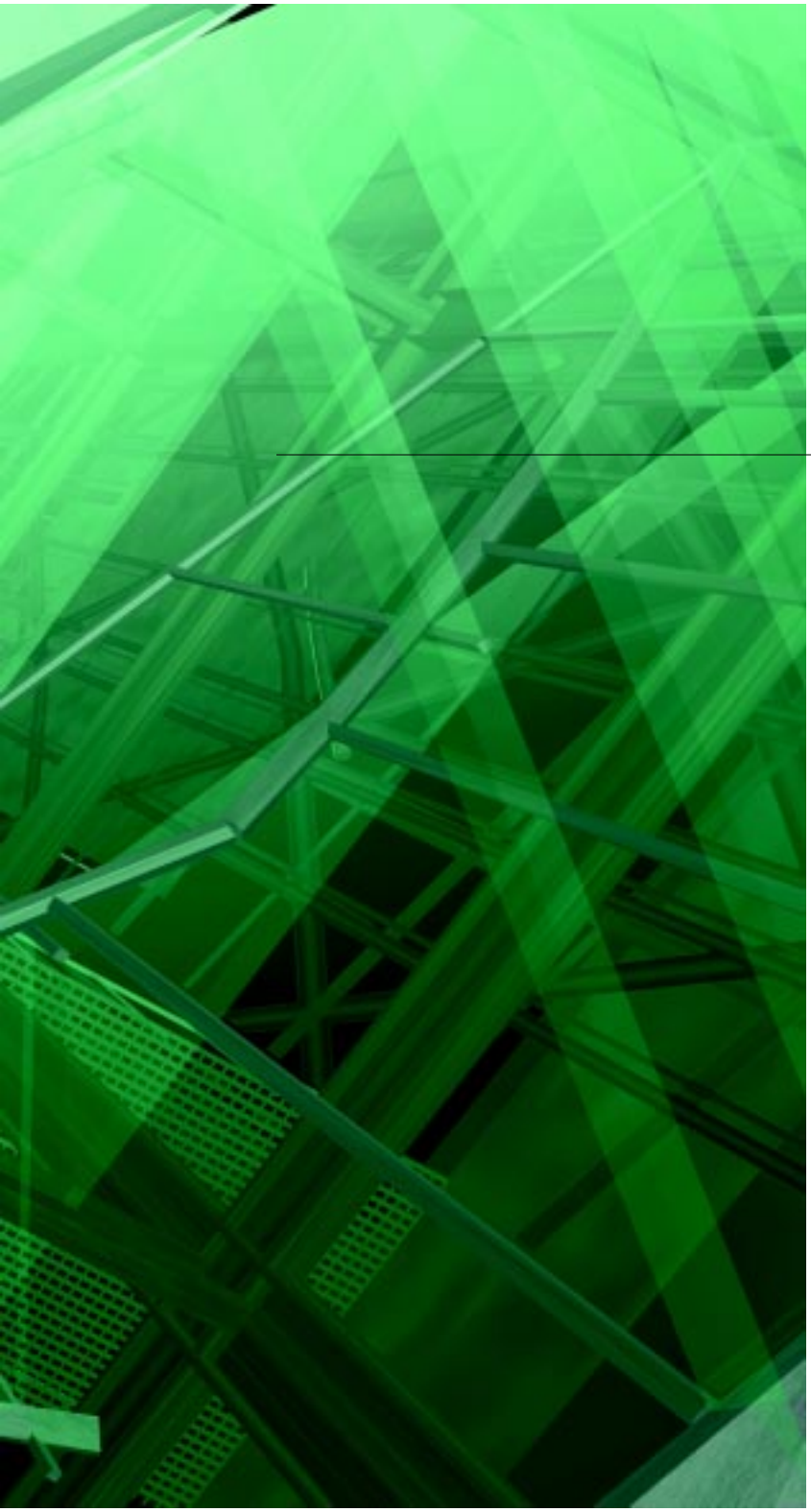

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Virtual Study Abroad and Exchange Studio

The digital design studio has an area of application where conventional media are incapable of being used; collaboration in learning, design and dialogue with people in places other than where one lives. This distinctive opportunity has lead the authors to explore a form of design brief and virtual design studio (VDS) format not well addressed in the literature. Instead of sharing the same design brief, students in this alternative format design a project in the other students' city and do not collaborate on the same design. Collaboration with other students takes the form of teaching each other about the city and culture served by the design. The authors discovered these studios produce a focus on site context that serves our pedagogical objectives–a blend of architectural, landscape architectural and urban design knowledge. Their students use a range of commercial CAD and computer supported collaborative work (CSCW) software common to that used in many VDS experiments reported on in the literature.

However, this conventional use of technology is contrasted with a second distinctive characteristic of these studios, the use of custom software tools specifically designed to support synchronous and asynchronous three-dimensional model exchange and linked attribute knowledge. The paper analyzes some of the virtual design studio (VDS) work between the Swiss Federal Institute of Technology, the University of Toronto, and the University of Melbourne. The authors articulate a framework of VDS dimensions that structures their teaching and research.

Etudes virtuelles outre-mer et studio d'échange

Le studio de design digital comprend des domaines d'application ou les média conventionnelles ne sont pas suffisantes; la collaboration lors de l'apprentissage ,et la conception et le dialogue avec des gens vivant ailleurs. Cette opportunité distincte a mené les auteurs à explorer une forme de description du design et de studio de design virtuel qui n'est pas bien addressée dans la litérature. Au lieu de se partager la même description, dans ce format alternatif les étudiants travaillent sur un projet situé dans la ville des autres étudiants, mais ne collaborent pas sur le même design. La collaboration avec les autres étudiants prend la forme de se renseigner les uns les autres au sujet de la ville et de la culture desservies par le projet. Les auteurs ont découvert que ces studios produisent un focus sur le contexte du site qui correspond à leurs objectifs pédagogiques–un mélange de paysage architectural et de connaissances en planification urbaine. Les étudiants utilisent une gamme d'outils pour le DAO commercial et travail collaboratif aidé par ordinateur (TCAO), analogues à ceux utilisés lors de plusieurs expériences sur les SDV décrites dans la litérature.

Cependant, cette utilisation conventionnelle de la technologie contraste avec une deuxième caractéristique distinctive de ces studios, l'utilisation d'outils informatiques conçus pour permettre l'échange synchrone et asynchrone de modèles trois-dimensionnels et la connaissance de leurs attributs. Ce papier examine la collaboration en studio de design virtuel qui a eu lieu entre l'Institut Fédéral de Technologie Suisse, l'Université de Toronto, et l'Université de Melbourne. Les auteurs articulent un cadre de dimensions SDV qui guide leur enseignement et leurs recherches.

introduction

Inspired by the first collaborative virtual design studio (VDS) work in 1993 (Wojtowicz 1995), we began conducting shared design studio learning with students at the Swiss Federal Institute of Technology, ETH Zurich and the University of Toronto in the 1995 session[1]. Our most recent virtual design studio took place between the Universities of Melbourne and Toronto in 1998. We have experimented with various formats in conducting a number of virtual design studio exercises. In discussing which technique to use this past year, we settled on an approach that proved extremely successful in our first studios and which has not received much attention in the literature on VDS teaching. The approach has students design a project in the other students' city. The students do not share the same project site and may or may not share the same design brief. The paper will focus attention on this format. A format that we have returned to after four years and find offers very good opportunities for learning. We think of it as a virtual form of study abroad or exchange.

Over the last few years, a number of institutions have conducted virtual design studios (Chen 1994; Danahy 1995; Dave 1995; Maher 1997; McIntosh 1996; Tan 1995; Yee 1998; Wojtowicz 1995, 1998) using a variety of approaches. This paper reports on our findings and aims to add to the developing discourse on virtual design studio with a description of our approach and a series of general findings from our experiments.

The paper is organized as follows. We offer a context for collaborative digital design studios and identify key dimensions for structuring virtual studio collaborations that we have observed in our work and describe the rationale for and design of a specific approach that we have adopted in our own work. We also present segments from our students' work. It is followed by a discussion of the results we have obtained, how they differ from traditional studio settings, and benefits and pitfalls that are associated with collaborative design studios. We present organizational and technical priorities for conducting such studios and identify technical challenges that need to be addressed. The paper closes with a summary of our experiences.

virtual design studio paradigms

The confluence of fast processors, cheap memories, and the developments in networking and distributed computing underpin new approaches in design computing (Mitchell 1994). Whereas the early efforts in design computing concentrated on the immediate activities of an individual designer, the new developments allow us to situate activities of an individual designer in the larger collaborative context. These developments are reflected in a growing number of virtual design studios in which students from geographically separated institutions work together using digital media as if they were virtually part of one design studio.

motivations

A number of motivations underpin our virtual design studios including the following:

1. The opportunities afforded by technological developments mentioned earlier are fundamental. New experiments in design teaching can be undertaken now which were either not feasible or conceivable earlier.
2. They expose students to *foreign* environments and ideas in a much more direct fashion than is possible in traditional studios.
3. The possibility for tapping into experiences and knowledge of design faculty from institutions other than one's own.
4. The fact that design practice is inherently collaborative in nature (Bucciarelli 1988). The virtual design studios can serve as contexts in which students develop their abilities to function as team members.
5. Virtual design studios provide settings in which the activities and needs of collaborating groups can be studied. They can lead to further research and development of computational means to support collaborative activities to benefit not only the pedagogical needs of educational institutions but also the pragmatic needs of professional practice.
6. The need to prepare students to operate in the contemporary technological context that will increasingly require professionals to compete and co-operate both locally and globally.
7. The possibility of bridging the gap between *the espoused theory* and *the theory-in-action* (Argyris 1974; Cuff 1991) that characterizes

what architects say they do and what they actually do in practice, namely flourishing as individuals while contributing to group work.

8. The possibility of bringing knowledge from the disciplines allied to architecture during more opportune stages of design development by way of virtual consultations.

There may well be other motivations such as economic pressures faced by higher education institutions, the need to continually acquire new skills, or new life-style and work patterns, not all of which may originate from the core inquiry of architectural design as a discipline but are nevertheless significant. These motivations, and many others no doubt, inform the new virtual design studio experiments.

In many respects, VDS experiments are breaking substantially new ground in design teaching. At the same time, there are historical precedents in architectural education, theory and practice that precede these experiments albeit in a different material context. The journeymen apprentices during the Middle Ages, travel and work experiences derived by budding architects, the Ecole Baux-Arts parti design projects, the Bauhaus studio experiments in which students were deliberately exposed to different talents, the visiting critics tradition in the many design studios of the day - they all represent different ways in which the same ideas that motivate current virtual design studios have been addressed before in various forms. In that respect, the new experiments bring digital media to bear on these issues and provide new means to build upon and extend inquiries into the core issues in architectural education.

distinguishing dimensions

The growing number of virtual design studios has led to a critical mass of recorded experiences (Tan 1995). There are emerging patterns of how such studios are organized and the kinds of design inquiries they appear to support. Based on these precedents and our own work, general distinguishing dimensions and key characteristics of design briefs in virtual design studios are proposed in the following. The dimensions proposed here will certainly be extended by researchers over time. Our intention here is to add to the critical and constructive discourse on virtual design studios in a way that abstracts from the particularities of specific studio contexts.

The distinguishing dimensions of virtual design studios include:

- *Patterns of collaboration*: Most virtual design studios incorporate various degrees of asynchronous and synchronous collaborations. These are typically spread over various moments in design development and last for various durations.
- *Media*: Although students may use both traditional and digital media in the design development, the collaborative aspects of studio require design representations to be in a digital form eventually. The degree to which various media are employed especially in collaborative sessions varies considerably. The different forms of representation - text, sketches, models, images, videos, 3D models, etc., employed in the process also differ in various studios and have a qualitative impact on collaborative exchanges.
- *Tools*: They range from simple file exchange protocols (FTP), data exchanges that may be asynchronous (email) or synchronous (talk), audio and video conferencing, white-boarding, real-time interactions with 3D models, shared databases of images and other data, hyperlinked documents publicly (e.g. on the World Wide Web) or privately (e.g. on shared accounts) accessible, and others. Each tool has a different bandwidth requirement and has different thresholds for the kind and volume of information it can support in both asynchronous and synchronous modes.
- *Duration*: This is the time period over which virtual design studios operate which may vary from a few days to months.
- *Distances*: These are temporal, spatial, cultural, technological, and other distances that separate various participants in virtual design studios. These distances affect, mostly positively but also at times frustratingly, the design and conduct of studios.
- *Design brief*: It may range from small and conceptual design problems to comprehensive and detailed, large scale design exercises.
- *Computing infrastructure*: Whether collabora-

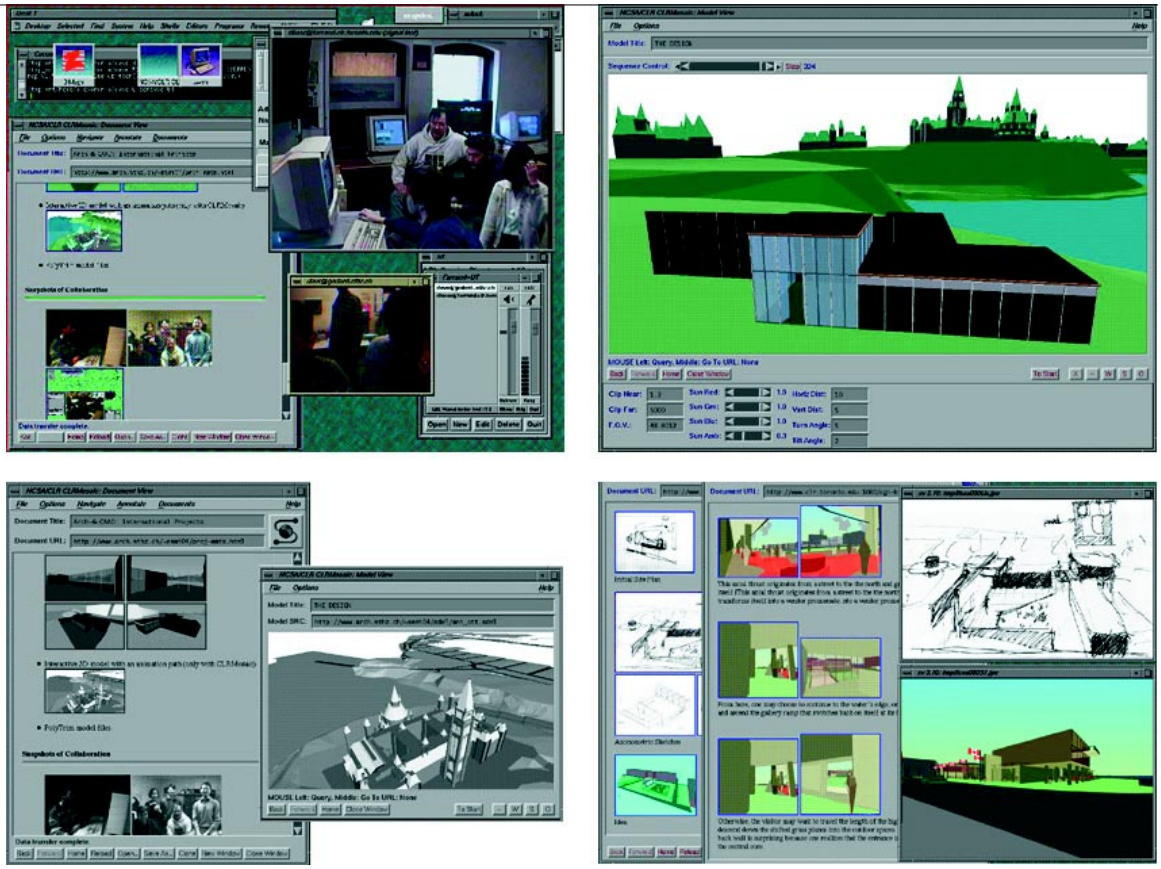

Figure 1: Snapshots from the Zurich / Ottawa studio.

tors use compatible or different computing and networking infrastructure, tools and services has an impact on how much advance preparation and lead time are required before studio advances into a productive phase of design collaboration and exchange.

Each of the distinguishing dimensions identified above typically intersects with another dimension. Informed by the institutional context and specific ambitions identified, each virtual design studio is thus a variation on a theme - not quite the same as those that went before but also not entirely different from the preceding ones. Many of these dimensions and their impact on virtual design studios have been studied and analyzed by a number of researchers (see, for example, references cited in Section 1).

The design brief in virtual design studios is one of the dimensions from the above list that deserves further attention. The design brief sets the tone of most virtual design studios and in a sense defines the nature of all other dimensions mentioned above. Among the common design briefs for virtual design studios, we distinguish the following types:

- One design brief on one site that is given to all the students in the virtual design studio.
- One design brief is to be resolved on different sites corresponding to the location of various institutions.
- One design brief is given to students but they need to design for a site that is in a location other than from where they are.
- Students from various institutions work on a different design brief on the same site.
- Students from various institutions work on one

design project but during different stages of its evolution, e.g. as the sun moves, students pick the same project from where it was left off by the previous group.

- Students work on different design problems on different sites but can use each others' work for borrowing ideas and commentary.
- Students work on design problems that are *virtual*. This is in contrast to all the previous kinds of design briefs that involve *real* design problems and *real* design sites.

There are many other variations that are possible and no doubt we will see them employed in future virtual design studios (see for example, an annotated list of projects in (Wojtowicz 1998).

our approach

The virtual design studios involve a plethora a range of computing and networking technologies and tools. Each of the enabling components in VDS has particular strengths and weaknesses that pose different challenges the design and conduct of studios. We also find that we need to pick pedagogical strategies that transcend technical learning. We want it to be worthwhile for students to make things work even when there can appear to be more reasons to give up than to persevere.

Our specific approach to transcending purely technical issues stems from our multidisciplinary situation. The authors work on urban design, building and landscape architecture problems in our research and teaching. As such, we want to experiment with tools and data sets relevant to the research agendas in our respective schools. We place an emphasis in the design brief on context and learning about the place a design is situated. It fosters a different type of dialogue among collaborators than we have observed with other virtual design studios' formats where students share the same site and problem with other students.

Our preference is for setting a virtual design problem that we term *virtual study abroad*. The following studio explorations centre on the idea of getting students from a *host* city to explain the place they live to students in another place. Students must design a project in the other students' city using the complete range of digital representation and spatial modeling tools (real-time interactive linked modeling, white-boarding, video conferencing, web design and email).

Since students need to *barter* information in order to get their work done, they are forced to form *social groups*. It fosters a reciprocity and degree of collaboration that provides an ongoing momentum to the studio that may be hard to achieve otherwise. There is also another reason to foster social groups in virtual design studios. In traditional environments, the atelier ambience of many studios is cited as a reason for the success of design education where students interact with each other and learn from each other. In virtual settings, this may not be possible so physical proximities need to be substituted by way of virtual encounters that are *designed* to take place and thereby preserve the positive aspects of collaborative interactions in traditional studio settings.

Zurich / Ottawa & Melbourne / Toronto

Of the two studios described here, the first one took place over a period of three months (1995)[2]. The project brief called for the design of an exhibition pavilion to display artifacts of national significance on the urban sites located in the cities of the partnering institution in the studio. The site in one case is an open square in the heart of the city of Zurich, surrounded by many institutional buildings and major public transport arteries. The existing buildings pose many restrictions in terms of any new development. The other site is located on the public park across a canal and bluff from the national parliament building in Ottawa. In both cases, the sites were chosen with a view to keep existing urban context as an integral part of any design development. The students on both ends were given 3D models of the respective sites. Unearthing and exchanging any additional information was their personal responsibility.

Students used a range of digital representation and spatial modeling tools such as Internet based audio and video conferencing, html documentation, FTP, and email technology typical of that used in other VDS studios. Our efforts to collaborate relied entirely on Internet-based communications. Toronto developed a real-time interactive Internet linked 3D visualization component in its

Figure 2: Snapshots from the Melbourne / Toronto studio.

Polytrim testbed in 1991 (Danahy 195). This was used for synchronous collaborative design reviews. In 1994, CLRMosaic and CLR's SDML language were developed by Rodney Hoinkes to embed interactive 3D models in HTML documents and URLs in interactive queries of a design model. This experimentation occurred prior to the wide spread use of VRML and pointed out some drawbacks in VRML to design communication applications[2]. During the passage of the studio, students and faculty conducted real-time consulting sessions with their partners at least once a week. In the intervening period, additional information exchanges took place via email messages and web-based information repositories. The time difference between the two institutions was six hours.

The second studio lasted for over seven weeks (1998) and required students to develop existing urban sites for residential use. The sites in both cities require high-density high-rise developments[2]. The site in Melbourne is in the center of the city, bordered by business, institutional and transport usage. An existing heritage building complicates any new developments on the site. The site in Toronto is on the harbour front where any new development needs to take into account a number of factors: proximity to buildings of national and local significance, its effect on the city skyline, and its fit within the harbour-side fabric. The collaborators *met* on a more regular basis during the early part of the studio, then less frequently, and then again twice a week towards the end of the studio. Almost the same toolkit of programs as before has been used with some changes during asynchro-

nous design development. Both institutions use different modeling tools in their studios which requires information to loop back and forth via a set of intermediate translations before it can be used for synchronous real-time interactions. Although using bit-mapped images is not a problem, working with heterogeneous computing infrastructure between institutions requires more technical input than would be the case otherwise. The time difference between the institutions is about 14 hours. As in the first experiment, pre-existing digital contextual models of each city were acquired. This time (four years later) the level of representational detail and context is significantly greater (Figure 2).

discussion

The introduction of digital media and networking in design studios results in some obvious and other quite subtle changes in the design process, design outcomes, and their presentations and assessments.

design process

In virtual design studios, most design development occurs in an asynchronous mode and the outcomes are used during subsequent collaborative consultations. Although students may use both traditional and digital media during design development, at some point these are converted in a digital form. Due to the nature of digital modeling programs available today, design representations quite often lack discursive quality of traditional drawings. It also has an unintended effect that a design's representations appear more definitive and decisive than its author may intend. Another tendency that we have observed is that the use of digital media in design development does not easily support generation of multiple alternatives. Of course, it can be done using a number of separate files but, unlike traditional tracing sheets, students tend to get drawn into refining one proposal very early on in the design process. The entity box controls of Polytrim have made some progress in diminishing this effect in the studios we have organized (Danahy 1995).

Also, the developmental records of a design get subsumed in the same model that is progressively refined. This is in contrast to working on paper where one may have separate sketches that are

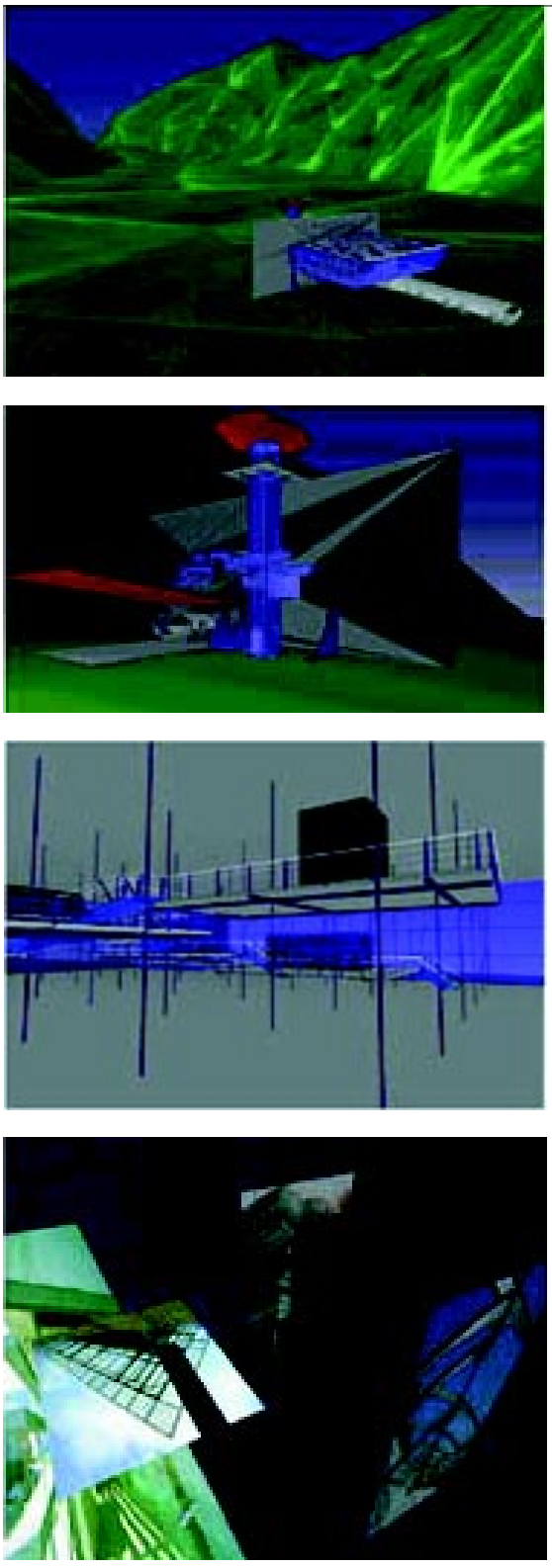

Figure 3. Snapshots, virtual project on a virtual site–CROSSINGS.

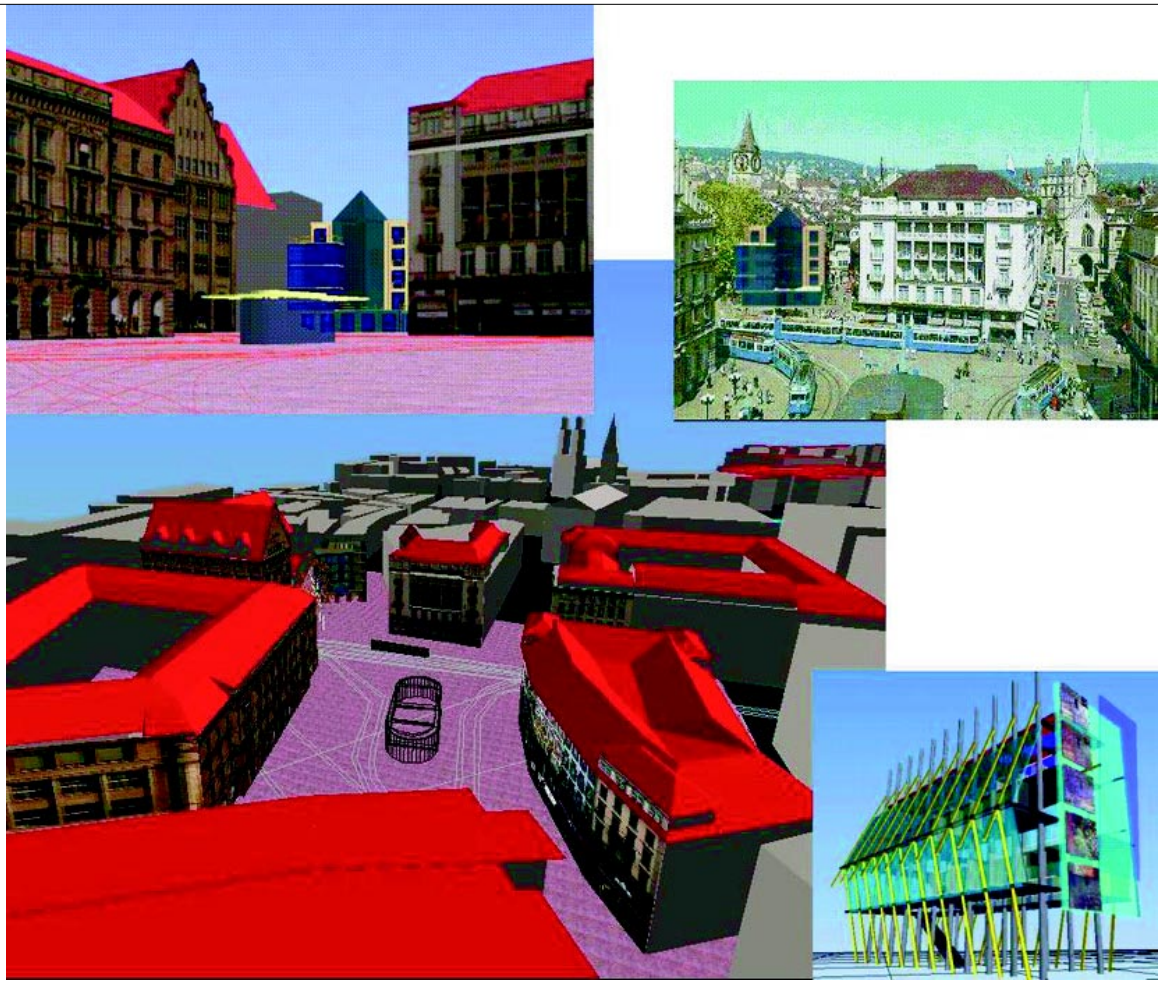

Figure 4: Contextual and representational complexity in the Paradeplatz, Zurich studio.

represented and refined separately. Although students may be able to articulate and recount the development of an idea, the use of commonly available digital media tends not to make these stages visible to an outsider. On the other hand, students become adept at literally taking many viewpoints from which to examine their design projects with respect to contextual issues. Being able to adopt any viewpoint, in addition to the standard orthographic projections, allows them to situate themselves within and around their designs and thereby engage with the project in a more experiential manner. CLRMosaic proved to be a very effective tool for posting this type of representation for collaborators to examine. We have seen VRML improve. VRML now replicates some of the two-way functions designed to support our approach that CLRMosaic provided. Unfortunately, it is the entertainment industry and one-way delivery of content that is driving VRML. It will be some time before it presents an efficient two-way support to collaborative spatial dialogue. In the meantime, the VRML standard offers a basic way to asynchronously post three-dimensional models.

Collaborative consultations provide additional opportunities for looking at students' projects from others' viewpoints. This has the effect of letting go of one's fixation as students become aware of competing issues and their possible resolution from a

number of perspectives. Partly, it results from the fact that students consult with other students and academic staff from a pedagogically and culturally different environment. The most manifest aspect of this is situation is when students implant *local* assumptions and values onto a *foreign* context that is usually followed by a vocal *protest* from the collaborators. Since students are not sharing the same brief and site they are not placed in a fundamentally competitive situation. In our observations, we find students more willing to offer suggestions and be open with information. Both students and academic staff in the process acquire design sensitivities we regard as invaluable.

To make collaborative consultations productive, the students also learn to be selective and organize their work so that it can be easily made part of collaborative interactions. Unlike traditional settings where one may shuffle through many drawings and other media and bring one or more representations into a conversation, in collaborative sessions students almost need to anticipate and plan in advance the content and form of interactions especially since synchronous sessions may well be of limited duration. Finally, the students develop not only the design skills but also the articulation of ideas that makes collaborative sessions feasible.

The only exception to this observation occurred when we have used the Internet server version of Polytrim. This implementation permitted students and faculty to load design models at each location and interactively (in real-time) alter the representation strategy, animation path, view points and alternatives under study while discussing the changes using an internet audio program such as VAT. We find the network video becomes the least important technical resource if we have a robust real-time model running with full-duplex audio.

Another anecdotal observation is that students now do most of their modeling work at home on PCs. In past studios, all modeling work was done on school workstations. Workstations are now used to review work in context and "sketch-model" ideas as part of a dialogue with instructors and classmates. The long hours of student time associated with modeling and crafting digital schemes are starting to take place mostly at home. This can be a problem when students do not have the foresight to put everything on a portable disk or ftp current work to the school system. Instructors can no longer "look" in on how work is progressing in the same way we can walk through a conventional studio or examine the contents of a shared disk drive. Serendipitous discussion and learning from peers in digital design studios may diminish if good collaborative tools and culture are not available. We plan to place greater emphasis and requirements on the virtual posting of work on school servers to see if this problem can be overcome.

design outcomes

The degree of resolution of final design projects is a direct function of the aims set out in virtual design studio briefs. In some cases, the studio context requires development of a design project at schematic and volumetric levels, in others the projects are just as detailed as what one may find in traditional design studios. The extent to which digital media and networking affect the quality of design outcomes is harder to identify and measure. On the one hand, one would think that the use of charcoal or pencil or any other representational tool does not affect the design in a qualitative sense although the generated solutions may carry some imprints of the tools used in the process. On the other hand, the representational media used in design development including digital ones affect the possibilities explored and thereby tend to be representative of forms and operations that are part of the available digital toolbox.

Another factor that occasionally intrudes upon design outcomes is the available resources, both in terms of memory and processor speed, for getting a task done in digital tools. Undoubtedly such trade-offs occur while using traditional media too. For example, watercolor sketches will take longer to dry than those done with pencils or pastels. The digital media introduce trade-offs of a different kind and, in addition, there may be less room for devising alternatives that allow one to bypass such trade-offs. Despite these characteristics of the digital media, the final design projects in virtual design studios can be qualitatively of the same level as those found in traditional design studios. After all, the tools may be different but the final designs depend as much on the creative skills of students as

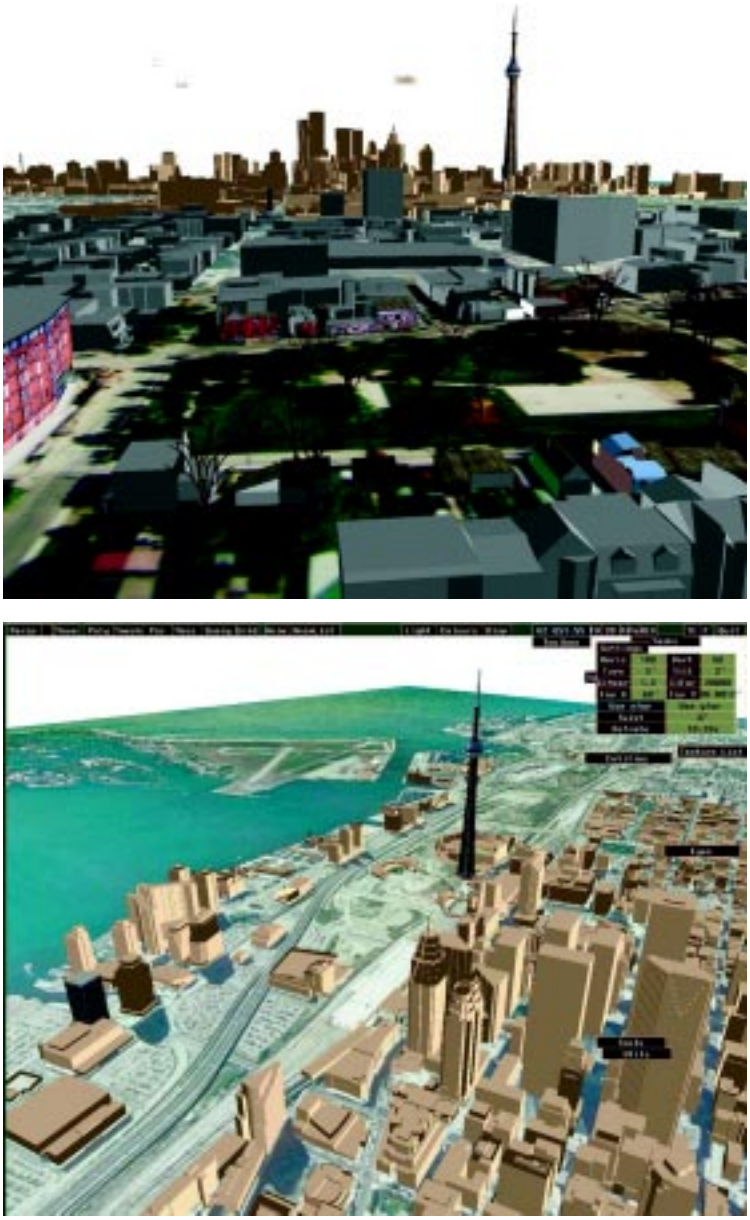

Figure 5: Landscape and urban design projects in the Melbourne / Toronto studio.

on the tools available to them.

presentations and assessments

This is one aspect of the virtual design studio that is visibly different from the traditional studio settings. First, the digital media such as modeling tools involve representation of a design project as a single digital representation from which various views are generated. In other words, a digital project file contains far more information than may be visible at any one time on screen. A single view of a project can hardly suggest to an outsider all the other information that may be embedded in the same model. Second, the total display surface available at any given moment in most cases may not be much larger than an A3 drawing. This is in stark contrast to the multitude of media such as large format drawings, photographs, models, etc. that are used in traditional design presentations. The use of occasionally redundant and parallel representations in traditional studio presentations enables viewers to mentally recreate a spatial reading of the project. This is not at all easy to achieve with the use of digital media in which only one or a few views of the project are visible at any given time. It effectively places the burden of keeping these fragments of digital views fresh in the memory on the viewers. We commonly use several workstations simultaneously in reviews and conferencing sessions in an effort to overcome these deficiencies. If reviewers are sufficiently capable, it is usually most productive if each reviewer can personally use a workstation to access specific information important to developing a critical line of thought. In conventional presentations, reviewers can scan the whole project presentation on a wall while listening to a presentation or commentary. We find this characteristic of reviews the most problematic to overcome.

Additionally, traditional representations also incorporate a selective use of information, i.e., lines of various thickness and densities that represent domain-specific meanings. In most digital tools, the accuracy of information display comes at the cost of getting all of the information, whether relevant or not, at any moment. Although it is changing in newer software programs, the quality of final design presentations can be affected not only by how much of a project is shown but also by how much

of it can be suppressed. We have had encouraging success using Polytrim's representational and layer controls matrix (the entity box) during reviews. Anyone involved in a spatial and visual "dialogue" structured in the computer model can alter the representation to suppress or add information in addition to changing viewpoints during the course of an exchange.

In one sense, students need to acquire and develop a new sensibility for visual presentation that takes into account these characteristics of digital presentations. The assessment of projects also undergoes some changes compared to digital media. The students need to become facile and inventive at using digital media over and above their design skills. Unless students learn the art of improvisation and being selective in their use of media, their design skills alone will not come through in the virtual design studios. As a result, within the framework of such studios, technical competencies and design skills both carry equal rewards in assessment of design projects.

The conventional social dynamic and formality of a design review changes when the representation of the work is open to change by any given participant in a design review. Typically (even in most VDS efforts to date), one cannot alter a complex design in real-time as part of a discussion. White-boarding tools support lively scribbling and diagramming exchange in reviews. We have experienced some profound changes in the nature of reviews when participants (not just the author of a design) engage and change complex image and model representations with Polytrim. The exciting aspect of this is that we have observed a dialogue of images and spatial models in reviews that does not happen as frequently when the tools are absent (Danahy 1992, 1988). Critics can do more than talk and they can do so freely without fear of destroying the design "property" of the student. We have only scratched the surface of this potential in the prototype software. We feel that collaborative tools are deficient in supporting this capability and are hampering the development of a significant potential for VDS teaching and practice.

The introduction of compatible synchronous and asynchronous real-time three-dimensional tools was significant. It allowed our studios to place greater emphasis in design critiques and web based communication on perspectival and moving experience analysis of a design's characteristics than occurred when these tools were not used in the VDS. The exchanges between Zurich and Toronto took on a different character than the conventional virtual design studios the authors have conducted with other schools using the more conventional technologies typical of work reported on in the literature (Wojtowicz 998). This opportunity produced an interesting bias in our communications and reviews. We began to emphasize virtual desk critiques and three-dimensional wed-based submission of work in our 1995 VDS. Inversely, our lack of access to tools such as the Picture Tel system used in many other VDS experiments has prevented us from placing as much emphasis on the formal end-of-project jury process that has characterized many previously reported VDS experiments.

organizational and technical issues for VDS

The first time we decided to run such a studio, the issues we had to grapple with were not obvious. Working with our colleagues, we planned some things; others were dealt with as they arose. What follows is a list of ingredients that we think are significant when designing and conducting networked studios.

co-ordinators

In networked studios, course co-ordinators from at least two or more institutions are involved. It helps if these people have met before or, at a minimum, they should have established a personal rapport before committing themselves to such an initiative. It is more than likely that unexpected events, such as a network crash, will happen just when you do not want it. At times like this, the course co-ordinators have to hold the fort, rally around students, and adjust the ongoing schedule of work and submission. Flexibility is the keyword. If the communication between primary co-ordinators breaks down, it will be difficult to establish a collaboration framework that works effectively. The other essential trait needed of co-ordinators is a willingness to become a sort of all-rounder in the use of tools and technologies for collaboration. Even if there are others assisting with technical issues, it is the co-ordinators

who need to feel at home with the technology, only then will they be able to focus on pedagogical issues.

collaboration projects

This is one of the most crucial ingredients of networked studios. If the project given to students does not provide for or require students from different institutions to collaborate and form social groups, the project may not be very fruitful. Unless there are reasons for students to seek information from each other, collaboration over the net will be hard to evolve. Simply transferring design projects from traditional courses into networked studios will not work. The traditional project drills (and assignments in most other disciplines) inculcate and reward individual work, probably for good reasons.

In contrast, networked design studios require interactions between students who have not met each other and need to entrust each other with their personal strengths and weaknesses whether they reflect the project specific knowledge or the use of technology or discipline. It requires students to develop a different mode of learning and interacting. To reiterate, design collaboration tasks need to be structured such that students cannot help but collaborate. At the same time, it is also necessary to provide room for individual work and project development. Those tasks should be paced as discrete steps that lead to visible results, to be shared with others on a regular basis.

collaboration tools

The selection of collaboration tools depends on the infrastructure available at the participating institutions. Our experience suggests that one should plan for as many ways to communicate as possible: email, talk, ftp, WWW, audio and video conferencing with a white-board, MUDs, mailing lists, etc. The addition of a networked interactive modeling and representation software package will permit networked exchange studios to enjoy many of the benefits we see in stand-alone digital design studios (Danahy 1995). We are very encouraged to confirm that the least demanding collaborative technology we have experimented with for synchronous collaboration is real-time interactive modeling. Once one has downloaded the initial model to each location the network demands of passing parametric and interface instructions between computers are trivial. All other forms of synchronous communication used in the typical VDS session (other than text chat windows) demand far greater network speed.

Use an integrated environment (i.e. one that rolls all the necessary services under one program) only if it has been successfully tried out under the same circumstances that students are likely to face. In our experience, a better option is to identify a suite of collaboration tools and use them as a toolkit from which one picks a tool appropriate for a given context. Access to multiple, separate channels of communication permits flexibility that one may not get in integrated tools. In addition, when one communication channel falls out (which is more than likely), users will still have alternate ways to tell someone on the other end that all is well and it is only a minor (or major) disruption.

infrastructure

Networked studios rely heavily upon various resources of the institution. Make sure that the system manager or administrator is on your side. Not only networked studios place heavy demands on network bandwidth, access to machines, and disk-space usage, they will require rapid fixing of any problems that arise while studios are in session. Along with collaboration tools, you may need a suite of web-publishing tools and, in particular, image processing, capture and postscript utilities (required for white-boarding). Once you add up all the services and resources needed for a networked studio, it becomes apparent that there is quite a bit of forward planning that is required (specially the first time around). Unless you have access to private and high-bandwidth network, there is no reliable way to predict network performance during synchronous sessions; experiment to find a slack time between two points. Keep in mind that synchronous sessions will generate conversations that may cause disruptions to others working in the same space.

training and help resources

During any of our studios, we did not provide any extended training in the use of collaboration tools. The students were shown once how to use these tools and then they tried out the tools with each other locally. The online documents supplemented information about using various tools and trouble shooting any problems. In a sense, the students received a minimum training and were thrown the deep-end. This does cause some confusion and chaos initially but it is surprising how fast students learn a skill in the context of actually using it.

review of end-products

This is another crucial ingredient of networked studios (something we learned in retrospect). At the end of the project, a collective review of work done and the process of collaboration is very instructive. If it is going to be an external review (i.e., someone external to the studio will participate), ensure that reviewers are aware of the project's background before they are invited. Unlike traditional reviews, critiques and discussions, an electronic review has a different character, feel and mode of operation. For one, unlike traditional studio reviews in which students pin up all their work perhaps together with a model, there is no way to see all the work of a student at a glance in an electronic jury. The documents may appear one after another, and they may not be immediately available for simultaneous cross-referencing.

Second, whatever information is being presented will probably come off a monitor that is quite small compared to a couple of A0 display panels. Even if the monitor is projected on a larger screen, you will probably get a larger image, not necessarily one with better resolution. In addition, if a larger projection on screen is used, the space will be dimmed out. This, of course, makes it difficult for the person on the other end of the video conference to see who is talking, how many people are participating, etc. Add to this the difficulty of using and sharing pointing devices between people discussing a project. If the discussion is based on a large-screen projection, the pointing device has to be passed around, probably with the use of a directional microphone and a camera (so that it focuses on the right person). With all the work that goes into such a studio, make sure the external examiner is aware of the potentials and problems of networked studios.

summary

The paper described our experiences in conducting collaborative design studios with an emphasis on fostering a particular kind of studio organization and design brief called *virtual study abroad and exchange studios*. Second, we have highlighted our experience with software tools specifically designed to support synchronous and asynchronous three-dimensional model exchange and linked attribute knowledge as a means of enhancing dialogue in our teaching.

The paper was organized around a set of dimensions of VDS teaching we hope will make it easier for readers to draw comparisons between our work and that of researchers at other schools. We also discussed the strengths and limitations of these experiments in comparison to traditional studio settings. The specific blend of design brief and collaboration tools reported on in this paper produced a shift in emphasis toward the contextual issues of a design than we observe when using other types of design brief. This type of brief turns out more like a virtual form of study abroad or exchange. It is less like a collaborative act of design between partners. The approach resulted in less emphasis on collaborative design development and virtual review processes than we see in other VDS work. This emphasis emerged first from our multidisciplinary urban design pedagogical requirements and second, from opportunities presented by the tools at our disposal.

The increasing convergence of a number of separate technologies will further enable new forms of teaching and learning opportunities. The most significant of such developments are increasing connectivity of global networks and tools for embedding and linking information with the most relevant content formats, e.g. 3D information that can be accessed using VRML, multimedia and other database connectivity layers featured as part of the many Internet protocols, drawing and image viewers that allow manipulations that are closer to the nature and use of information, and others. All

these developments suggest that many new possibilities are likely to arise in future that can qualitatively enrich the virtual design studios. What can be achieved in architectural education depends on the extent to which we engage these possibilities with a constructive and critical attitude.

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endnotes

[1] See http://www.clr.utoronto.ca/CLRMOSAIC/help-about.html. This site documents CLRMosaic and CLR's SDML language.

[2] See http://www.clr.utoronto.ca/vds/virtualstudyabroad.html. This site contains images and documentation of the studios referred to in this paper.

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