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Revitalizing architectural design studio teaching using ICT: Reflections on practical implementations

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ABSTRACT

The advancements in ICT are reshaping the architectural design studio teaching and design practices. The digital-imperative to switch from analogue to digital mode has already begun to manifest itself at the schools of design. This paper introduces the application of two approaches representing various dimensions of revitalizing architectural design studio teaching using ICT: paperless design studio and collaborative virtual design studio. The paper reflects on the practical implementations of these two approaches including design process, communication and presentation, studio pedagogy, and students' learning. The next step ahead for architectural design studio teaching in which ICT acts as a partner is introduced.

Keywords: *Architectural design studio teaching; paperless design studio; virtual design studio; digital design education.*

INTRODUCTION

The digital-imperative to switch from analogue to digital mode has already begun to manifest itself at the schools of design and architecture. Design and architecture students routinely use the best of new technologies that provide information-rich and fully networked multimedia environments (Muir & O'Neill, 1994). The developments in design computing and digital media in the last decades have been phenomenal and what the next decade will bring can only be imagined. However the advancements in digital design and communications are already reshaping architectural design studio teaching and design practice. On the other hand, some of the design and architecture schools are still using manual techniques similar to those used at the beginning of the last century. For long time, design studio activities have been carried out using manual sketching, drawings and physical modeling. Since the late 1980s architecture and architectural education have witnessed an important transformation with the introduction of computers and information and communication technology (ICT) in which they have become pervasive in all aspects of practice and education. The pervasiveness of information and communication technology in architectural education and practice has been manifested in the growing proportion and importance of IT related courses in the curricula of architectural schools. Many schools have increased IT content in their curriculum and are investing to acquire computing resources to ensure that they provide their students with the necessary skills and competitive advantage. Modern information and communication technology and digital tools have been adapted in the architectural education and practice since the 1990's. Computer Aided Design (CAD) has been adapted into architecture and became the major working environment. CAD and digital media have also been adapted by many architectural schools around the world. The rapid developments in information and communication technology and its applications in architecture have introduced a new opportunity to design studio teaching. There have been various ways to integrate computation and digital media into design teaching that led to alternative models for digital design studio including computer augmented design studio, CAD-plus studio, virtual and web design studio, cyberspace design studio, intelligent building studio, and toys and tools studio (Do & Gross, 1999).

This paper introduces the application of two approaches implemented by the author representing various dimensions of revitalizing architectural design studio teaching using information and communication technology. These approaches for architectural design studio teaching using the advancement of information and communication technology in design computing and digital media include (a) paperless design studio; and (b) collaborative virtual design studio. Such approaches are inspired by: Resnick's (1996) view to new paradigms of computing as new paradigms for thinking; Schmitt's (1997) perspective of the computer as a design medium that is more than a tool and it is an interactive counterpart through its capabilities and what it offers; and Madrazo's (1999) assumption that designing with computers is based on establishing a fruitful dialogue between the designer and the tool. The thrust of this paper is not about the software, hardware, networking configurations, or even on the approaches themselves but rather on addressing the models used in the practical implementation of these approaches including strategies that are most suitable in both stand-alone paperless design studio and collaborative virtual design studio. Furthermore, this paper reflects on the effects of utilizing such strategies while implementing the proposed models including design ideas and artifacts created by students while designing with computers. The implementation of these two approaches of paperless design studio and collaborative virtual design studio was conducted at two consecutive design studios (Semester 1 & Semester) respectively for the first year students of Design Computing at the Faculty of Architecture, University of Sydney, Australia. The next step ahead for architectural design studio teaching in which information and communication technology acts as a partner is addressed in this paper.

THE PAPERLESS DESIGN STUDIO

The approach of paperless design studio was emerged initially in the early 1990s and was characterized by eliminating, as much as possible, hand drawn designs, and developing strong dependencies upon the usage of high-end software such as Alias/Wavefront, Softimage, and Maya. Software ability to create fluid diagrams, character animations, and other special effects, (first thought to be un-useful in architectural design), has proved to be extraordinary tools to test unproved architectural speculations. Circulation and mobility studies, building program variations, and quick diagrammatic ideas allowed paperless studio students to explain and experience in a totally new way for their design formulations. The software soon proved to be more useful than a mere rendering tool; it started to inform and transform the design process (Andia, 2001; 2002).

Designing with Computers: Why Paperless?

The infusion of digital media into the practice of design and architecture is changing how the design process is carried out, what is designed (i.e. artifacts), and the culture of design education. There is a transition from a completely analogue system of representation to one of computer immersion or the "paperless studio". Design and architecture schools have already begun to struggle with the physical issues of either integration of new media or going completely digital (infrastructure and economics). However, the pedagogical integration should be of a greater concern. New media and its forms of representation are challenging traditional skills of communication and representation. Changes in practice as well as design education should look to new media with the opportunity for further exploration of design ideas, creation of new forms, and new design vocabularies. The creation of new forms comes with a responsibility of seeking new forms of representation (Norman, 2001).

It may be asked why is it necessary to provide digital immersion environment in which traditional models for design exploration such as physical models and manual drawings would be excluded? An attempt to answer this question is with posing another question that is "why does it seem satisfactory to exclude digital media when exploring with traditional methods?". The validity of a

paperless design studio lies in the notion that digital media can change the process of design, the forms of design, and how design ideas are communicated. A comparison could be made between a paperless design studio and another traditional studio that has casting as the only medium for exploration. A casting studio would force changes in ones process, forms and experience (Norman, 2001). To draw a parallel to the paperless design studio, one needs to become aware of the unique capabilities of what digital media offers and how it can be used to explore the design process. Digital models and web-based project sites are becoming normal practices within the real world of building construction. As the world becomes a more global society, the ability and means to transfer, communicate, and collaborate design ideas in more efficient ways and timely manner is ever increasing.

Design Tools in a Paperless Design Studio (PDS)

Design tools in a PDS should be primarily employed at the conceptual stage of designing and at an early level of design education to provide the opportunity for the students to comprehend the use of computers as design medium instead of a tool solely for drafting. As design tools are incorporated into the design process the student's ability to test and investigate design ideas is becoming more thorough. Using design tools that are object and time-based at the conceptual stage of designing is quite important. Utilizing objects in a design tool is simple to conceive and to simulate reality. For instance, time-based animation allows one to approach, test and investigate a simulated reality. Lynn (1999) describes animation as "evolution of a form and its shaping forces". The use of time-based media in the PDS allows understanding objects in space, their relationships, and influences over other objects. The indiscriminate application of computer design tools at the conceptual stage might allow the student (designer) to be removed from the design process and the software to be in control of the design outcome, however designers must be in control of the design tool (software) and design outcome. The ability to utilize the computer as a design tool comes with a responsibility of understanding its roles and limits as a tool for inquiry.

Pedagogical Concerns with Paperless Design Studio

Pedagogy is any conscious activity carried out by one person designed to enhance the learning of another (Mortimer, 1999). While pedagogy can be a personal matter it is more often conceived of as the art or science of teaching; a set of principles and practices to improve learning. Educational technology, as a subset of pedagogy, is the sound use of any technology to support and improve learning. Information technology, on the other hand, focuses more on the digital delivery of information. Technical issues tend to take precedence. Christie & Ferdos (2004) argued that educational and information technologies cannot be separated. For better or for worse they impact upon one another. When one seeks to improve learning using digital media pedagogical considerations are always an issue. The same fundamental questions that are asked of traditional university pedagogy need to be asked of ICT-based curriculum but, in addition, the potential for a radically different, more innovative pedagogy has to be explored. Good pedagogy can inform and be supported by good ICT. Poor pedagogy can subvert the very point of using good information technology and communication. A combination of bad pedagogy and bad ICT is a disaster for the future of students' learning in general and architecture in particular.

While moving to a PDS design studio instructors need to be concerned with the pedagogical issues of integration and how to infuse the computers into the design process. This is a larger educational issue of concern compared to how to afford and place computers into a design studio that is a financial or an organizational dilemma on the part of institution or the student. The success of a PDS relies on the ability of its students and instructors to implement these new digital tools and to change the culture of the design studio environment. If students are not adequately taught the digital skills of concern in advance, the digital media will not become part of

a process of design and will be degraded to instructional labs for software training. To avoid weakening the pedagogical endeavor in a PDS, the students need to learn the related digital media tools in advance and then use the computers as a design tool for inquiry and exploration (Norman, 2001).

Experience Designing with Computers in the Paperless Design Studio

The first year design computing students in their first semester have been given a brief to design a café on a vacant land next to the Faculty of Architecture's Tin Shed Gallery at the University of Sydney and were asked to design this café using ArchiCAD as a platform. ArchiCAD is very effective software that can be utilized as a design tool at the early stages of the design process and it satisfies the criteria outlined in the above Section of Design Tools in a PDS. Other digital media tools such as Adobe Photoshop, Microsoft PowerPoint, Macromedia Flash and Dreamweaver were used in the PDS as image processing and presentation tools. The typography and surroundings of this land were modeled by the students in ArchiCAD. The climatic changes and effects on the site from surroundings were calculated and presented using ArchiCAD at specific hours of the four seasons as shown in Figure 1, e.g. 3pm. This had a primary effect on where the proposed building might be located on site to avoid the overshadowed areas. The students have produced a QTVR (Quick Time Virtual Reality) animation showing the analysis of shadow studies. This simulation of reality was of a great importance to the students and facilitated their understanding of the climatic effects on design.

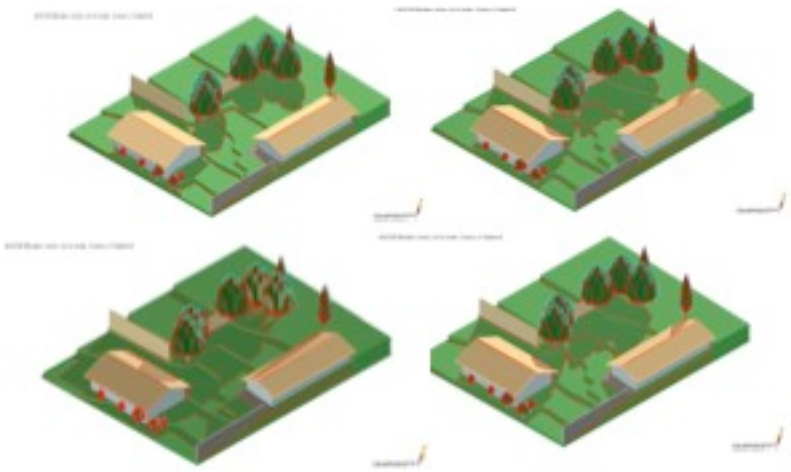

***Figure 1**: Land topography and shadow analysis of the proposed site to design a café developed in the paperless design studio*

A major teaching and designing strategy that has been elaborated in the PDS is that the limitations of ArchiCAD as the platform should not be considered as constraints in creating design ideas but rather utilize its capabilities as primitives in developing various design ideas. Instead of viewing the platform as a shell to generate typical and routine designs, it is rather to facilitate the features of this platform as a starting point to explore design ideas. This approach had a great impact on how the students interpreted the brief depending on where and how they started to explore their designs and which features of the platform were selected as design primitives to create and compose their design ideas. Some examples of students' diverse design ideas are

shown in Figure 2. Students have also found that the experience of designing with computers within this approach has opened up an enormous amount of new design ideas and imaginations for them that may have not crossed their minds if they were designing on paper or constructing physical models. Not only are their ideas become richer and innovative, but also they were able to test the behavior of their designs, such as climatic changes to achieve thermal comfort, color and texture scheme to achieve aesthetics and harmony with the surrounding environment, etc.

Figure 2: *Some examples of first year design computing students' designing a café project produced in the paperless design studio*

THE VIRTUAL DESIGN STUDIO

The Virtual Design Studios (VDS) explores the asynchronous and synchronous techniques in remote design collaboration. By using technologies, such as video conferencing, Internet publishing, e-mail, Web3D, and digital modeling, students gain an increasing understanding of the new modes of collaboration and media integration in design practices. The VDS also enriches the architectural experience by exposing studios to different design cultures and to a larger context of design feedback. The first Virtual Design Studio was attempted at the University British Columbia, during the early 1990s, in collaboration with other schools of architecture such as Harvard, MIT, Washington University, Cornell University, and Hong Kong University (Wojtowicz, 1994). These early experiences relied heavily on asynchronous communication technologies that supported e-mail, bulletin boards, FTP, and Internet publishing. As collaboration technologies evolved and became available to the masses, virtual studios began to foster more international experiences that lasted a complete semester. Most studies report that cross-cultural and global nature of the VDS experience usually motivates students. Also several interdisciplinary experiences emerged in the mid-1990 as students from architecture, engineering, and building construction from institutions such as U.C. Berkeley and CIFE at Stanford University, have collaborated in virtual studio experiments (Kalay, 1995).

Teaching Architectural Design in Virtual Environments

The concept of virtual environments has emerged from advances in computer networking, image processing, modeling, simulation, and multimedia representation (Simoff & Maher, 1997). Virtual environments that mimic the spatial arrangements of the physical world have changed the role of 3D CAD systems from drafting to producing blocks of the new 3D virtual environments. Virtual Environments (VEs) are attractive platforms for learning in which they provide opportunities for new kinds of experience that enable users to interact with objects and navigate in 3D space in ways not possible in the physical world. Claims have been made about the added-value that can be gained from interacting with these kinds of virtual representations including easier learning, better understanding and training, more engagement, and pleasure (Psotka, 1995). These benefits are manifested on the key properties of VEs in their ability to captivate. For instance, Byrne (1996) suggests that immersion in 3D environments is highly motivating, inducing users to spend more time on a given activity. Pedagogically, Wickens (1992) argued that virtual environments encourage people to be more active in the way they interact with external representations, through having to continuously choose their position and viewing perspective when moving through the virtual environment. It has been suggested that learning and retention of information can be increased. Kvan (2001) asserts that the advent of virtual design studio appears to raise promising opportunities for reconsidering the way we teach design. Utilizing virtual environments in architectural design teaching advances the concept of designing with computers (e.g. in a paperless design studio), to a multi user real-time 3D virtual environment for achieving collaborative designing and learning (Reffat 2003, and 2005).

Virtual Environments have proliferated and a large number of architecture and design schools are currently engaged in them as virtual architectural design studios. Virtual Environments can either support teaching in a single studio within an institution or bring together students from several institutions. There are various motivations for engaging architecture students in VDS including instinctive feelings that Virtual Environments present an essential learning for practice of the future, exploiting technology in design teaching, researching the nature of design communication and processes, and searching for ways to improve the educational experience of a student (Kvan, 2000). Virtual Environments provide powerful communication and navigation environments wherein users can collaboratively design in centralized or distributed environments. Some examples in this field include “Phase X” (Schmitt, 1997) that is a design course at ETH, Zurich which starts using the computer as a medium but in a passive approach. Another example is a

collaborative virtual studio in an immersive environment that allows experiencing design ideas differently in which the interaction of idea and creation was direct (Schnabel et al, 2001). Collaboration was possible and teams engaged in intense discussions about design, concepts and forms.

An Alternative Teaching Model for Collaborative Learning in a Virtual Architectural Design Studio

In collaborative learning, students work together as members of a learning community by questioning each others, discussing, and sharing information. Flexibility and interactive communication are key features in collaborative learning. In order to achieve collaborative learning, the author has developed an alternative teaching model that includes four major phases as shown in Figure 3: Inhabiting, Designing, Constructing and Evaluating (IDCE). These phases are carried out in a multi-user real-time 3D virtual environment platform (Activeworlds), wherein activities do not occur sequentially but rather in a constructive loop that maps in part to the activities in the conventional face-to-face design process. The new activities in this model are inhabiting and constructing. Inhabiting requires users to virtually familiarize themselves with: (a) nature of the design problem to be solved, (b) electronic interaction with their colleagues and studio instructor, and (c) design environment within which they will design, construct and evaluate their ideas. All of these are happening virtually (students and studio instructor do not have to be physically collocated), within one sitting, that is the multi-user real-time 3D virtual environment.

This is an alternative to the various settings of the traditional face-to-face, paperless design studio, and previous VDS that included disjunction among lecture sessions, discussion groups, studio sessions, individual drawing boards or individual and a single user CAD platform. The real difference here is that all previous activities are now taking place within one sitting in a multi-user real-time 3D virtual environment wherein students' actions, communications, and designs are viewable to all participants from a single computer interface. Within this interface each user selects his/her view point and location in the 3D virtual environment, interacts with objects and navigates in 3D space. Students build their designs in the VDS in a similar fashion to the construction process in real world. Therefore, they evaluate their designs and modify them as they build or construct them. This is an unparallel experience for each student to realize the design as it evolves without mental transformation efforts and shift of focus between various design representations. It also allows studio instructor, teaching assistants and each student to view each design from his/her computer interface (as s/he moves "teleports" to its virtual location), interacts and communicates with the designer and provides alternative solutions in one to one or one to many collaboration settings since many users can be at the same virtual location simultaneously.

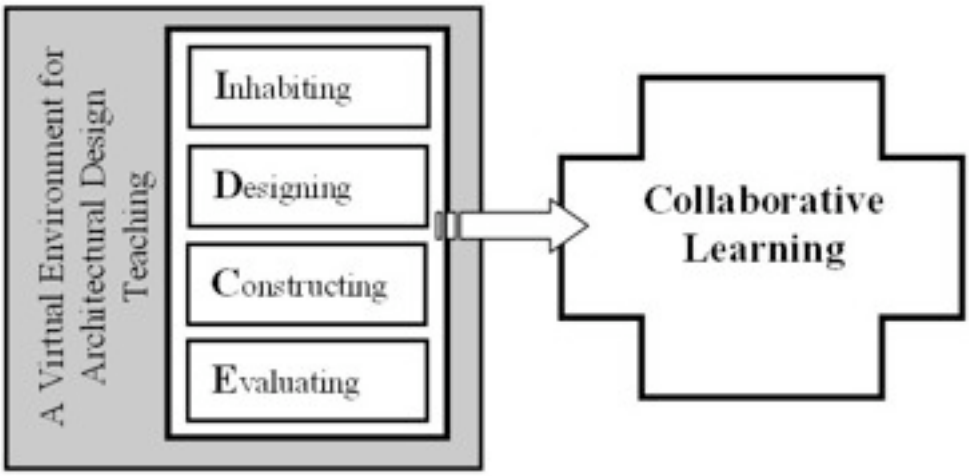

Figure 3: *The IDCE teaching model for collaborative digital architectural design learning within a multi-user real-time 3D virtual environment (Reffat, 2006a)*

The IDCE teaching model has been applied by the author in teaching the first year design studio (Semester 2) at the University of Sydney within a multi-user real-time 3D virtual design platform (Activeworlds). Students can access the VDS through client software (Activeworlds client) that is required to be installed on their local computers that can connect to the server (via local area network, or DSL, or dialup) in which the VDS platform (Activeworlds galaxy server) is installed. Therefore, students can access and work on their designs at any time day or night. All designs and actions are saved on the server and can be viewed and modified from anywhere. Objects created by each user are owned by him or her. Hence, these objects that constitute the design can not be modified except by their owner or the studio instructor who has full access to the whole environment. Students have constructed their design ideas of 3D virtual café taking into considerations that design objects are modeled in real size (1:1 scale), achieving a sense of presence, directedness and engagement in the design of their virtual cafés, and designing objects to be interactive with user's actions. Students' designs are constructed from objects that were either imported from the Activeworlds object library or were designed and modeled using 3D CAD modeling tools (AutoCAD, ArchiCAD, 3D Studio and FormZ), converted, exported to augment the Activeworlds object library at the server, and used to construct the proposed designs. Examples of students' designs in the VDS are shown in Figure 4.

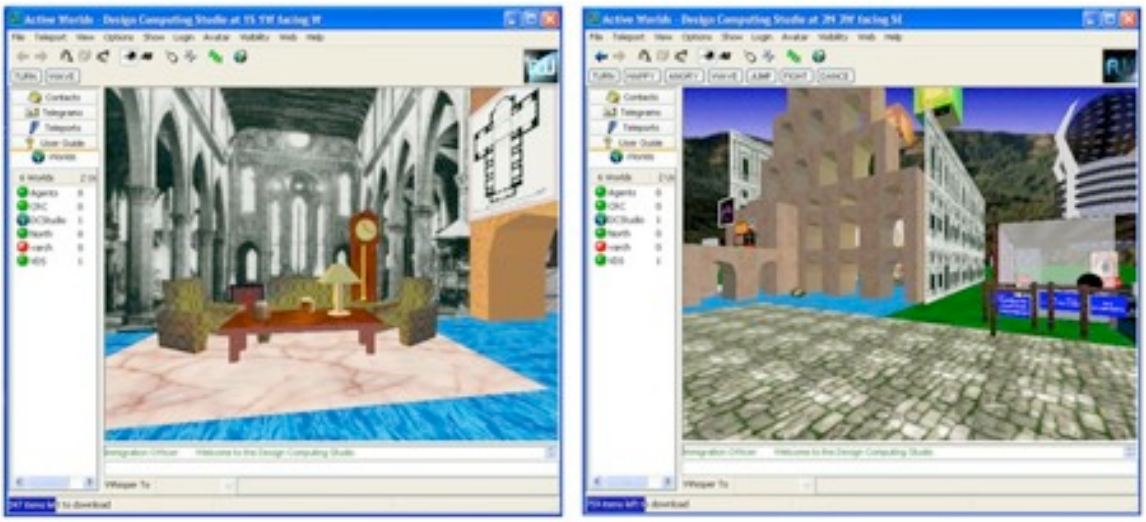

Figure 4: *Examples of students' designs developed in the collaborative virtual design studio*

REFLECTIONS ON STUDIO EXPERIENCES IN THE PAPERLESS & VIRTUAL DESIGN STUDIOS

Reflections on Studio Experience in the Paperless Design Studio

Design Process in the Paperless Design Studio

In the conventional design studio the design process is carried out through the use of sketching, physical modeling and orthographic drawings. A unique characteristic of the conventional design studio is that sketching, tracing and recording ideas are left visible. This provides richness to the exploration through revisiting and revising previous ideas. The ability to see where a design idea is at present and where it came from seems to be of benefit while working in a physical or tangible medium. All of this and more can be offered using digital media in the paperless design studio (Norman, 2001). The history of a project and process of design must be evident in the educational techniques employed in the paperless design studio. Editing a digital file might cause the history or part of the design process to be lost. This was simply resolved by using the design tool to benefit the design process in the paperless design studio. Whenever a design idea was revised then a new file was saved providing a record of the past. This strategy was not applied by our students at every change in the design process but rather at times of conceptual changes. Another alternative to document the design process is with taking frequent captures and snapshots of the computer's screen state, well prior to final presentation. This allowed the students to see the evolution of their designs from various concepts to design developments. The documentation of the design process in the form of a digital sketchbook "digital portfolio" has broaden the students' design universe to utilize the design tool to digitally merge design ideas created at different time intervals of the design process.

Communication and Representations in a Paperless Design Studio

The newcomer to a paperless design studio might expect instant efficiency as a result of the move to digital design studio. Yet, even after developing a basic fluency with a given program, this efficiency is not likely to be immediate. Initially, a significant amount of time must be devoted

to mastering computing in the design context. It is important to anticipate a “time sink” at the early stages of the digital engagement and to allow for it (Lewis & Wojtowicz, 2001). The forms of representation in the traditional design studio include the use of physical models, manual drawings, and even to some extent two and three-dimensional CAD drawings. In a paperless design, design tools are used as tools for inquiry. Furthermore, various types of representation forms are produced by students including, real-time modeling, web-based presentation, dynamic presentation incorporated with sound, QTVR animations and walk-through. A promising aspect of the digital model lies in its inherent ability to be used as data for the production of design and to serve as data in CAD-CAM (computer aided manufacturing), or the quick prototyping process using rapid prototype machine that was made available to students to produce physical models of their designs from their digital 3D models. This has created a new relationship between designer, project and design objects; perhaps turning the designer into the digital artisan-craftsman. The nature of the digital design medium has permitted designers to think more naturally in three dimensions and to a greater degree than previously imagined.

Paperless Design Studio and its implications on Studio Pedagogy

The nature of design with its uncertainty and irregularities are congruent with the epistemology and ontology of the constructivist pedagogy. The inclusion of constructivist ideology within the paperless design studio helps to increase learning and advance constructions of knowledge (Powers, 2001). Similar to a traditional design studio the responsibility in the learning process is shared and negotiated amongst teachers and learners. Utilizing digital media in a paperless design studio enriches the design studio environment with a multiplicity of informational sources and representations that help students and teachers to reflect upon design ideas at different time intervals at the early conceptual stage of the design process. The paperless design studio is an excellent place for the outgrowth of exploring, investigating and constructing design ideas.

Reflections on Studio Experience in the Collaborative Virtual Design Studio

Multi-user 3D virtual learning environments provide the capacity to merge the institutional infrastructure for academic subjects with the educational principles of constructivist pedagogy. The educational aims of higher education form a constructivist pedagogy may be divided into the categories of: (a) Knowledge and skills acquisition, including competence with tools and techniques; (b) Socialization, particularly induction into the canons of particular communities, disciplines or professions; and (c) Development of intentional learning, a form of learning in which learning itself is the goal and the individual becomes a self-organized learner, capable of critical thinking, reflective practice and active open-ended inquiry. The multi-user 3D virtual collaborative learning environments provide immersive, learner centered educational environments that are based on the constructivist pedagogy (Lombardi & McCahill, 2004). In the VDS students bring multiple perspectives, diverse backgrounds, learning styles, experiences and aspirations. In order to foster collaborative learning there should be a structure that encourages student conversation and communication (Kvan & Yunyan, 2005). The utilization of the IDCE teaching model in the VDS has permitted a range of communication media and engaged students, studio instructor, and teaching assistants over a relatively long duration allowing more freedom in learning approaches. From a studio instructor's perspective, it has been witnessed that students have been captivated by the opportunities provided by the activities of inhabiting, designing, constructing and evaluating their design ideas in the VDS in which they have been fully immersed, engaged and enjoyed the experience of design process within a more social sitting. Furthermore, from students' perspective, the advantages of applying the IDCE teaching model in a VDS compared to using a single user CAD software in a traditional face-to-face studio include:

- Improving students' motivation for active, creative and explorative learning.

- Fostering learning electronic communication, collaboration techniques and etiquette in addition to design technology.
- Online archiving of design information and keeping track of previous design actions, approaches and critique helped students to improve design reflection and moving into new directions.
- Synchronous communication within the current design as it is developed at the VDS across all stages of the IDCE model has stimulated the sense of presence and collaboration between students themselves and between students and studio instructor and teaching assistants.
- The process of designing has become more exciting and natural in a social sitting for learning and design development.
- Extending collaboration time due to the availability of access to the VDS at all times and from anywhere.
- Enriching collaborative learning experience wherein students realized exploring and learning together without ego, embarrassment or domination.
- Strengthening the social bonds between studio participants since they occasionally had chance to talk about other issues during their collaboration or just surfing or walking through the VDS to observe what others are doing in their designs.

On the other hand, there are some drawbacks that have been realized and faced during the processes of applying the IDCE teaching studio in VDS. The capacity of bandwidth (via networking, DSL, or dialup) and firewalls are limiting factors governing the speed of mobility, access, resolution of visual and sonic objects, and quantity of data transferred in (near-) real-time in a multi-user online environment. Modeling objects and modifying their geometries are other important limitations that should be taken into account while adopting Virtual Environments (basically Activeworlds), in virtual architectural design studios. The above limitations were the most important constraints that interrupted all participants during this experiment. However, these are technological limitations that are expected to be overcome in the near future with the fast and advanced rate of development in IT and communications.

The Next Step Ahead in Architectural Design Studio Teaching: ICT as a Partner

When information and communication technology was introduced in architectural education, the reflection on building practice was seen very clearly. The use of ICT tools within architectural offices came much later than any other engineering disciplines. In the historical developments of ICT utilization in the education of architectural students, the computer was used as information processing tool, communication tool, and visualization tool during the design process. It was mainly used in processes such as animation, simulation and the whole spectrum of visualization. By the developments of advanced 3D visualization tools including Virtual Environments platforms such as Activeworlds, Adobe Atmosphere, Second Life, etc., one may expect enormous improvements in the approaches of digital architectural design studio teaching. Therefore, ICT is not any more used only as a tool for architects but are becoming a new medium besides the other existing ones within the architectural design process (Sariyildiz et al, 1998). ICT is becoming a valuable media for designers and architects in relation to the use of conventional medium. The widening of Internet opened the horizon for computers to become more and more an open medium and speed up ongoing processes. Hence, there is a growing need for advanced ICT supportive tools that enables architects to cope with the increasing complexity in design and with the increasing need of efficient communication with many partners in the building process.

The ICT is expected in the near future to play a more important role than being a medium; it will potentially play the role of a reliable partner in the design process as depicted in Figure 5. How can they become a partner and what will be the role of this partner in the design process?. ICT will be used as partner when its advancements and supportive tools successfully function as: knowledge integration tools, decision support tools, and design assistant tools (Sariyilidz & Van der Veer, 1998). Therefore, viewing information and communication technology as a partner in architectural education requires developing new methodologies and techniques to realize the goal that computers can be put into the education process and act as a reliable partner. The need for such methods and techniques presents challenging tasks to architectural educators with expertise in information and communication technology to carry out and provide creative directions. An approach that envisages the new generations of supportive collaborative medium architectural designing and studio teaching has been developed which carried out synchronously within smart and real-time 3D virtual environments within which architects are designing with intelligent agents based on the view of situated digital architectural design (Reffat, 2006b).

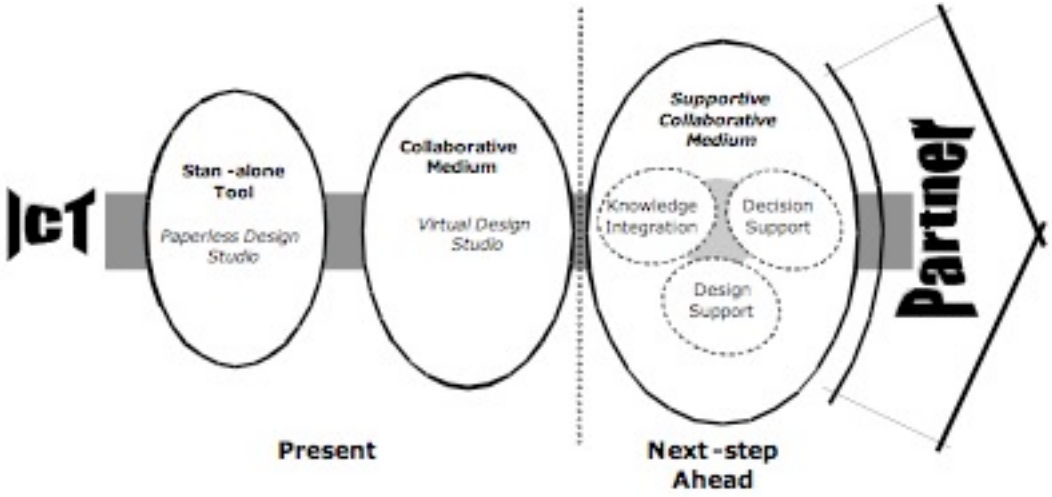

Figure 5: *The Next Step Ahead in Architectural Design Studio Teaching: ICT as a Partner*

DISCUSSION

In the paperless design studio there were different types of interactions that took place between the students and the design tools, between the students themselves and between the students and their design instructors and teachers. The focus on the interaction between the student and design tools in the paperless design studio distinguishes the approach presented in this Paper rather than using computers as generative systems. The generation of shapes using generative systems is very different with the creation of design ideas within a form of fruitful dialogue between the student and the design tool where designing is viewed as an activity that occurs with active participation. Designing with computers is not a systematic process by which a set of rules would generate design solutions (Madrazo, 1999). Designing with computers is rather a situated process wherein the result of design artifacts is based on the design situation that each student encounters, the state of interaction with the design tool, and which objects primitives of the design tool the student is utilizing. A designer, through analysis, investigation, research and interaction begins to synthesize an idea for a possible solution to respond to the situation at hand. The

process is then to chase this idea down to see if it works, to test it, to modify it, and to branch out in a different direction, or to reject it back all together.

On the other hand, the application of the IDCE model in the collaborative virtual design studio has offered a rewarding opportunity with challenges and dilemmas. The implementation of this model has facilitated active exchange of ideas, increased the interest among participants, promoted creative exploration, and made the learning more natural. The utilization of IDCE model in VDS made the design studio not to be any longer solo teacher and leave individual students with their own designs. It became more of an interdependent community with all joys, tensions and difficulties that attend to all communities. The assumption that studio instructors act as keepers and dispensers of knowledge is no longer valid. It fostered the VDS to be a collaborative learning environment with shared responsibility, persistence and sensitivity. In order to succeed in the future of digital architectural design studio teaching, one needs to know more about how the digital world is likely to change. We live in a universe of continuous change; a world in which most the unchanging things in the past keeps on changing based on discoveries and interpretations. Information and communication technology and digital media are real indicators of a changing world. Such a world requires responsive design studio teachers and instructors to make the best use of latest developments including information and communication technology. This will help design studio instructors to improve the quality of design studio processes and products in addition to enhancing student's learning and design skills to better prepare them for an ever changing world of everything wherein architecture is not an exception.

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