A SCALABLE WORKING MODEL FOR CROSS-DISCIPLINARY GLOBAL TEAMWORK EDUCATION

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ABSTRACT: Our mission is to prepare the next generation of architecture, engineering, construction (AEC) professionals who know how to team up with professionals from other disciplines and leverage the advantages of innovative collaboration technologies (ICT) to produce higher quality products, faster, more economical, and environmentally friendly. To achieve this mission we have been offering the AEC Global Teamwork course established at Stanford in 1993 in collaboration with universities worldwide. The AEC Global Teamwork course was described in many previous papers. This paper examines this course as a scalable working model for cross-disciplinary global teamwork education. More specifically we discuss the following dimensions: (1) a growing global learning network, (2) expanding the cross-disciplinary engagement, (3) evolving ICT EcoSystem, and (4) increasing number of social worlds students distribute their attention.

KEYWORDS: project based learning, global teamwork, ICT, social world.

1 INTRODUCTION

"The globalization of economic activity is perhaps the defining trend of our time. It is reshaping not only the grand, macro level aspects of economic life but the personal aspects as well, including where, when, how, and with whom we perform our daily work." [O'Hara-Devereaux and Johansen 1994] Our mission is to prepare the next generation of architecture, engineering, construction (AEC) professionals who know how to team up with professionals from other disciplines and leverage the advantages of innovative collaboration technologies (ICT) to produce higher quality products, faster, more economical, and environmentally friendly. To achieve this mission we have been offering the AEC Global Teamwork course established at Stanford in 1993 in collaboration with universities worldwide.

Teamwork, specifically situated cross-disciplinary learning, is key to the design of this course and PBL Lab. Students engage with team members to determine the role of discipline-specific knowledge in a cross-disciplinary project-centered environment. They exercise newly acquired theoretical knowledge. It is through cross-disciplinary interaction that the team becomes a community of practitioners-the mastery of knowledge and skill requires individuals to move towards full participation in the socio-cultural practices of a larger AEC community. The negotiation of language and culture is equally important to the learning process - through participation in a community of AEC practitioners; the students are learning how to create discourse that requires constructing meanings of concepts and uses of skills. [Greeno 1998] [Dewey 1928, 1958] [Lave and Wenger 1991]

The AEC Global Teamwork course was described in previous papers. [Fruchter 1999] [Fruchter 2004] [Fruchter 2006]. This paper examines the course as a scalable working model for cross-disciplinary global teamwork education. We present the AEC Global Teamwork education model as background to our discussion and focus on the following scalable dimensions: (1) a growing global learning network, (2) expanding the cross-disciplinary engagement, (3) evolving ICT EcoSystem, and (4) increasing number of social worlds students distribute their attention.

2 THE CROSS-DISCIPLINARY GLOBAL TEAMWORK EDUCATION MODEL

The AEC Global Teamwork course is a two Quarter learning experience that engages architecture, structural engineering, and construction management students from universities in the US, Europe and Asia. Each team is geographically distributed, and has an owner/client. Students have four challenges: cross-disciplinary teamwork, use of advanced collaboration technology, time management and team coordination, and multi-cultural collaboration. An innovative features of this course is represented by the role the participants play, i.e. undergraduate and graduate students play the roles of *apprentice* and *journeyman*, and faculty and industry experts are the *master builder mentors*. The industry mentors play a key role in providing real world industry data and feedback to students that increases the authenticity of the PBL learning experience.

The core activity of the AEC Global Teamwork course is a building project with: (1) a program – a university building of approx. 30,000 sqft of functional spaces that include faculty and student offices, seminar rooms, small and large classrooms, and an auditorium. The project is based on a real building project that was scoped down to address the academic time frame of two academic quarters. (2) a university site where the new building will be build, such as San Francisco, LA, Madison, New Mexico, Weimar. The site provides local conditions and challenges for all disciplines, such as local architecture style, climate, and environmental constraints, earthquake, wind and snow loads, flooding zones, availability of access roads, local materials and labor costs. (3) a budget for the construction of the building, (4) a time for construction and delivery, (5) a demanding owner that typically wants an exciting, functional and sustainable building that meets at least the requirements for a silver LEED certificate, on budget and on time.

AEC teams model, refine and document the design product, the process, and its implementation. The project progresses from concept exploration and development in Winter Quarter to project development in Spring Quarter. The deliverable of the concept development phase of each student team are two distinct AEC concepts, a decision matrix that indicates the pros and cons of the two alternatives and justifies the selection of one of the two concepts to be developed in Spring Quarter. The project development phase engages students in further iteration and refinement of the chosen alternative, detailing, modeling, simulation, cost benefit analysis and life cycle cost investigation. Spring Quarter culminates with a final AEC Team project presentation of their proposed solution, and reflection of their team dynamics evolution. As in the real world, the teams have tight deadlines, engage in design reviews, and negotiate modifications. A team's cross-disciplinary understanding evolves during the project. The international structure of AEC teams adds the real-world collaboration complexity to the learning environment, which includes space, time, coordination, and cooperation issues. To view AEC student projects please visit the AEC Project Gallery at
http://pbl.stanford.edu/AEC%20projects/projpage.htm.

3 SCALABLE WORKING MODEL

Since its launch in 1993 the AEC Global Teamwork course has continuously grown in many directions, engaging new university and industry partners, integrating new competencies and expanding the cross-disciplinary learning experience, leveraging new knowledge and technology that augment and inform our understanding of the nature of global teamwork and learning. The following sections examine these directions of growth and provide insights into the research, development, and efforts that allowed us to achieve the present outcomes.

3.1 *A growing global learning network*

Based on the original vision of the AEC Global Teamwork course to engage students, faculty, and industry mentors from architecture, engineering, and construction management we stated in 1993 with a seed partnership between Stanford University and UC Berkeley, and a few pioneering industry mentors from AEC firms in the Bay Area in California. As we tested and demonstrated the value of the education model and partner framework, new universities and firms joined the growing learning network. The aim is to emulate the participation framework at all levels, i.e., students, faculty and industry mentors from each university, region, and country. This requires a joint effort between the PBL Lab at Stanford and the local champion with vision, sustained institutional support, local committed and motivated faculty liaison and industry experts who act as mentors to all students, and funding for ICT, travel, and membership. Some universities joined for a number of years with a mission to learn how to establish and run similar programs in their university and country. Other universities joined and continue to engage in the ever evolving education model and ICT.

We are pleased to see that the AEC Global Teamwork is a growing learning network that engaged to date numerous AEC firms worldwide and the following universities: Stanford University, UC Berkeley, Cal Poly San Luis Obispo, Georgia Tech, Kansas University, University of Wisconsin Madison, in the US, Puerto Rico University, Stanford Japan Center Kyoto and Aoyama Gakuin University Tokyo Japan, Strathclyde University Glasgow, Manchester University, UK, Bauhaus University Weimar Germany, University of Ljubljana Slovenia, University of Oslo Norway, FHA and ETH Zurich Switzerland, TU Delft Netherlands, KTH Stockholm, IT University Goteborg and Chalmers University in Sweden.

All partners play a key role towards the goal to educate a new generation of professionals that have a unique skill set, i.e, cross-disciplinary, project-based, ICT mediated global teamwork.

3.2 *Expanding the cross-disciplinary engagement*

As new partners join the AEC Global Teamwork course they gain an intuition and insight of the objectives, roles, and complex process during the first three years of participation. In some cases they contribute new competences and offer opportunities to expand the cross-disciplinary engagement of students in new areas. The following two cases present examples of learning growth that leverage the scalable framework of the AEC Global Teamwork education model.

Sustainable Design and Construction. As Sustainability is becoming a growing concern and goal in the world, the PBL Lab at Stanford and mentors from two firms – Ms. Adhamina Rodriguez from Swinerton Builders Inc. and Mr. Cole Roberts from Ove Arup - engaged a couple of years ago in an effort to integrate sustainability concepts and requirements into the AEC project. This required: (1) the revision and calibration of the AEC project requirements to include sustainability requirements, (2) development of a new module focused on sustainability, links to introductory and advanced material on sustainable, green design, construction and maintenance, and operation as a data resource for the students, (3) a session presenting signature case study projects that demonstrate how sustainable and green aspects where integrated from concept to execution, and (4) last but not least, industry mentors who provide real world guidance and data to the AEC students. This year Swinerton Builders announced at the opening of the 14th AEC Global Teamwork generation a competition for the best AEC project solution that minimizes CO_2 emission. This provides an additional incentive and challenge for the AEC global teams to present creative sustainable solutions.

Public Private Partnership (PPP), Life Cycle and Finance Management (LCFM). The PBL Lab at Stanford and colleagues from the Knowledge Center @ Weimar (KC@W) at Bauhaus University engaged in an effort to integrate PPP and LCFM concepts into the PBL learning experience of the AEC Global Teamwork course. This effort was motivated by the fact that PPP projects represent one of the fast growing global markets. To realize successfully projects of such complexity special competences are needed among the stakeholders. Life cycle considerations represent one of the key aspects in PPP projects as the project's duration spans over 25-30 years. State-of-the-art education of civil engineers, architects, and construction management starts with the design phase, covers the construction phase and stops at the stage when the building is delivered and operation phase begins. Students have little awareness of the operation and maintenance phase when they graduate. Our goal was to broaden the students' learning experience through the integration of PPP and LCFM and prompt them to look at a building beyond cost to design and build to include operations, maintenance, repair, replacement, and disposal costs. To achieve this goal we: (1) developed a new module focused on PPP, financing, and life cycle, (2) provided background information and references, (3) extended the original AEC team to include a new team member – the life cycle and financial manager (LCFM) – and become the AEC+LCFM team, (4) revised the project definition as a PPP offering, and (4) engaged faculty and industry mentors with PPP and LCFM expertise to guide the students and provide real industry data. The KC@W offered an opportunity to select from their program students for the new LCFM team member. Consequently, students were coming from four distinct programs / departments with the specific discipline knowledge and skills - architecture, structural engineering, construction management, and finance departments.

The revised project definition included (1) a technical part, i.e., architectural design, structural engineering design, construction and project management solutions, and facility management concept; and (2) an economical part, i.e., financial analysis (cash flow model) considering life cycle cots, and risk management (identification, categorization, analysis, allocation), life cycle cost to operate and maintain the building for the university over a period of 25 years. The AEC+LCFM student team had to understand life cycle costs as strong indicators of value for money. This required the team to include from the start of the project new considerations, such as: mirroring the project's value for money, long range planning and budgeting, comparing competing projects, controlling an ongoing project, etc. It is a fact that the earlier decisions are made within the design and planning phase the higher the potential savings with regard to the overall costs. Nevertheless, it might be necessary to consider a higher initial investment to achieve savings of the overall costs. The PPP project approach offered an opportunity to bring key LCFM decisions and issues to the forefront. This is a paradigm change that the AEC+LCFM student team was exposed to.

As the project team increased in number of participants and disciplines it created new performance and process advantages and challenges. On one hand, having more disciplines and more participants on board enabled the team to address more issues in depth increasing the quality of the final product, i.e., the proposed building as a PPP offering. On the other hand, increasing the number of disciplines and team members increased the complexity of task interdependence, cross-disciplinary impacts to be considered, and coordination of tasks and activities. A preliminary study indicates that the process the AEC+LCFM team chose can be divided into two main stages. In the first stage understanding the change of paradigm was the primary aim. The team moved closer to the role of an owner as they looking at the building from a life cycle perspective. Raising the awareness for the life cycle considerations was the focus during the first few weeks. A key challenge was to build awareness and understand the role of the LFCM team member, understand life cycle issues and the benefits of low life cycle costs. Definitions and examples of the life cycle approach were available. The issues were constantly discussed. Consequently, their understanding evolved and common ground was built. Once the team achieved a shared understanding of the life cycle approach they started to translate their knowledge and understanding into life cycle strategies. The LCFM constantly prompted all team members for information and engaged them in developing a cash flow model. Through this iterative process all the disciplines reached a shared understanding what their specific tasks were and how their decisions influenced on the one hand the financial analyses and on the other hand the other disciplines. Furthermore, the LCFM encouraged the team to think about discipline specific risks that could occur in the different phases of the life cycle of the building. The second stage comprised the implementation of life cycle strategies into concrete project solutions, i.e., what materials to use to achieve sustainability, what technical solutions to choose for heating, ventilation, air condition (HVAC) to reduce life cycle costs.. The strategies were followed more efficiently and rigorous as all the team members in each discipline had achieved the same level of understanding. The whole teamwork process was goal oriented. During the second stage the LCFM categorized and analyzed risks of the different life cycle phases, and discussed them with the team in an iterative exploration and decision process. The LCFM developed the cash flow model with the project specific data and was responsible to realize the affordability of the project by keeping the finance specific stipulation (e.g., dept. service cover ratio and loan life cover ratio).

After four months in which the team collaborated to develop the offer for the university to design, build, finance, maintain and operate the building the results were presented. The product consisted of a building that incorporated the life cycle approach and offered high value to the university. The team had implemented the life cycle considerations in the architectural, engineering and construction solution. The offer comprised a risk management package and a project specific financial package. Contractual issues were not considered. This might be one of the next topics the PBL learning experience could include in the future.

3.3 *Evolving ICT EcoSystem*

To support the complex communication, collaboration, and coordination activities over time and space that engage the global student teams, faculty, and industry mentors, we have been developing an evolving ICT EcoSystem. The current PBL ICT EcoSystem addresses the ever changing needs of the global teams as they become more mobile, create more digital content, and engage in interactive creation, capture, sharing and manipulation of digital models and content. The PBL ICT ecosystem provides a heterogeneous environment that includes:

1. *Network Infrastructure* includes LAN/WAN, I2, WiFi, and cellular network (GSM/GPRS).
2. Devices enable the mobile learners to stay connected with their peers, team members, faculty, and mentors, as well as the content they create and share. These devices range from smart cell phones with embedded cameras, PDA, Tablet PC for mobility, pen-based desktops, Web cameras, SmartBoards, to the iRoom [Johnson, Fox, Winograd 2002] for collaborative synchronous and distributed project review and decision support.
3. Collaboration Applications support synchronous and asynchronous communication, inter-action and feedback, direct manipulation, knowledge capture, sharing, and re-use; and data collection and analysis. The evolving collaboration application set includes commercial solutions such as Skype, MSN, MS NetMeeting, GoogleCalendar, GoogleDocs, VSee (VSeeLab.com) [Chen 2001, Chen 2003], and PBL Lab developed technologies, such as TalkingPaper [Fruchter et al 2007], RECALL [Fruchter and Yen, 2000], ThinkTank [Fruchter et al 2003], ProMem (Project Memory) [Fruchter and Reiner, 2000], and CoMem (Corporate Memory) [Fruchter and Demian 2002].
4. Places. The spectrum of places includes private, public, local and global learning and work places in support of learners' communication and teamwork needs. Such places are - private (e.g., home, dorm), local (e.g., office, coffee shop), regional (e.g., meeting rooms, iSpace, classroom, PBL Lab), and networked global learning places in which learners can interact.
5. People. The global teamwork PBL testbed engages students, faculty, and industry mentors from architecture, structural engineering, and construction management. They are the key asset in the PBL EcoSystem. This allows us to further study the impact of ICT on team dynamics, emergent work processes, and learning practices.

3.4 *Increasing number of social worlds students distribute their attention*

We studied the ICT setting, activities, and discourse of larger (10-15 collocated participants) and smaller groups (2-4 collocated participants) in the AEC Global Teamwork course, such as the groups at Stanford and Chalmers University, respectively. We used qualitative methods of inquiry in order to look at participants′ engagement, how they used the site and the means (their social and material resources) to accomplish their interaction needs, and how they engaged throughout project reviews. Figure 1 illustrates the ICT setting in each site and global distribution of students and industry mentors during project review sessions in class [Fruchter 2006]. The ICT setting in the PBL Lab at Stanford included: (1) RECALL collaboration technology and knowledge capture, (2) VSee™ technology (VSeelab.com) for parallel video streaming over the IE browser to enable the PBL participants to see all the remote sites, (3) MS NetMeeting Videoconference for application sharing (e.g., RECALL™) with all the remote sites, (4) a SmartBoard for direct manipulation and sketching through the RECALL application, (5) a Webcam that enables the remote students to see the interactive workspace in the PBL Lab at Stanford, (6) additional SmartBoard or projector and projection screen for the parallel video streams over VSee (7) a microphone for audio capture that feeds into the SmartBoard computer that runs RECALL, and .(8) a high end speaker phone and teleconference bridge for high quality audio. The ICT setting in the other sites where composed of (1) two or three tablet PC laptops to allow similar interactivity and direct manipulation as SmartBoards afford, (2) VSee™, running on one laptop, (3) PC camera for VSee™, (4) MS NetMeeting Videoconference for application sharing running, and (5) speaker phone and teleconference bridge for high quality audio.

We chose a cross-case explanatory-exploratory methodology to investigate of distributed design teams mediated by ICT and compare two specific sites – Chalmers University and PBL Lab at Stanford University. During the AEC Global Teamwork course we collected data at Chalmers and Stanford University. At Chalmers University video cameras arranged in two angles to capture the three participants while in class for seven course events of approx 7 hours each (a total of approximately 70-80 hours of digital video). Data for the study of students′ engagement at Chalmers during project review sessions was collected in the following ways:

- One angle of digital video footage of the three Chalmers students′ activities;
- One angle of digital video of the laptop showing videostreams with remote participants;
- Verbatim transcripts of selected portions from one angle of the digital video footage;
- Transcript of selected portions from stimulated-recall interviews with two Chalmers students.
- Observations and comments made by the researcher during the sessions.

The data was collected in the PBL Lab at Stanford in the following ways:

- Indexed and synchronized sketch and discourse captured through RECALL,

- Interactions, movement and use of collaboration technology within the PBL Lab workspace was captured with a video camera (Figure 1),
- Interaction and engagement of remote students was captured through a screen capture application that recorded all the concurrent VSee™ video streams for parallel analysis of interaction and engagement of all students at all sites.
- Digital pictures and observations made by the researcher during the sessions.

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- two video cameras – one capturing the three Chalmers students′ activities, and the second capturing the laptop showing videostreams with remote participants;
- Verbatim transcripts of selected portions from one angle of the digital video footage;
- Transcript of selected portions from stimulated-recall interviews with two Chalmers students.
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Our study was exploratory [Yin, 1994], as we aimed to describe and explore the real-life context in which the project reviews occurred and explain some complex relationships between people and their surroundings. The study also was intrinsic [Stake, 1995], as Dr. Fruchter designed the course and taught in it. Case study research matched our goals to undertake an inductive process that attempted to provide a holistic description using the informants' perceived realities and the observed reality of the events and processes being observed. Our unit of analysis was the locale [Fitzpatrick et al 1996] that is a place where a group of students in each geographic location defined a social world [Strauss, 1978]. A social world defined a system of action in which a group of people shared a commitment, used a site and its resources to fulfill their interaction needs. Each group and its social world interact with other groups situated in other locales. Locales include physical and virtual spaces. Locales can be composed of a mix of overlaid or intermeshed sites and means that constituted the ICT augmented workspace used for the project reviews and throughout the global teamwork course. We combined the use of the case study with grounded theory as the overarching method to study data from our exploration in a natural setting. Some features of Grounded Theory in the version elaborated by [Strauss and Corbin and, 1998] were used to analyze the selected data set. The video data analysis process included [Ecksson, 1992] reviewing the whole event, identifying major constituent parts of the event, identifying aspects of organization within major parts of the event, focus on interactions of individuals, comparative analysis of instances across the research corpus.

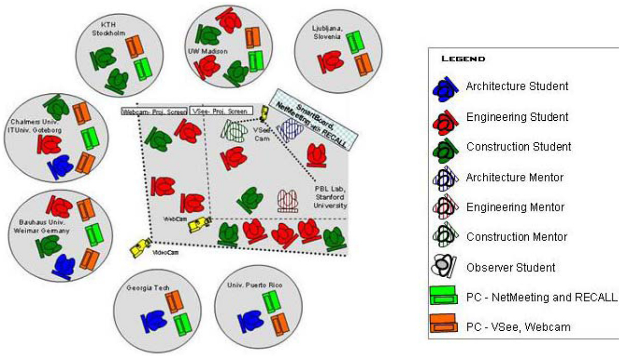

Figure 1. ICT setting and global distribution of students and industry mentors.

The entire video footage was viewed with Transana (free video data analysis program www.transana.com) and five content logs were created [Jordan and Henderson, 1995]. The level of detail of the content logs was at a meso-level. Some portions of social talk in Swedish were translated verbatim. Theoretical notes were produced while viewing the video footage. Once the recordings were loosely indexed and partially transcribed, the footage from the DV data source (screens) was imported into Adobe Premiere Pro and converted into digital files. Instances of engagement/disengagement, side conversations, gaze foci, and use of technological tools were noted. This provided a sense of the types of engagement occurring within the group. We observed: (1) How do the collocated participants make their engagement (or lack thereof) visible to each other? (2) How do artifacts and ICT support or constraint engagement activities? (3) When participants engage with ICT, where are their eyes? (4) When and how do their gaze move between objects, from person to objects and back again? Four interesting situations were observed: (1) one student on task-the other(s) off task but observing, (2) one student on task-the other(s) off task and disengaged, (3) none on task and disengaged, and (4) none on task but observing. We were interested in findings related to: how spaces were organized; how students behaved in the different spaces –in a different location from the instructor, vs where the instructor is; how the students shared and negotiated the space – access, visibility and awareness to digital content, devices, seeing each other; degree of engagement, side conversations; and multitasking.

We selected 11 clips (nearly 30 minutes in total) for a detailed video analysis after two attentive reviews of the collected data. Analysis of the data was achieved through analytic induction, constant comparison, open coding, axial coding, and cross-case analysis [Strauss and Corbin, 1998]. Jordan and Henderson (1995) stated that building generalizations from data of particular, naturally occurring activities, and holding emergent theories accountable to that evidence through an inductive process could provide a foundation for analytic video work. We began the analysis of each clip with open coding the field notes by attaching codes, or labels, to pieces of descriptive observations and interview extracts that were relevant to our questions. In parallel with coding data, we wrote memos to articulate propositions about preliminary hypothesis to be considered and note conditions and properties of emerging concepts, especially relationships between concepts. To discover relationships between concepts, we constantly compared each clip and related interview extracts to other clips and related interview data. We grouped the 77 concepts that emerged from open coding into 7 preliminary categories, on the basis of their similarities. The categories were: *Interaction, Communication, Attention, Temporal Mobility, Technology, Site, and Social Relationship.* We performed axial coding and assembled data in new ways by making connections between categories.

Social Relationship and Communication **-** *Personal Relationships, Informal Talk and Disengagement.* The three co-located participants at Chalmers established a close personal relationship and often engaged in different forms of spontaneous conversations during the project reviews. Instances of informal and spontaneous talk occurred throughout the session, and reached a peak during a team presentation, in which none of them were directly involved. During the project review sessions, it emerged that informal talk happened mostly – if not exclusively – between the co-located students, while chats with cyber team members were almost always task-related. The characteristics of the course, such as fast pace, tight deadlines, and pressure to achieve, forced the communication with team members to be focused on the task. One condition for spontaneous conversation to occur was being able to find some time. The data highlights the emergence of a private *locale* or *place* from the spontaneous interaction of the co-located participants to fulfill their need of feeling safe and finding a "relief valve" used to relieve the pressure from the course and other simultaneous school demands. When this private locale arose, the focus of the students' attention was on their private conversation and the other course participants remained in the public space as a background. In their private locale, which interlaced with the attendance to the virtual environment, the three students spoke their native language and referred to other co-located people, who acted outside the course and helped them with project tasks. Within their locale, the students moved between different forms of informal talk. They shifted from making a joke and disclosing something about their personal life to serious talk about project presentations and sharing experience. The nature of constrains on more personal relationships and informal talk is likely to be associated with the demands of the course than with the characteristics of technology, since participants were all familiar with using ICT for informal communication. However, the mediation of technology influenced the ways participants got to know each other, as the following quote states:

"We were in the same boat. We were very dependent on each other. This is why we got to know each other so quickly. The other people in my group, I never had to chance to get to know them at Stanford because we had two days but it wasn't until the second day that we got to know the groups. You didn't have much time to get to know the people in the group. Basically you got to know the group members via Internet. It's very different to get to know someone not physically, but virtually. When we came back in May, it was like, these are the people I have been chatting with almost every day for four months now but it felt a bit strange. It's not the same getting to know someone here in Sweden in the same room compared to sitting in front of the PC and chatting. It's not the same really."

Bonding, knowing and talking to each other, were considered essential conditions for enduring the stress and performing well in the course, as the students felt they were going to be dependent on each other. This data shows evidence that interpersonal communication at work depends on physical proximity. Numerous studies have shown that the closer together offices of coworkers are located, the more likely they are to interact [Isaacs, et al 1997]. Physical proximity was perceived as crucial to enable mutual support and to sustain the students throughout the course for two main reasons: one was the lack of personal relationships with the cyber students, and the other one was the perceived lack of support at the local institution.

Attention, Temporal Mobility and Technology Mediation **-** *Continuous partial attention, multitasking and partial engagement.* Stone (quoted in Roush, 2005) coined the term continuous partial attention to indicate the state people enter when they are in front of a computer screen and try to pay attention to different things at the same. When in such a state, people are aware of several things at once, shifting their attention to whatever they think is most urgent, like, for example, the chime of incoming e-mail, or the beep that indicates a cell phone is low on battery. Our data shows that the students almost continuously engaged in continuous partial attention, especially when they were not on-task (not involved in a team presentation). There was almost continuously a rapid shift of attention on a second-to-second timescale between topics of talk and actions. Most shifts were mediated by technologies, some were not. The following short narrative shows an example drawn from one of the team presentations when one of the Chalmers students was presenting and another one was off-task. Note: M, L and H represent three students collocated at Chalmers University.

The project review of a team just started with the presentation of the project of the Central Team. L. began her presentation. She looked nervous. She was the first presenter. It was 06:30PM local time. Her gaze moved frequently between her laptop where she had the presentation and M.'s laptop with the webcam so that she could see and be seen by the other cyber participants. She used a lot of iconic gestures to produce a visual image of the ideas she was presenting. L.'s full attention was on her presentation, she was fully involved and moved her hands and torso to convey information about the object of her speech, to convey her feelings about the content and to elicit feelings in the audience. Soon after L. started to present, M. looked towards the video screens on her laptop, then her gaze moved towards the projected screen on the wall. She moved and resized the video screens on her *laptop screens. After a few minutes, she opened MSN and wrote something very quickly. Then she closed MSN and looked back at the projected screen. Her gaze switched between the projected screen and her laptop as she was waiting for something. She turned back to her laptop, reopened MSN and started to write. For the rest of the time, M. kept on interspersing looking at the presentation and reading and writing messages in MSN.*

M. was the observer, the peripheral participant. Her interspersing exchange via MSN with her listening to L.'s presentation suggested that she was in a state of *continuous partial attention.* In other instances, M. tried to balance her efforts across the two demands, listening to the presentation of her colleague and coordinating her group presentation with her team members on line over MSN. At least four social worlds are visible here: the one of co-located participants; the AEC course visible through the public virtual space (video screens); the Central team visible through L.'s participation and M.'s team visible through her chatting with team members over MSN. They all share one locale, which is the public space mediated by multimodal technology (VSee), but in this public space private sub locales arise, like the one emerging from the relationship between M. and her team mates, their interaction needs (discussing their team work) and the site (shared public space) and means (MSN) used to meet those needs. During this episode, there was also a shift of attention between the co-present students at Chalmers and the locale at Stanford from which information was expected to come through as industry mentors coached. M. and L. gazes moved between each other and objects (e.g., the between the laptop and the projected image on the wall), and back again, changing the focus of attention as the salience of something changed. According to Stone, continuous partial attention differs from multitasking: in the former, people are in a situation of constant connectivity and pay partial attention continuously to remain a node in the network; in the latter, people want to use their time more efficiently and productively and give the same priority to what they do.

Our findings suggest that continuous partial attention and multitasking intertwine. Indeed, almost all the instances we examined for this study show that the participants switched their attention continuously and acted in relation to what they considered most urgent or more appealing at any given moment during the project reviews. They felt the need to be connected almost all the time – except for those episodes in which they engaged in informal conversation with one another – but they also felt that they had to deal with multiple tasks simultaneously to balance their achievement in the course with other school responsibilities. A hypothesis emerging from the examined extracts of the recall interviews with the participants is that there seems to be a potential relationship between continuous partial attention, multitasking, the requirements of the course, the short time frame to complete the team project and the demands from external work. Data suggests that the multiple demands of the course, including learning to use a range of new tools, keeping track of a variety of information and knowledge sources, and staying on top of things at the same time, are conditions for the students to engage in continuous partial attention. Such a relationship in turn seems to influence engagement during the session.

All students in the AEC Global Teamwork course are members of four social worlds: (1) their local cohort of students attending different courses, (2) collocated local students who participate in the project review sessions, (3) professional communities, i.e., architects, structural engineers, construction managers who participate in the course, in each team, and (4) their specific architecture-engineering-construction student team. Each social world constrains the student and impinges on the student's view of priorities and time management, since they do not live in each world sequentially and exclusively but simultaneously. The four social worlds interact to shape their view of time management and levels of engagement. The following instance shows how M. was immersed in two of the social worlds (AEC course and her team), the two which were mediated by technology (the third world being the physical and co-located):

M. chatted with another team member. The text of the chat is not readable but seems to be course-related. Multiple windows were displayed by her laptop: she kept the presentation area visible while chatting. Her gaze was focused on her laptop screen

These worlds are *attentional worlds* (Lemke, in press), in the sense that she attended to what happened in them, sights, sounds, meanings of those worlds. She attended the two worlds simultaneously, or at least she tried to move rapidly between them. In the above instance, the seamless and fluid transitions between the two different social world activities were supported by the minimal effort needed to move a cursor or to enter a new command. Technology-mediation offers different kinds of option for communication and collaboration to support different *degrees of commitment and responsibility* from the participants. The nature of informational resources required by participants who share the contributions and responsibilities for taking up each other's actions (active presenters) is different from that required by "overhearers" or observers (as M., in the described instance) and seems to be associated to what participants view as their *main focus*, or *perspective* on the social world locale. M.'s involvement was about two social worlds and she kept those worlds and related tools on her ICT interface. *The degree of focus and attention* she gave to her interaction in a given social world context (the presentation or the chat) is indicated by the prominence of the corresponding windows/activities at the interface e.g., open, iconified, in the foreground or background, large or small, etc. In the complex environment of the AEC course, the ICT *affordances* offer participants *choices* as to how they want to take up these affordances and what modes of engaging with multiple attentional worlds during the session they prefer (Lemke, in press). A choice can be continuous partial attention to be able to act constantly as a member of different worlds, to remain connected to all of them at the same time, by cycling rapidly between them. Another choice is using technology to multitasking to deal with personal and organizational constraints. Continuous partial attention and multitasking were typical behaviors of students who where observers. Following are excerpt examples from a MSN conversation between two team members. Team member Y is at Stanford, team member X is at University of Wisconsin Madison. In the first excerpt X and Y discuss some of their project issues and also pay attention to the project review discussions. They observe and comment about the status of the River team who went over the allocated 10min time slot.

Y says: The River team now is already at 12 min.

Y says: I know. But this is so short, and it will certainly be a part of the work session.

X says: yeah its too bad for them

X says: ok lets c

Y says: Just an initial thought based on what I am observing now.

X says: we have a long time to go... lets decide this by 1pm or so

In the next excerpt X and Y relate some of the questions raised by the mentors regarding students' cost estimates for the construction to their own project cost estimates and challenges.

X says: coming to the kind of questions being raised by the mentors

X says: 6.8 Million for 30000 sq ft

Y says: We knew our estimates were low, but we also didn't put that on our slides.

Y says: They did.

Y says:But that doesn't mean they won't ask. And we can tell them our initial estimate and how we know willincrease as the level of detailin the estimate increases.

In the mean time a third team member Z at Stanford takes notes pertinent to their project, as illustrated in the following excerpt from Z's word document:

"Auditorium: fix seating-> 60psf; Green roof 6in-1foot of soil for shallow plants, 2-3 feet for others (250lb roof, DL should be 150lb) soil damps roof activities; Code require 7'6" min height for ceiling (some system for acoustic); Be careful about sloping down to entry (rainstorm)

Elevator must reach basement for ADA, Possibly group all ductworks to ventilate area together…"

The continuous partial attention and multitasking activities enable the observer students to take notes, discuss observations related to other team performance, and relate the project review issues to their project. These are strong indicators that they are fully engaged in their teams and try to learn as much as possible from the other teams' reviews.

We compared the (1) ICT workspaces, i.e., PBL Lab at Stanford and Chalmers University, and (2) the size of the groups, i.e., large group at PBL Lab at Stanford and small group at Chalmers. We observed interesting differences in access to and transition between public and private digital workspaces. The PBL Lab at Stanford offered (1) a public shared workspace composed of a SmartBoard, and two project screens used for streaming the concurrent videos of all sites (for visibility), and (2) private workspaces for each student in the form of tablet PCs. Consequently, each student used the tablet PC for continuous partial attention, multitasking, observations, or be disengaged, e.g., to chat on line with remote team members, take notes as they listen and identify ideas and input they can use in their project, browse the Web, read email, etc. In parallel with these private activities, participants were engaged in the global discourse of the project review using the SmartBoard, and the two project screens. The students at Chalmers used and shared their three tablet PCs for both public and private activities. Consequently, the private activities were in fact semi-private, as the three devices were shared among them. This was possible because of the strong collocated social bond between the three Chalmers participants.

4 CONCLUSIONS

This paper examines AEC Global Teamwork course as a scalable working model for cross-disciplinary global teamwork education. More specifically we discuss the following dimensions: (1) a growing global learning network, (2) expanding the cross-disciplinary engagement, e.g., integration of sustainability, public private partnership, life cycle and financial management concepts and requirements into the AEC learning experience, (3) evolving ICT EcoSystem, and (4) social worlds students distribute their attention. Through this study we defined a spectrum of degrees of engagement, commitment, and responsibility that includes the following states: *engagement, reflection, continuous partial attention, multitasking, observing,* and *disengagement*. These are mediated by the interplay between ICT virtual and physical spaces and the different social worlds the participants are part of.

ACKNOWLEDGEMENT

This study was partially funded by the Wallenberg Global Learning Network. Dr. Fruchter thanks all the past and present partner universities and corporations, AEC course alumni, and most importantly all the AEC student generations.

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