Proceedings of the International Conference on
Computing in Civil and Building Engineering
W Tizani (Editor)

From learning to space

R. Fruchter
PBL Lab, Department of Civil and Environmental Engineering, Stanford University, USA

Abstract

"We shape our buildings and afterwards, our buildings shape us." (Winston Churchill) This paper focuses on the relation between space and learning vs. space and teaching. A key challenge faced by education organizations is to find a balance between teaching and learning to ensure knowledge acquisition and transfer to students. This can be achieved by offering engaging learning experiences, and providing students with learning spaces and ICT (information and collaboration technologies) that foster participatory problem solving, creativity, collaboration, and socialization. This requires understanding the relation between and impacts of (1) learning spaces, (2) activity and content that is created and shared, and (3) behavioral, social, and cognitive aspects of learning and teamwork. The paper discusses key features of learning spaces that start to address the generation of students that is "born digital" and hyperconnected, that uses space and ICT as transformative elements. The paper presents enablers, hindrances, and requirements for physical, virtual, and social learning and teamwork environments. The brick & bits & interaction (BBI) methodology developed in the PBL Lab was used to analyze the relationship between space, ICT, and learning experience, respectively. The study identifies key learning and teamwork space factors that facilitate dynamic participation of all members, i.e., students, instructors, and mentors, in the knowledge transfer and learning activity. The paper uses concrete examples of learning spaces from the Y2E2 building, PBL Lab and iRoom (interactive room) in the Department of Civil and Environmental Engineering to demonstrate some of these factors.

Keywords: learning, interaction experience, teamwork, ICT, physical, virtual, social spaces

1 Introduction

"We shape our buildings and afterwards, our buildings shape us." (Winston Churchill)
A key challenge faced by education organizations is to find a balance between teaching and learning to ensure knowledge transfer to students. This can be achieved by offering engaging learning experiences, and providing students with learning spaces and ICT (information and collaboration technologies) that foster creativity, collaboration, and socialization. It requires understanding the relation between and impacts of (1) learning spaces, (2) activity and content that is created and shared, and (3) behavioural, social, and cognitive aspects of learning and teamwork.

This paper focuses on the relation between space and learning vs. space and teaching. Looking in the rear mirror, typical spaces in education organizations are shaped to address the teaching needs of the industrial age focused on production line efficiency. Traditional classrooms with rows of desk and a blackboard/whiteboard supporting the “Sage on stage” model of instruction. Academic institution buildings optimized to deliver content based on the industrial age production line focused on efficiency, i.e., efficient scheduling of facility spaces, optimization of course schedule and time of instructors. Newer academic facilities offer a mix of industrial age and information age instruction spaces that have digital displays during the teaching lecture, and computer clusters. Nevertheless, these too are optimized to efficiently schedule and streamline the use of spaces, instructor time, and flow of students through the facilities. These spaces afford very little interaction, engagement, and participation in the knowledge creation and transfer. They are typically large teaching spaces designed for a broadcast interaction mode to deliver content with fixed furniture and ICT configurations. These spaces are often under-utilized when instructors organize breakout sessions where groups of students need to interact. In such cases one or two groups would remain in the large teaching space and other student groups would move to adjacent spaces.

The nature of learning and teamwork is changing. It is becoming more collaborative, global, digital, mobile, and interactive in converging physical and virtual environments. This creates new opportunities to design effective knowledge transfer interactions and learning experiences that engage students, instructors, domain experts and mentors, and allow them to express their ideas and knowledge in rich multi-modal and multi-media environments. Examples of participatory design environments, learning experiences, and ICT infrastructure are offered by universities and programs such as Aalborg University in Denmark (http://en.aau.dk/) established in 1974 where the all campus facilities and the curriculum are designed to foster interaction and learning through project based learning and teamwork, Havey Mudd College in California (http://www.hmc.edu/) project based learning Clinic Program established 40 years ago, and product design programs such as the dSchool at Stanford University (http://www.stanford.edu/group/dschool/) and the Aalto Design Factory at the Helsinki University of Technology in Finland (http://www.tkk.fi/en/about_tkk/aalto/design_factory/).

The paper discusses key features of learning spaces that start to address the generation of students that is “born digital” and hyperconnected, that uses space and ICT as transformative elements. The paper presents enablers, hindrances, and requirements for physical, virtual, and social learning and teamwork environments. The paper presents key factors that facilitate dynamic participation of all members, i.e., instructors, students, and mentors, in the knowledge transfer and learning activity. The paper uses concrete examples of learning spaces from the Y2E2 building, PBL Lab, and iRoom in the Department of Civil and Environmental Engineering to illustrate some of these factors.

The objectives of these next generation interactive learning spaces are to:

- Transform the way students, instructors, and mentors express their ideas, concepts, and solutions.
- Foster new and rich interaction experiences.
- Increase engagement and participation.
- Leverage knowledge in context.
- Maximize flexibility, remixing, repurposing of space, content, models, and people.
- Lead to emergent work practices and processes, team work and social dynamics.
- Capitalize on core institutional competences and assets.

2 What we know and where we go

It is through intra-disciplinary and cross-disciplinary interaction that the students become a community of practitioners. Our efforts over the past two decades to develop, implement, and assess innovative learning spaces builds on empirical and ethnographic studies (Fruchter, 2006; Fruchter et al. 2007) and theoretical points of departure that include: learning theory (Dewey, 1958; Greeno, 1998) and distributed cognition (Hutchins, 1995), design theory and methodology (Schon, 1983), knowledge management (Fruchter and Demian, 2002; Nonaka and Takeuchi, 1995), and development and use of interactive workspaces in support of collaborative work (Rosenberg, 2003; Chachere et al. 2003; Fruchter et al. 2007; Coakes et al. 2008).

Central to our discussion is the cognitive perspective that characterizes learning in terms of growth of conceptual understanding and general strategies of thinking and understanding (Dewey, 1928, 1958). In addition, the situative perspective shifts the focus from individual behaviour and cognition to larger systems that include individual agents interacting with each other and with other subsystems in the environment (Greeno, 1998; Goldman and Geeno, 1998). Situative principles characterize learning in terms of more effective participation in practices of inquiry and discourse that include constructing meanings of concepts and uses of skills. 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 brick & bits & interaction (BBI) methodology developed in the PBL Lab was used to analyze the relationship between space, ICT, and learning experience, respectively. It is at the intersection of the design of physical spaces, i.e., bricks; rich digital information and collaboration technology (ICT), i.e., bits, and emergent work practices, process, and new ways people behave in communicative events using the affordances of their physical workspace and ICT, i.e., interaction (Fruchter 2001). If we better understand the relationship between bricks or physical space, bits or virtual space, and interaction or social space, we will be able to: (1) learning spaces that address to the activities performed by mobile learners, (2) develop ICT that support natural communication idioms among learners, instructors, and mentors, and (3) engage them in richer interaction experiences. Any change in one of the three aspects will impact the other two. Consequently, it is critical to take a BBI integrated approach in the analysis of the current state of practice and the creation of future learning environments.

The development and use of these interactive learning spaces aim to achieve: (1) *effectiveness*, i.e., to improve space utilization, maximize space flexibility and repurposing, and increase interaction between students, instructors, and mentors; (2) *engagement*, i.e., participatory design and modelling of the space by instructors and students, alignment of goals and needs of all stakeholders (e.g., facility managers, administrators, ICT service providers, faculty, and students) in order to support diverse activities, participants, and interactions; and (3) *embodiment* of the vision into working space models that support: integration of education and research, fluid transitions from formal to informal learning, teaching, and social activities; collocated, remote and virtual collaboration; as well as experimentation, rapid prototyping, and reinvention of learning spaces.

3 Enablers: working models for next generation interactive learning spaces

3.1 New university building model

Our Civil and Environmental Engineering Department at Stanford University moved into a new building in 2008, the Yang and Yamazaki Energy and Environment (Y2E2) building. It provides a new university building model, thanks to the university vision, participatory design process that engaged faculty and students, and to a responsive project team that included Boora Architects and Arup. The new building not only significantly reduces energy and water consumption, but provides new choices for learning and interaction for students, faculty, mentors, and visitors – from structured formal such as case study classrooms and design studios, to unstructured activities and semi formal and informal interaction spaces, for individual quiet reflection-in-action work and reflection-in-

interaction team work in collocated or geographically distributed settings. Most of these spaces provide wide whiteboard surfaces and interactive touch displays such as SmartBoards, and furniture that can be very quickly reconfigured by the participants (i.e., students, faculty) to support the specific activity at hand. Corridors are not only pathways, but are extended to provide informal space with flexible mobile furniture where students can work, interact, and engage in informal dialogue.

As more project based learning activities are integrated in the curriculum one type of space that is extensively used almost twenty four times seven during the academic year, are the team spaces. They are organized around the four atria of the building. These spaces are free address spaces used on a first come first served bases by individual students for reflection-in-action or by teams for reflection-in-interaction. They provide semi formal quiet spaces. These spaces have glass walls letting natural light from the atrium pass through but more importantly, making the activity inside visible and transparent. This in turn allows for serendipitous engagement of peers or faculty passing by and often contributing input to the tasks at hand, e.g., problem solving, brainstorming, modelling, etc. increasing the level of participation and engagement. Figure 1 provides instances of such spaces in use.

Figure 1. Instances of informal learning spaces for teamwork activities

3.2 On demand transformer learning spaces

One of the most innovative interactive rooms in the Y2E2 building is the next generation iRoom. It is designed as a space that can be transformed on demand to support both intra-disciplinary (Schon, 1983) and cross-disciplinary (Fruchter, 2006) activities that are collocated or geographically distributed. Its flexible design in terms of furniture, i.e., chairs and tables that can be quickly and easily stacked, folded, and rolled around by students and instructors, folding acoustic partition wall, and most importantly, twenty one fixed and mobile SmartBoards large touch displays (Figure 2).

The AEC Global Teamwork course (Fruchter, 2006) is used to illustrate some transformation instances and use case scenarios of this specific iRoom. Figure 2a shows the central space of the iRoom configured to support concurrent parallel teams using the SmartBoards for brainstorming, exploration, problem solving. Figure 2b shows the central space of the iRoom divided by the flexible acoustic wall, where on one side a intra-disciplinary global interaction session is in progress. The central iRoom space is surrounded by four breakout mini iRoom each having three SmartBoards to allow each of the AEC disciplines to display their models and information in parallel.

Teamwork, specifically cross-disciplinary learning, is key to the design of the AEC Global Teamwork course. Students engage with team members to determine the role of discipline-specific knowledge in a cross-disciplinary project-centered environment, as well as to exercise newly acquired theoretical knowledge. Since the AEC teams are composed of students from different disciplines, each student acts as a professional in the sense that Goodwin (1994) uses it. Being professionals in different fields, each student brings a different professional perspective to bear on the design of a building. This is revealed in how they represent and shape the design of their building (Goodwin, 1994). Consequently, physical and virtual spaces support the cross-disciplinary teamwork by allowing the display of content in context, i.e., visualization, exploration, comparison, and decision making through concurrent display of the discipline models, data, and simulations. (Figure 2 c). Schön (1983) proposes the concept of the reflective practitioner paradigm of design. He defines the process of tackling unique design problems as knowing-in-action. When knowing-in-action breaks down, the designer consciously transitions to reflection activities, called reflection-in-action. This concept was expanded into a reflection-in-interaction framework to formalize the collaborative team process (Fruchter et al, 2007).

Theories of intra-disciplinary (Schon, 1983; Hutchins, 1995; Goodwin, 1994) and cross-disciplinary (Fruchter, 2006) activities inform the design of the next generation learning spaces and interaction experiences (Fruchter, 2007a). Reflection-in-action and reflection-in-interaction represent steps in the "knowledge life cycle" that includes "creation, capture, indexing, storing, finding, understanding, and re-using knowledge" in the physical and virtual space. (Fruchter and Demian, 2002; Fruchter et al., 2007a). Knowledge that is created through dialogue among practitioners, or between mentors and learners represents instances of what Nonaka's knowledge creation cycle defines through four steps "socialization and externalization of tacit knowledge; and combination and internalization of explicit knowledge" (Nonaka and Takeuchi, 1995). These multi-modal and multimedia communicative events are in part captured to be shared and re-used by the students.

(a) (b) (c)

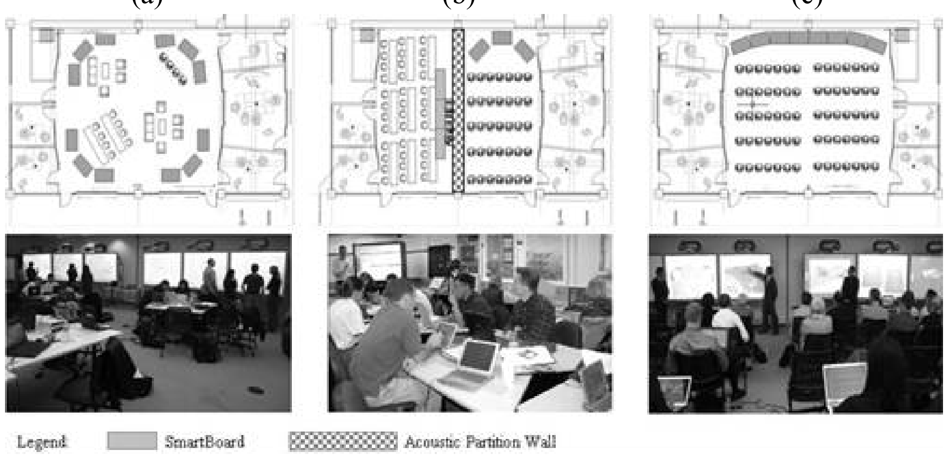

Figure 2. Floor plan configurations and instances of the iRoom as an "on demand transformer learning space:" (a) central space configured for parallel teams at work using the SmartBoards, (b) central space divided into two spaces by flexible mobile acoustic wall, (c) central room configured for multi-disciplinary concurrent AEC project presentation displaying on each SmartBoard a different discipline building model or simulation data. Adjacent to the central space there are four mini iRooms each with three SmartBoards for collocated team breakout sessions and cyber project teamwork.

4 Hindrances and future development of interactive learning spaces

The following hindrances of the learning space use in the new Y2E2 building are identified based on the observations over the past two years. These hindrances can become opportunities to design the future learning physical and virtual spaces and the corresponding interaction experiences.

Students collect, create, and display various digital models on their laptops or on SmartBoards, write information on whiteboards, print documents and sketch on paper, and build physical at different stages of their project or home work. Consequently, the content displayed does not represent the complete set of information resources available at different stages of the project. Large flexible surface that would enable the display of mixing media and would provide diverse display surfaces, e.g., board to pin up printed material, interactive touch displays, and HDTV for multimedia content e.g., videos and 3D CAD models, could provide a richer interaction and exploration experience.

All the interactive learning spaces are used for limited periods of time, typically hours. They are not dedicated project team spaces. All the displayed content needs to be saved, folded, and stored until the next task or interaction activity. This creates only a temporal persistence of the content during the session. The material is no longer visible and available to all participants, and more importantly it looses the contextual organization in which it was displayed and discussed. In addition, the evolution of the content in context is not captured. Consequently, it is hard to share and re-use the complete data, information and knowledge set in its original context it was created.

5 Conclusions

Based on these observations and findings we identified bricks-bits-interaction key criteria to be considered in the design of next generation physical, virtual and social spaces. These include:

- *Bricks*: proximity to the knowledge and social network; tangible shared public display surfaces, visibility and access to peers, instructors, and mentors in the knowledge and social network; visibility of people's local conditions; transparency of activity; and choice of diverse spaces to support different learning activities and interaction experiences.
- *Bits*: connectivity through small, medium, and large devices (e.g., smart phones, laptops, tablet pc, SmartBoard, HDTV) in a mobile knowledge environment that is supported by a reliable, robust, accessible, affordable, and available ICT infrastructure anywhere, anytime. ICT that supports:
  - Mixed media display and content creation, sharing, and reuse in globally distributed teams.
  - Capture, sharing, and retrieval of project evolution history.
  - Visibility of people, activities, and content.
  - Diverse choices of multi-modal and multimedia communication channels.
- *Interaction*: social interaction spaces and places integrated in both physical and virtual spaces that allow self-representation; visibility of roles and activities; formal and informal interaction experiences; serendipitous encounters, and emergent learning and work practices and processes.

References

CHACHERE, J., KUNZ, J. and LEVITT, R., 2003. Can you accelerate your project using extreme collaboration? A model based analysis", CIFE Report TR154, http://cife.stanford.edu

COAKES, E., COAKES, J. and ROSENBERG, D., 2008. Co-operative work practices and knowledge sharing issues: a comparison of viewpoints". *International Journal of Information Management*, 28 (1), 12-25.

DEWEY, J. 1928, 1958. Experience and nature. New York: Dover

FRUCHTER, R. 2001. Bricks & Bits & Interaction, in "Exploring New Frontiers on Artificial Intelligence," Eds. T. Terano, T. Nishida, A. Namatame, Y. Ohsawa, S. Tsumoto, and T. Washio, *LNAI 2253*, Springer Verlag.

FRUCHTER, R. and DEMIAN, P. 2002. CoMem: Designing an Interaction Experience for Reuse of Rich Contextual Information from a Corporate Memory, *AIEDAM International Journal*, 16, 127-147.

FRUCHTER, R. 2006. The Fishbowl: Degrees of Engagement in Global Teamwork*, LNAI*, Springer Verlag, 241-257.

FRUCHTER, R., SWAMINATHAN, S., BORAIAH, M. and UPADHYAY, C. 2007. Reflection-in-Interaction, *AI&Society Journal*, Vol. 22 nr. 2 November 2007, 211-226.

FRUCHTER, R., SAXENA, K., BREIDENTHAL, M., and DEMIAN, P., 2007a. Collaborative Exploration in an Interactive Workspace. *AIEDAM International Journal*, 21 (3), 279-293

GOLDMAN, S. and GREENO, J. G. 1998. Thinking practices: images of thinking and learning in education. In, Goldman, S. and Greeno, J. G. (eds.) *Thinking practices in mathematics and science learning*. Lawrence Erlbaum, NJ. 1-13

GREENO, J.G., 1998, The Situativity of Learning, Knowing, and Research, *American Psychologist*, 53, 5-26.

HUTCHINS, E. (1995), How a cockpit remembers its speeds. *Cognitive Science Journal* 19, 3, 265-288.

LAVE, J. and WENGER, E. 1991. Situated learning: legitimate peripheral participation. Cambridge University Press.

NONAKA. I. and TAKEUCHI, H. 1995. The Knowledge-Creating Company, Oxford University Press.

SCHON, D. A. 1983. How Professionals Think in Action. Basic Books.

ROSENBERG, D., 2005. Complex Information Environments: Issues in Knowledge Management and Organizational Learning. In: Y Merali & D J Snowden, eds. sComplexity and Knowledge Management, *Emergence*, 2 (4), 136-150.