

FRAMEWORK FOR A CROSS-BORDER TRANSDISCIPLINARY DESIGN STUDIO EDUCATION

Rahinah Ibrahim, Renate Fruchter, and Roslina Sharif

Abstract

This paper presents a conceptual framework for an architectural-construction integration (A-CI) design studio curriculum in the context of an architectural graduate program. It aims to apply trans-disciplinary principals to educate competent graduates in sustainable global design-build practice. The A-CI curriculum emulates the computer-integrated Project Based Learning Laboratory (PBL) model developed at Stanford University by building on the PBL's framework, and principles of learning and teaching professional, cultural, technological, and spatial differences amongst the building stakeholders. We extend it to include a project's financial and regulatory decision-making process along the planning and architectural design processes at the earlier project development life-cycle phases. The paper will first present the literature review on trans-disciplinary learning, followed by a description on the framework and principles of the PBL model before proposing how we extend the PBL model to integrate the early architectural design phase. The proposed program's framework covers a four-semester curriculum at graduate level during which, students from participating universities in developing countries have the opportunity to participate in a global building project with students from participating universities in developed countries. An additional benefit of this curriculum is that it would allow students from both developing and developed countries to

experience cross-border trans-disciplinary learning and teaching.

Keywords

Architectural Curriculum, Trans-disciplinary Learning, Project Based Learning, Sustainable Architecture, Integrated Design Management.

Introduction

Despite emerging processes and high performance team skills that develop as a result of efficient and effective use of advanced IT solutions, knowledge still gets missing in the complex design and development processes for building projects (Ibrahim & Paulson, 2005). Although the building industry claims to have standardized its process of delivery products, Reed and Gordon (2000) argue that these delivery processes are still limited to concerns regarding structural safety and temperature controlled shelter — i.e. very “engineering” requirements. They highlighted the ignorance about the other sustainable components, such as socio-cultural and economic sustainability of the community where the building will be

located. Ibrahim and Paulson (2005) also recommend a broader understanding of the building process that includes the early planning and conceptual phase. However, this phase requires multiple disciplinary inputs such as planning, engineering, financing, architectural, etc. All the abovementioned scholars are calling for an integrated design and building process very early in the design process in order to achieve the successful integration of all social, environmental, and economic aspects for sustainable development.

In supporting multi-disciplinary collaborations, advanced technologies are recognized as the main source of creating and improving the competitive advantages of a firm, where automation and robotics are recognized as critical solutions to reducing cost, and to improving construction productivity (Ping Ho & Liang, 2003). With many developing countries already feeling the impacts of globalization, there is an increasing need for the utilization of computer-integrated design and construction processes by a project team to become competitive locally and internationally (MBAM, 2004). The added skills and technologies will allow construction stakeholders to at least partner, if not participate, in global projects with their foreign counterparts. On the other hand, a typical global project team usually consists of several design professionals and builders who come from different cultures, cross several time zones, and are exposed to different technological skills. More importantly, the project team member must have the tacit knowledge about the structure of important phases of the process that contain different levels of design thinking: conception, function and practical knowledge as well as

the transitions from inception to construction (Öztürk & Türkkan, 2006).

Successful design and building integration requires trans-disciplinary inputs very early during the design process (Nicolescu, 1996; Rowe, 2002). Each discipline must provide sound professional input, while being capable of accommodating the requirements of other disciplines (Rowe, 2002). Architecture students at present would obtain their architectural competencies through lectures and course works from their respective university programs. However, most graduates will acquire the leadership and teaching skills through real-life experiences only. Therefore, many architectural bodies worldwide require architecture graduates to acquire several years of compulsory postgraduate professional working experience before qualifying to sit for their professional examinations. Given the above scenario, it is not possible for students to participate in global projects immediately upon graduation hence, straining the supply of “experienced” professionals in supporting developments in hot developing countries. We foresee and support the need to include real-life experiences through a well-developed curriculum at the university level. We would like to propose a curriculum that 1) embraces ICT, 2) allows trans-disciplinary learning, and most importantly 3) brings forward the real-life global experience into a safe classroom setting.

Trans-disciplinary architectural education embraces the concern between disciplines, across the different disciplines, and beyond all discipline. Its goal is to understand the present built environment, of which one of the imperatives is the unity of knowledge from

design, engineering, financing, socio-cultural, etc. We found the Project Based Learning (PBL) Laboratory at Stanford University (Stanford) very close to implementing trans-disciplinary learning. It focuses the students' learning around a specific scenario or trigger, rather than upon the curriculum content itself (Roberts, 2004; Douvrou, 2006). We explain the key components of PBL in the third section of this paper. PBL's mission is to prepare the next generation of architecture/engineering/construction (AEC) professionals who know how to team up with professionals from other disciplines worldwide and leverage the advantages of innovative collaboration technologies to produce higher quality products, faster, more economical, and environmentally friendly (Fruchter, 1999; Fruchter, et al., 2003).

The proposed Architectural-Construction Integration (A-CI) curriculum emulates the computer-integrated Project Based Learning Laboratory (PBL) model developed at Stanford University, but focuses on the early design phase of a project's design development process. The A-CI curriculum builds on the PBL's framework and principles, extending it to include the project's financial and regulatory decision-making process along the planning and architectural design processes. The proposed extended model shares PBL's advantages and cost-effectiveness of working collaboratively in a cross-disciplinary environment. The A-CI model will initially build bridges across disciplines by addressing different stakeholders' issues in earlier development life-cycle phases. The paper will first present the literature review, followed by a description on the framework and principles of the PBL model before proposing how we extend the PBL model to integrate the

early architectural design phase.

Background Literature Review

In the following section, we present some literature on trans-disciplinary education and explain how it can support the education of building professionals in understanding the complex facility development processes.

1. *Trans-disciplinary Education*

Adapting from Bruder (1994), we propose that *trans-disciplinary* architectural education should embrace the concern between disciplines, across the different disciplines, and beyond all discipline. Bruder (1994) states that its goal is to understand the present built environment, of which one of the imperatives is the unity of knowledge from design, engineering, financing, socio-cultural, etc. The *trans-disciplinary approach* is a framework for allowing members of an educational team to contribute knowledge and skills, collaborate with other members, and collectively determine the services that most would benefit a student (Bruder, 1994).

As opposed to *interdisciplinary* — the additive use of knowledge from several disciplines to confront a problem or to form a new understanding—Bruder (1994) explains that *trans-disciplinary* is a meta level above interdisciplinary and is best described as a way to find the patterns and the differences that make a difference by taking the epistemologies from each discipline to drive inquiry. For better understanding the term *trans-discipline*, Nicolescu (1996 in Seaton, 2002) explains the differences between *disciplinary*, *multidisciplinary*, *interdisciplinary*, and *trans-*

disciplinary. Figure 1 illustrates the differences, where:

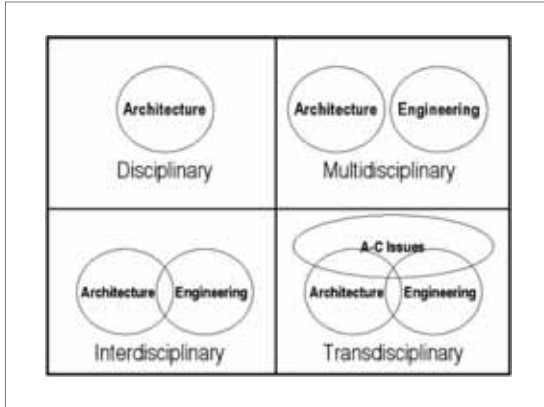


Figure 1: The difference between disciplinary, multidisciplinary, interdisciplinary, and trans-disciplinary (Adapted from Seaton, 2002).

- i) *Disciplinary*: Epistemologies, assumptions, knowledge, skills, and methods are within the boundary of a discipline; i.e. Architecture or Engineering.
- ii) *Multidisciplinary*: Using the knowledge understanding of more than one discipline; i.e. Architecture and Engineering.
- iii) *Interdisciplinary*: Using the epistemologies methods of one discipline within another, i.e., Architectural Engineering. One can distinguish the three degrees of interdisciplinarity by:
 - a) *A degree of application*. For example, the arch to support building loads is used as a decorative entrance into a building.
 - b) *An epistemological degree*. For example, electrical knowledge versus mechanical knowledge can both support thermal comfort.

- c) *A degree of the generation of new disciplines*. Natural ventilation can be incorporated with spatial planning thereby, creating a field called indoor air quality.
- iv) *Trans-disciplinary*: Focuses on an issue, such as 'sustainability' or 'conservation,' both within and beyond discipline boundaries with the possibility of new perspectives. For example, financing is not taught in detail in architecture schools, but does impact the sustainability of a facility project after its completion.

Seaton (2002) additionally outlined several trans-disciplinary learning methodologies for inquiry. First, trans-disciplinary investigations involve students in using more than one discipline in solving significant real world questions or problems. In doing so, students increase their capacity to make connections in their learning across the curriculum and between disciplines. For example, architecture students learn about their professional practice while observing the structural engineer having difficulties trying to fulfill the design objectives in a complex building design. Secondly, trans-disciplinary learning is engaging for students because it supports their involvement in tasks that are worthwhile, significant and meaningful such as those undertaken by successful adults. A close to real-life project can support the global experience one can obtain during postgraduate working. However, while a significant part of learning will be trans-disciplinary, there will still be a need for dedicated teaching of some aspects of disciplines. This requires architecture students to learn about construction methodologies while they work on their architectural design. Finally, trans-disciplinary inquiry involves multiple disciplines, *and* the space between the disciplines *with* the possibility of new

perspectives 'beyond' those disciplines. One such example is the need to understand the financing requirements during a facility development process. The architect, engineer, and construction managers must understand that developers of affordable housing can apply certain federal grants only twice a year. If they missed the deadline — i.e., due to a delay in the design production — they may have to postpone the whole project for several months or to another year because the project cannot proceed further without a guaranteed funding.

2. Complexity in the Building Development Process

Another factor in trans-disciplinary study is the fact that the property development process is a complex process. A comparison was made by Ibrahim (2005) between three viewpoints — namely the city's, the property developer's, and the architect's — to see whether the three parties match in their definitions of a facility development process. She studied affordable housing developments in the USA. In general, the city is not concerned with whether property developers profit from their development projects. Property developers are concerned more about the financial sustainability of their building projects, while architects are assisting the property developers to design and build their projects. From a property developer's point of view, how the design proposals advance from schematic drawings to construction documents is not its concern as long as it is aware that the architect is coordinating the design and construction documents. The period during which a formal application for a development permit is made until when construction actually commences at the site is called *entitlements*

phase (Ibrahim, 2005). This is because, during this period, property developers are busy lining up their permanent financing in order to close their construction loans. This scenario hints a dual side of the development process prior to the construction phase: the well-known architectural-engineering-construction (AEC) design-construction process versus the property developer's public and financing process. The only period when both processes require one another's continuous interaction is during the entitlements phase. During the entitlements process, architects are the ones preparing or coordinating the bulk of planning and architectural documents for entitlements approval. The documents provide the means for property developers to cost and plan their development schedule. They use these documents to obtain construction and permanent financing.

Based on the organizational behavior theory, the *contingency theory* framework categorizes the property development's life cycle operating *environment* as having the characteristics of high complexity, high uncertainty, and high equivocality (Burton & Obel, 2003). It has high complexity because, despite having a functional organizational configuration, the property development organization also reflects a strong matrix configuration. There are also many interdependencies between workflow processes in a development project. A property development project has high uncertainty because, despite having a general sequential development activity schedule, each project is unique. Project managers cannot accurately predetermine which workflow path they need to concentrate on at any given time. The operating environment has

high equivocality, because there exist multiple and conflicting interpretations, confusion, and lack of understanding among the stakeholders. These are apparent especially when dealing with regulatory agencies, city officials, and the public. The intricate environmental characteristics point to the need for research on how we can ensure the transfer of decisions and information (i.e. knowledge that enables the enterprise to act) from one team to another efficiently while the process progresses, and while property developers maintain their feasibility.

3. Trans-disciplinary Learning of the Complex Property Development Process

At the meta-level, the complex property development process is about the ability of a property developer in delivering a project that is financially sustainable, yet fulfilling the socio-cultural requirements of the community it is located at, and yet sustainable to the natural resources. Most architectural education simply puts a limit to the maximum amount a project should cost, but lacks experiential emphasis on why it has to be so. Using trans-disciplinary inquiry principals, students learn the sources of financial, social, and regulatory constraints that would influence the end product of their design studio problem. In this context, for instance, architecture as well as engineering and their underlying ethics have to be based on rather different principles than during the past. Problems are no longer solved or met with a purely “technical” or become a mere “architectural” resolution. They are interconnected as they have always been, and definitely require a trans-disciplinary approach including landscaping, social as well as political

parameters. For example, a living room exudes the cultural needs of hosting guests in a house, but utilizes day lighting for energy saving. In other words, a viable education can only mean integral education about the human being. Trans-disciplinary education has its origins in the inexhaustible richness of the scientific spirit, which is based on questioning, as well as on the rejection of all *a priori* answers and certitude contradictory to the facts (Bruder, 1994). At the same time, it revalues the role of deeply rooted intuition, of imagination, of sensitivity, and of the body in the transmission of knowledge (Ibid.). We concur that this is one way the society of the twenty-first century can reconcile effectiveness and affectivity.

The PBL Model

Problem Based Learning (PBL) is a term used within education for a range of pedagogic approaches that encourage students to learn through the structured exploration of a research problem (Mills, 2006). It is a term describing techniques that make students take an active, task-oriented, and self-directed approach to their own learning (ibid; Roberts, 2004). This section describes the fundamental principals of the PBL model at Stanford University (Fruchter, 1999; Fruchter, 2002). It explains how close we can apply the four pillars of trans-disciplinary learning in the PBL model. The four pillars are: learning to know, learning to do, learning to live together with, and learning to be (Nicolescu, 1996).

1. The PBL AEC Global Teamwork Test Bed

The Architecture / Engineering / Construction (AEC) Global Teamwork course is a two-

quarter class established in 1993 at Stanford University that engages architecture, structural engineering, and construction management students from universities worldwide. Every year there are between 4 to 12 AEC teams in the class, and all the teams are affiliated with universities in developed countries. Each AEC team is geographically distributed, and has an owner/client with a building program, a location, a budget, and a time line. Currently, participating universities are based on developed nations. Consequently, each student has four challenges — i.e. cross-disciplinary teamwork, use of advanced collaboration technology, time management and team coordination, and multi-cultural collaboration.

2. The Evolving PBL Global Teamwork Ecosystem

Fruchter (2003) recommends minimal infrastructure to support the PBL. We agree that participating universities from both developing and developed countries would need to provide the following infrastructure for trans-disciplinary learning that includes:

- (1) *Network Infrastructure*, including LAN/WAN, Internet2 and the wireless zones.
- (2) *Devices*, including diverse interactive wireless and wired devices to enable mobile learners to stay connected with their peers. They range from PDAs and pen-based laptops (Tablet PCs) for mobility, Web cameras, SmartBoards, to the iRoom (Johanson, Fox, and Winograd, 2002) for collaborative synchronous review and decision support.
- (3) *Collaboration Applications*, which address the need for synchronous and asynchronous communication, interaction and feedback, direct manipulation, knowledge capture, sharing, re-use, and data collection and analysis.
- (4) *Places*. PBL learners work at various private, public, local and global learning and work places. Such places range from home (private), office (local), meeting rooms (regional), and networked learning hubs (global).
- (5) *People*. The global teamwork engages students, faculty, and industry mentors from architecture, structural engineering, and construction management.

3. Innovative Learning and Teamwork Experiences

The AEC Global Teamwork learning to know by doing and 'living' together experiences are both structured (i.e. AEC round table discussions about product, process and role of each profession, signature building project case studies, project review sessions, project crits, project presentations) and unstructured (i.e. team meetings, students informally meeting with industry mentors, individual brainstorming, asynchronous discussion of ideas and solutions). Several cutting edge technologies were developed to support such collaboration such as RECALL (Fruchter and Yen, 2000), ThinkTank (Fruchter, et. al, 2003), and CoMem (Corporate Memory) (Fruchter and Demian, 2002) into the iRoom environment and mobile devices. Other supporting applications include MS Netmeeting videoconference, Web Group Space for document management, and instant messaging.

4. Mentoring and Reverse Mentoring

Understanding the goals and constraints of other disciplines is key to working well in trans-disciplinary project teams. In the PBL, students learn trans-disciplinary design skills through interacting within their design teams through carefully constructed mentoring relationships. Students learn to know by participating in regular meetings between students and mentors. The meetings are structured to include project reviews, project crits, *Fishbowl* sessions, project presentations, etc. A fishbowl session is a project review session where students watch industry mentors participate in real-life how AEC professionals were to work together on solving a problem (Fruchter & Chao, 2004). The student is at times the center of the activity, supported by mentors, and other times observing the industry mentors at work. The mentors, in turn, learn how to use the technologies they observe the students make new IT practices explicit, and are able to bring these ideas and technologies into their work place (Fruchter and Lewis, 2003).

5. Cross-Disciplinary Assessment

PBL utilizes the cross-disciplinary learning (CDL) assessment, defined as a journey from the state of island of knowledge (discipline-centric) to a state of understanding of the goals, language, and representations of the other disciplines (Fruchter and Emery, 1999). The objective of the AEC Global Teamwork class is for all or majority of the students to position themselves at the center of the learning experience in understanding by the end of the course. More studies will be conducted to use the four trans-disciplinary pillars of learning as the future assessment methodology. The four CDL tiers are:

- (1) *Island of knowledge*: The student masters his/her discipline, but does not have experience in other disciplines.
- (2) *Awareness*: The student is aware of the other discipline's goals and constraints.
- (3) *Appreciation*: The student begins to build a conceptual framework of the other disciplines, is interested to understand and support the other disciplines' goals and concept, and knows what questions to ask.
- (4) *Understanding*: The student begins to build a conceptual understanding of the other disciplines, can negotiate, is proactive in discussion with participants from the other disciplines, provides input before the input is requested, and begins to use the language of other disciplines.

6. Emerging Processes and Skills

Observations through the years have indicated that high-performance teams that use collaboration and communication technologies effectively exhibit the following two behavioral and process changes that Fruchter and Chao (2004) coined as:

- (1) *Collaboration readiness* that entails early and continuous knowledge sharing, responsiveness, and timeliness, and
- (2) *The 3rd Way* that entails establishing a team communication process based on the team's preferences for communication channels, protocols and norms. Any technology choice leads to behavioural, process, and team dynamics changes.

Here, we look forward to observe emerging trans-disciplinary learning experiences in the AC-I design studio.

Extending the PBL Model to Support Early Architectural Design

We plan to extend the PBL model by introducing planning and financing concepts in the schematic conceptual diagramming of a design studio problem. The planning and financing concepts would entail a complete due-diligence feasibility analysis that includes site selection, site analysis, title analysis, governmental requirements study, product design, market analysis, product cost estimation, and financial feasibility analysis (Ibrahim, 2005).

At the conclusion of this analysis, project sponsors decide whether or not they want to proceed to

the next stage, i.e. submitting for development approval (ibid.). In architectural education, the components of the due-diligence analysis are essential to achieve successful integration of building, community, natural and economic systems in a sustainable development project. However, the financial aspects are normally omitted as to not impede the creativity of the design process in budding architecture students. Here, we propose adding these earlier design components into an extended PBL curriculum at a graduate level program to expand the current professional competency requirements in an undergraduate architectural education program (Table 1).

Semester	Development Issue	Project Type	Design Challenge
ONE	Owner's Financing	100 Unit Housing	Preparing a conceptual design and project feasibility report that include financial cash flow projections following the regulatory planning procedure and design phases.
TWO	Builder's Constructibility	100 Unit Housing	Determining the selection of industrialized building system for integration in the design proposal while producing aesthetically pleasing building products that have the ease for delivery.
THREE	Project Team's Knowledge Movements	University Building	Deliberating on design decisions between students from developing nations with their counterparts from developed nations.
FOUR	Sustainability	University Building	Refining financial feasibility and project design through value engineering with the incorporation of selected energy efficiency components into the conceptual design proposal.

Table 1: Sequence of Transdisciplinary Design Studio Curriculum

1. Sequence of Trans-disciplinary Design Studio Curriculum

The extended curriculum embraces sustainable development practices, and is divided into four semesters. The design studio emulates the PBL model. Each design studio has a project based learning component covering the different emphasis of the early facility development concerns that affects the AEC professionals. They are:

- (1) *Semester One:* Students will develop an understanding of the challenges of optimizing financial profit during negotiations with planning authorities. Students will learn how to evaluate different sites for property development, analyze their constraints in terms of regulatory, natural, or manmade constraints. They will learn how to prepare financial cash flow projections that suit the overall development schedule, and experience developing high level project scheduling, costing, and risk analysis tools for decision-making. Among the tools they will be exposed to are MSEXcel®, MSProject® or Primavera®, Timberline®, or SimVision®. The students will learn how to make decisions on whether or not they should proceed with a development project.
- (2) *Semester Two:* Students will develop an understanding of the challenges of construction managers. Students will be exposed to *Modular Coordination* (MC) (Ibrahim and Sumarni, 1999) and *Industrialized Building Systems* (Ibrahim, 1999) concepts in design-build integration processes. Students will learn how to select the best IBS components for integration

in their design proposals, and produce aesthetically pleasing products that have the ease of delivery. Students will present their findings using 3D/4D CAD softwares.

- (3) *Semester Three:* Students will participate in the AEC Global Teamwork PBL class offered and organized by Stanford University in collaboration with other worldwide universities. Details as described in the previous section, and the proposed program introduces interactions between students from developing nations working with their counterparts from developed nations.
- (4) *Semester Four:* Students will develop value-engineering (VE) skills in refining the financial feasibility and design of their projects from Semester Three. Students will conduct VE exercises on at least two selected energy efficiency components in their project. The VE exercises will guide students to refine the previous semester's work through the innovative use of advance materials, processes, recyclable and renewal energy systems, etc.

2. Design Studio Problems

The choice of building typology that will allow optimum exposure to early design issues directs us to propose a 200-unit housing development project as the problem to work on in both Semesters One and Two. A housing development project will expose students to the planning and environmental requirements, i.e. local structure plan, environmental impact assessment, etc. Students will gain experience in negotiating with the local authorities and creating solutions that would support the sustainable needs of the

community and environment where the project is located. In addition, they will be exposed to rigid financial constraints that would influence the final outcome of the development since all project sponsors want optimum profit in all their ventures. In the following second semester, students will utilize industrialized building systems for the delivery of the housing units. The problem will allow students to experience the planning of just-in-time delivery that will coincide with just-in-time financing at the design phase.

On the other hand, the Semesters Three and Four design studios will utilize the same problem that PBL uses, i.e. a 3,000 meter-square educational building project on a chosen site in USA. The American-based problem will allow students to experience working on a global project with global teammates. Although the PBL class concludes in one semester, the extended PBL design studio continues to utilize the outcome of the third semester to further study energy efficiency design in detail. Students will conduct value engineering that emphasizes energy efficiency in their evaluation and guide their product refinement.

3. A-CI Ecosystem and Faculty Requirements

The A-CI program at the architecture school will emulate the PBL ecosystem developed at Stanford. The architectural design studio will offer students an opportunity to engage with students from other disciplines and work together on a studio project. The design studio shall include students with graduate standing from additional disciplines synonymous with the common design professionals involved during the early planning phase of a facility development process. Besides

the main players (i.e. architecture, structural engineering and construction managers), other students shall include planners, quantity surveyors, facility managers, urban designers and landscape architects. In view of the additional disciplines participating in the A-CI program, the number of faculty and industry mentors shall reciprocate as diversified as the students'. Nevertheless, departmental, faculty, and university support to develop the A-CI ecosystem and human resource development to support the A-CI program is critical. Although we can expect technological challenges in cross-border applications, any extent of technological differences between universities from developed vs. developing countries will become a case study by itself.

Conclusions

This paper outlined the components of a framework for an architectural-construction integration (A-CI) design studio curriculum for an architectural graduate program that supports the production of competent graduates in sustainable global design-build practice. The curriculum embraces ICT, allows trans-disciplinary learning, and most importantly brings forward the real-life global experience into a safe classroom setting. This paper proposes to extend the Stanford's PBL model to include several key components of the early feasibility or conceptual design phase — namely financing and planning regulations — towards developing a sustainable facility development project. At the end of the four-semester program, students will understand the non-technical aspects of the complex facility development process, and move from the

island of knowledge state of their discipline to the understanding state of the whole facility development process. The proposed program's framework covers a four-semester curriculum at graduate level during which, students from participating universities in developing countries have the opportunity to participate in a global building project with students from participating universities in developed countries. An additional benefit of this curriculum is that it would allow students from both developing and developed countries to experience cross-border trans-disciplinary learning and teaching.

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References

- Bruder, M. B. (1994). 'Working with Members of Other Disciplines: Collaboration for Success,' In M. Wolery and J.S. Wilbers (eds.), *Including Children with Special Needs in Early Childhood Programs*. National Association for the Education of Young Children, Washington DC, USA, PP. 45 – 70.
- Burton, R. M. & Obel, B. (2003). 'Strategic Organizational Diagnosis and Design: Developing Theory for Application,' Kluwer Academic Publishers, Boston, Mass., USA.
- Douvlu, E. (2006). 'Effective Teaching and Learning: Integrating Problem-Based Learning in the Teaching of Sustainable Design,' *CEBE Transactions*, Vol. 3 (2), PP. 23 – 37.
- Fruchter, R. (1999). 'Architecture/Engineering/Construction Teamwork: A Collaborative Design and Learning Space,' *Journal of Computing in Civil Engineering*, Vol. 13 (4), PP. 261-270.
- Fruchter, R. (2002). 'Global Teamwork: Cross-disciplinary, Collaborative, Geographically Distributed e-Learning Environment,' In J. Bento, J. Duarte, M. Heitor, and W. Mitchell (eds.), *Collaborative Design and Learning: Competence Building for Innovation*, Quorum Books Greenwood Publishing Group, Inc.
- Fruchter, R. & Demian, P. (2002). 'CoMem: Designing an Interaction Experience for Reuse of Rich Contextual Information for a Corporate Memory,' *AIEDAM Journal*, Vol. 16, PP. 127 – 147.
- Fruchter, R. & Emery, K. (1999). 'CDL: Cross-Disciplinary Learning Metrics and Assessment Method,' In *Proceeding of Computer Support for Collaborative Learning Conference*. Stanford University, PP. 357 – 364.
- Fruchter, R. & Lewis, S. (2003). 'Mentoring Models,' *International Journal of Engineering Education (IJEE)*, Vol. 19 (5), PP. 663-671.
- Fruchter, R. & Yen, S. (2000). 'RECALL in Action,' In R. Fruchter and F. Pena-Mora (eds.), In *Proceedings of ASCE ICCCBE-VIII Conference*, Stanford University.
- Fruchter, R., Zitterbart, M., Pehrson, B. & Effelsbert, W. (2003). *Mobile learners in dSpace*, Final Project Report, Wallenberg Global Learning Network, SCIL, Stanford University.
- Fruchter, R. (2005). 'Degrees of Engagement,' *International Journal of AI & Society*, Vol. 19, PP. 8-21.
- Fruchter, R., & Chao, Y.C. (2004). 'AEC Global Teamwork: Emergent Work Processes,' In *Proceedings of ICCCBE-X*. Weimar.
- Fruchter, R. (2003). 'Innovation in Engaging Learning and Global Teamwork Experiences,' In I. Flood (ed.), In *Proceedings of Computing in Civil Engineering Conference in conjunctions with ASCE National Convention*, Nashville, Tennessee, USA.

Johanson, B., Fox, A. and Winograd T. (2002). 'The Interactive Workspaces Project: Experiences with Ubiquitous Computing Rooms,' IEEE Pervasive Computing, Vol. 1 (2), PP. 67-75.

Ibrahim, R. (2005). Discontinuity in organizations: Impact of knowledge flows on organizational performance, PhD. Dissertation, Department of Civil and Environmental Engineering, Stanford University.

Ibrahim, R. and Paulson, B. C. Jr. (2005). Discontinuity in Organizations: How Environmental Characteristics Contribute to the Project's Knowledge Loss phenomenon, CRGP Working Paper, Vol. 12, Stanford University.

Ibrahim, R. (1999). 'Malaysianising the Industrialized Building System: Towards a Cultural Engineered Industrialized Building System,' In Proceedings of the World Engineering Congress and Exhibition, Kuala Lumpur, Malaysia, PP. 49-53.

Ibrahim, R. and Sumarni, I. (1999). 'Modular Coordination: A Design Guide Towards Open Building System in Malaysia,' In Proceeding of the World Engineering Congress and Exhibition, Kuala Lumpur, PP. 19-23.

Master Builders Association Malaysia (MBAM) (2004). 'The Presidents and CEOs Roundtable 2004,' Master Builders Journal, Vol. 3, PP. 34-3.

Öztürk, M. N. and Türkkan, E. E. (2006). 'The Design Studio as Teaching/Learning Medium — A Process-Based Approach,' International Journal of Art & Design Education, Vol. 25 (1), PP. 96-104.

Mills, B. (2006). Problem-Based Learning: The Higher Education Academy, Available online http://www.c-sap.bham.ac.uk/resources/project_reports/ShowOverview.asp?id=4. Accessed on April 15, 2006.

Nicolescu, B. (1996). La Transdisciplinarité: International Congress What university for Tomorrow? Towards a Transdisciplinary Evolution of the University, Available online <http://perso.club-internet.fr/nicol/ciret>. Accessed on December 10, 2005.

Ping Ho, S. and Liang, Y.L. (2003). 'How to Evaluate and Invest in Emerging A/E/C Technologies Under Uncertainty,' ASCE Journal of Construction Engineering and Management, Vol. 129 (1), PP. 16-24.

Reed, W. and Gordon, E. (2000). 'Integrated Design and Building Process: What Research and Methodologies Are Needed,' Building Research and Information, Vol. 28 (5/6), PP. 325-337.

Roberts, A. (2004). 'Problem Based Learning and the Design Studio,' CEBE Transactions, Vol. 1 (2), PP. 1-3.

Rowe, P. (2002). 'Professional Design Education and Practice,' In A. Salama, W. O'Reilly and K. Noschis (eds.), Architectural Education Today: Cross-Cultural Perspectives, Comportements, Lausanne, Switzerland, PP. 25-29.

Seaton, A. (2002). 'Reforming the Hidden Curriculum: The Key Abilities Model and Four Curricular Forms,' Curriculum Perspectives, Vol. 22 (1), PP. 9-15. (Online) <http://www.andrewseaton.com.au/reform.htm>.