Dimensions of Teamwork Education*

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This paper discusses key issues related to the pedagogical approach, the learning and team work culture, the choice and scope of projects, collaboration and information technologies employed, and new metrics and assessment methods that need to be considered in the development and deployment of team-oriented, project-based cross-disciplinary teamwork education programs.

INTRODUCTION

THIS PAPER is about teamwork education at the start of the 21st century and beyond. It presents key dimensions in the development, implementation, and assessment of an Architecture/Engineering/Construction (A/E/C) education program that was launched at Stanford in 93/94 and presents its 6th generation during the academic year 98/99. The course takes a multi-site, cross-disciplinary, project-based, team-oriented approach to learning and mentoring. The following dimensions of teamwork education include PBL, participants, content, projects, information technology, and assessment.

PBL DIMENSIONS

The A/E/C education program is based on a PBL pedagogical approach, where PBL stands for Problem/Project/Product/Process/People-Based Learning. PBL is a methodology of teaching and learning that focuses on *problem* based, *project* organized activities that produce a *product* for a client. PBL is based on re-engineered *processes* that bring *people* from multiple disciplines together.

Project-based learning proposes a teaching and learning approach that focuses on improving and broadening the competence of engineering students to:

- understand the role of theoretical and real-world discipline-specific knowledge in a multi-disciplinary, collaborative, practical project-centered environment;
- recognize the relationship of the engineering enterprise to the social/economic/political context of engineering practice and the key role of this context in engineering decisions, and
- learn how to participate in and lead multi-disciplinary teams to design and build environmentally conscious and high quality facilities faster and more economically.

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The development of PBL builds on cognitive and situative learning theory [1–4] as well as on design theory [5, 6].

PARTICIPANT DIMENSIONS

The A/E/C teamwork in PBL creates a new culture that brings together faculty, practitioners, and students from the different disciplines. Each plays a well-defined role in the program, such as undergraduate students play the role of apprentice, M.Sc. students play the role of journeyman, faculty, and industry practitioners play the role of mentor, coach, or owner. The vision behind developing this learning environment is the master builder's atelier projected into the information age.

The key atom in the A/E/C program is the A/E/C team. Each team has one architect, one structural engineer, one construction manager and one or two apprentices. Each team has an owner with a program, a budget, a time line, and a site. All students have access to a pool of mentors from all three disciplines. Students collect real industry data from the mentors and discuss their ideas and solutions with them. Each team is required to talk with at least two mentors from each discipline. This offers the students an interesting perspective that indicates multiple approaches and solutions for a design problem. The 6th generation of the A/E/C course has been launched in 98/99 as an international pilot that includes universities from US, i.e. Stanford University, UC Berkeley and Georgia Tech; Europe, i.e. Strathclyde University, Glasgow, UK, and Slovenia, Ljubljana, and Japan, i.e. Aoyama Gakuin University. Teams are typically in three or four time zones, e.g. architect at Georgia Tech, structural engineer at Stanford, construction manager in Glasgow, and apprentice at Stanford.

The design of the PBL lab is grounded in cognitive and situative learning theory. The cognitive perspective characterizes learning in terms of growth of conceptual understanding and general strategies of thinking and understanding [1]. The design of the A/E/C PBL—to provide team

interaction with the professor, industry mentors and team owners—provides a structure for modeling and coaching which scaffolds the learning process, both in the design and construction phases, as well as for techniques such as articulating and reflecting on cognitive processes.

The situative perspective shifts the focus of analysis from individual behavior and cognition to larger systems that include individual agents interacting with each other and with other subsystems in the environment [2]. 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. Greeno argues that the situative perspective can subsume the cognitive and behaviorist perspectives by including both conceptual understanding and skill acquisition as valuable aspects of students' participation and their identities as learners and knowers. Teamwork, specifically cross-disciplinary learning, is key to the design of the A/E/C PBL. Students are expected to engage with other team members to determine the role of discipline-specific knowledge in a multi-disciplinary project-centered environment, as well as to 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 sociocultural practices of a larger community. The negotiation of language and culture is equally important to the learning process—through participating in a community of practitioners (A/E/C), the students are learning how to create discourse that requires the constructing meanings of concepts and uses of skills.

CONTENT DIMENSIONS

The goal of the A/E/C education program is to significantly increase the number of students who will understand:

what the three disciplines' role, issues, values, and cultures are;

- how the three disciplines—architectural design, structural design, and construction—impact each other;
- how new information and collaboration technologies support A/E/C teamwork;
- how information technologies impact the individual's and team's behavior and performance.

Traditional courses teach fundamental knowledge and give students problems that they can solve using theory and knowledge, i.e. learning and exercising *know-what* and *know-how*. PBL and pedagogically informed information technologies can guide students to discover disciplinary and interdisciplinary objectives, and thereby to develop

know-why knowledge in a cross-disciplinary context.

In order to achieve these goals the A/E/C program is structured around the following activities:

Role modeling that takes place during discipline lectures, A/E/C round table panel discussions, project case studies. Discipline lectures present basic principles, concepts, and goals in each of the three professions. A/E/C round table panels focus on the role and the value that each discipline brings to a project, the process that links the disciplines together, i.e. what information and knowledge is shared and required across disciplines. Project case studies bring to the class signature projects that have been challenging and innovative in the way they integrate the three disciplines, e.g. Frank O. Gehry's Bilbao project, G. Luth Aspen Music Hall. These real-world projects are dissected from the perspective of all three disciplines as well as analyzed in terms of cross-disciplinary solutions to challenging problems.

Information technology lecture series and *computer laboratory exercises* that introduce cutting edge collaboration tools. The concepts, benefits, limitations, and system architectures of these tools are discussed. During computer laboratory exercises students learn how to use the new collaboration technologies. Students use these collaboration and information technologies to support their global team work.

Project-based teamwork in which student teams are engaged in designing and planning complex and challenging new buildings. Teamwork is the process of reaching a shared understanding of the design and construction domains, the building to be built, the design process itself, and the commitments it entails. The understanding emerges over time as each team member develops an understanding of his/her own part of the project and provides information that allows others to progress. The process involves communication, negotiation, and team learning.

PROJECT DIMENSIONS

The project that is the driver in the A/E/C Teamwork education program is discussed as a function of: project; team formation; and mentoring and coaching.

Project

Teams of A/E/C students are involved in a multi-disciplinary building project in which they model, refine and document the design product and process. The project is based on a real-world building project that has been scoped down to address the academic time frame of two Quarters. The project requires the design, planning, and scheduling of the construction of a classroom

and laboratory facility on a university campus, with 30,000 sq ft program requirements, a lot, a $5.5m budget, a time line, and a specific geographic location (e.g. Oregon, Texas, Florida, etc.). Each geographic location raises different challenges from architectural context constraints, to structural load issues, e.g. earthquake, wind, snow loads, and construction issue, e.g. access to construction site, cost, fabrication, constructibility, etc.

The A/E/C student teams go through two phases:

1. A concept development phase in which the team members explore the problem and solution space and produce four alternative solutions during the first Quarter.
2. A project development phase in which they elaborate the A/E/C details of the most challenging and exciting of the four concept alternatives, during the second Quarter.

The students learn to:

- regroup as the different discipline issues become central problems and impact other disciplines;
- use computer tools that support discipline tasks and collaborative work;
- use videoconferencing and desktop sharing technology to have face-to-face meetings, interact with the teaching team and industry mentors.

The project progresses from conceptual design to a computer model of the building and a final report. As in the real world, the teams have tight deadlines, engage in design reviews, and negotiate modifications. A team's cross-disciplinary understanding evolves over the life of the project. The students start with individual discipline information and knowledge, using each discipline's natural idioms.

As the project progresses a number of events are expected to happen:

- the concepts are transformed into models;
- the models become more detailed;
- discipline models are linked, providing the students with a building systems integration perspective;
- information is reorganized so that it can be shared among the participants.

Typical project examples can be viewed in the project gallery of PBL under http://pbl.stanford.edu

Team formation

Team formation in the A/E/C education program has been a function of team size, member roles, and participant location. The size of the teams is determined by two factors, (1) the three disciplines, and (2) the roles, i.e. journeyman and apprentice. Consequently, each team will have one architect, one structural engineer, one construction management student as journeymen from the MS programs (i.e. 5th year of study outside US), and one or two apprentice students from the BS program (i.e. 2nd or 3rd year of study outside US).

The pedagogical reason behind the decision not to have more students from any of the A/E/C disciplines in a team is to ensure that all students maintain a constant, high engagement in the project and have a well defined responsibility to represent their profession within their team. The geographical location of the team members provides the students with an opportunity to be exposed to a virtual teamwork in a cross-cultural environment, as well as justify the use of information technologies to accomplish the goals of the project.

Mentoring and coaching

The role of the instructor is changing in a PBL learning environment, from the traditional teacher who delivers the course material in class to the *coach*. Industry practitioners play the role of mentors. They become active participants in the teaching process and education of the next generation of practitioners.

INFORMATION TECHNOLOGY (IT) DIMENSIONS

The roles of information technology (IT) as mediator and facilitator for improved communication and cooperation within multidisciplinary teams are determined to support the diverse modes of interaction over time and space.

Time

Throughout the teaching, learning, and building project process, participants transition between synchronous and asynchronous types of interaction:

- Synchronous collaboration occurs in face-to-face meetings. At that time, faculty and practitioners offer lectures and present case studies, and team members define the overall design of the future building and determine the various discipline models. They communicate discipline concepts and assumptions that may have cross-disciplinary impacts.
- Asynchronous collaboration, in which (1) faculty and practitioners provide feedback to students, (2) students go over course material delivered over the Internet or via the World Wide Web, or (3) team members work independently at concurrent or different times on detailing discipline subsystems of their project.

Space

Faculty, practitioners and students get together for lectures, round-table discussions, or project team meetings to review design proposals and decisions. Such face-to-face meetings can take place in a collocated setting, where all members travel to the meeting place, or in a distributed setting, where team members remain in their

offices and use network applications (e.g. group-ware, video conferencing) to share and exchange information and discuss their design decisions.

Knowledge management

Needs of content capture, sharing, exchange, and reuse have to be met. Project team members work on their discipline design solutions. As the design progresses, team members, faculty and industry mentors need to:

- use a shared project workspace to publish shared 3-D graphic building models to identify shared interests, multicriteria semantics of graphic features and share symbolic, multicriteria critiques, explanations from all disciplines, and expert feedback as they work in a synchronous mode;
- use discipline models, exchange design information, and change notifications related to building features in which they expressed a shared interest, as they work in an asynchronous mode.

TYPES OF INTERACTION

Interaction must take place among:

- instructor/students, during presentation or lecture;
- instructor/student, during office or cyber-office hours;
- peer-to-peer, i.e. student/student and instructor/instructor;
- students/instructors/practitioners.

A wide spectrum of Internet-mediated, Web-based, and videoconference environments are provided to support the different types of interactions among learners, instructors and mentors, such as the World Wide Web is used:

- for team building through an on-line call-reply for bids game;
- as a medium to capture, share, and re-use conceptual and final design solutions of the teams asynchronously among students, instructor, mentors.

Two central shared Web work environments were developed to support this objective:

1. *Shared WWW Project Workspace* was created for each A/E/C project team to archive, share, access, and retrieve project information that ranged from sketches, Word documents, Excel spreadsheets, AutoCAD drawings, e-mail notes, and CAD-related change notifications [7, 8].
2. *Team Discussion Forums* are set up for each team to facilitate asynchronous capture, sharing, tracking, and re-use of ideas, issues, and topics raised by students, instructors, or practitioners [9].
3. *Digital Lecture Archive* enables interactive learning, as well as supports the diverse learning

styles and preferences goals of the students anywhere, anytime. Windows Media facilitates live broadcast, capture, and on-demand access to digital lectures, A/E/C panels, and team meetings.
4. *Videoconferencing and application sharing* are available to the students for face-to-face meetings in cyberspace, distant learning lectures, office hours in cyberspace, and final project presentations.

ASSESSMENT DIMENSIONS

Multidisciplinary teamwork in an information age learning environment is posing new assessment challenges. Current studies of university courses in which technology is a key component tend to focus on the technology—specifically, on media selection and media effects. Neither of these issues address the individual learner [10]. In the A/E/C PBL the focus is on determining how to design and conduct an assessment within the perspective of cognitive and situative learning theory. If traditional assessment methods have limited value in evaluating a collaborative, multidisciplinary, geographically distributed team of students, they are equally ineffective in measuring:

- effective participation in practices of inquiry and discourse;
- increase in skill acquisition and conceptual understanding through multidisciplinary collaboration.

The following assessment dimensions have been developed in conjunction with the A/E/C PBL program.

Assessment of cross-disciplinary teamwork learning experience

This proposes a classification of four key dimensions to measure the students' evolution of cross-disciplinary learning during the two Quarters of the A/E/C program. These dimensions are:

- *Islands of knowledge:* the student masters his/her discipline, but does not have experience in other disciplines.
- *Awareness:* the student is aware of other disciplines' goals and constraints.
- *Appreciation:* the student is interested to understand and support the other disciplines' goals and concepts and know what questions to ask.
- *Understanding:* the student can negotiate, is proactive in the discussion with other disciplines, provides input before the input is requested, and begins to use the language of another discipline.

Students respond to a questionnaire in which they are required to place themselves in this classification at the start of the program, at the end of the first Quarter of the program and at the end of the second Quarter of the program. The objective of

any multidisciplinary education program or class is for all or the majority of the students to position themselves at the end of the learning experience in the *understanding* category.

An additional key metric is based on a longitudinal assessment that can track the programmatic changes such a cross-disciplinary education program can lead to. More specifically, a survey poses the following questions: *After this experience, do you plan to take any courses in any of the other disciplines? Which topics?* Preliminary studies of the past five A/E/C generations indicate that a large percentage of the students exercise the option to take classes in the complementary programs after going through the A/E/C program. For instance, architects take construction classes, structural engineers take costing and scheduling classes, and construction management students take structural design classes.

1. *Assessment of student activity in PBL and the A/E/C Team Project.* Students' activity during their A/E/C project-based teamwork is based on the following metrics: discipline solutions, i.e. mapping the problem and solution space; synergy of multidisciplinary solutions, i.e. systems' integration; documentation of product evolution and process; presentation of A/E/C alternatives.

2. *Assessment of value and impact of IT in creating a richer learning experience* includes: (a) the transition period necessary for the users/team to adapt and adopt any IT and change their work habits, the way they interact, share and communicate; (b) exercising IT to reach out and leverage the distributed knowledge and expertise of mentors; (c) the change in social dynamics; and (d) the impact of IT in the evolution from synchronous to asynchronous communication, and from sequential to collaborative teamwork.

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