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Product-Based Learning in an Overseas Study Program: The ME110K Course*

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Experience in a foreign country has long been considered a vital part of a well-rounded education. Engineering students, though, seem to have been considered an exception; many students and educators see such experience as being unnecessary, or an unaffordable luxury, given the large number of subjects that are required in the undergraduate curriculum. Stanford University has made a commitment to making overseas study available to as many students as possible, including those who don't traditionally participate. A prime example of that effort is found in the Spring quarter Stanford Center for Technology and Innovation, a program held at its Kyoto, Japan overseas campus, targeted specifically at students in engineering and science programs. Required courses are made available through videotape, live discussion, and such, with the support of on- and off-site professors and teachers' assistants. Expanding on this, we have begun an overseas design project course, aimed ultimately at fulfilling the ABET capstone design course requirements for upper-level engineering students. In this paper we report briefly on the first iteration of the course, taught in the Spring quarter of 1998 in collaboration with Prof. Itsuo Ohnaka of Osaka University. Students in the course teamed up to work on design projects sponsored by four Japanese companies. Because of this unique setting, it was possible to educate the students about the influence of culture on design, creativity, perception of needs; about conventional and unusual approaches to teamwork; and about often culture-dependant assumptions about what criteria an acceptable solution must possess. Studying design in such a foreign context, we have found, can be an extraordinary, eye-opening experience, enabling students to better see the context of their future work, especially as more and more will take place in a global arena. The course was taught again in the Spring of 2000, and included students from Osaka University in the project teams. As of this writing, preparations are underway to carry it out again in the Spring of 2001 in Kyoto and Berlin overseas campuses, with further enhancements.

INTRODUCTION

IN THIS PAPER, we briefly introduce and discuss product-based learning, an effective approach to education that is becoming more widely studied and applied, as it has been developed and practiced in the Mechanical Engineering Department of Stanford University. We then focus on an engineering design course developed and taught for the first time in the Spring of 1998 in Kyoto, Japan, called ME110K [1]. Participants in the 10-week course were Stanford undergraduates in technical majors, who were studying at the Stanford Japan Center in Kyoto, prior to working as interns in Japan for the summer. The course was conducted with the help of several collaborators from Osaka University and with the support of four Japanese corporate sponsors. In the course, the students were organized into four teams, and each team worked on one of the conceptual design projects proposed by the four sponsors.

PRODUCT-BASED LEARNING

For more than two decades, the Design Division of the Mechanical Engineering Department at Stanford University has offered a 9-month-long design course for Master's-level students called ME210. In it, the students (many of whom have professional engineering experience) form teams and work on real design projects proposed and supported by corporate sponsors. Students benefit by gaining exposure to the challenges of real engineering problems, but in an environment where a teaching and mentoring staff can encourage them to reflect on and learn the most they can from their experience. Sponsors benefit by having a chance to draw on fresh approaches to their engineering problems and to own any inventions that come from the students' work; by making contacts with talented students who may be future employees and faculty who may be future collaborators; and by getting exposure to current research and experimentation in improved design methods.

ME210 exemplifies an approach to education called 'PBL'. This stands for, variously, 'Problem-based Learning', 'Project-Based Learning', or, more appropriately for this course, 'Product-Based Learning'. Traditional courses center the students' learning process around a series of abstract concepts, which are taught in lectures and reinforced by problem sets and exams. This approach is optimized to get the students to

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score well on standardized tests; an oft-forgotten assumption behind this is that high test scores are strongly correlated with real-world knowledge and ability. However, there is relatively little effort made to tie abstract concepts closely together, or to tie them to applications and deeper skills, like understanding of and abstraction from real situations. These latter skills are vital to engineering design practice, and to other professional and intellectual pursuits as well.

PBL, on the other hand, is oriented towards drawing the students through a coherent, extended, concrete set of experiences and projects. It is then up to the mentors and instructors in the course, and to the students themselves, to find places in that concrete experience from which to draw abstract concepts. (Indeed, sometimes the experiences are designed specifically to offer these opportunities for abstraction, though designed experiences risk offering a far-too-limited set of them.) This way, the students learn not only the higher-level, more general concepts, but they also learn the ability to confront the concrete details of real problems, and to abstract a relevant understanding of them—to build ties between these problems and abstract concepts. Finally, the focus is not just on teaching, which is a means to an end, but on learning, which is the more appropriate goal of education. Students learn not just from course teachers and supervisors, but from each other and from an extended group of mentors associated with the course and the project.

THE ME110K COURSE

We took the opportunity to take many of the lessons learned from the ME210 course, and apply them in a new situation by creating a similar course for students studying at the Stanford Japan Center (SJC) in Kyoto, taught in the Spring quarter of 1998. The course was designated ME110K. The students were undergraduates, studying in such technical fields as Product Design, Mechanical Engineering, and Computer Science; they had also taken at least a year of Japanese language and culture courses prior to moving to the Kyoto area in April of 1998 to study.

The infrastructure for the ME210 course has been evolving and accumulating for its 20+ year existence, and the teaching and design practices, and other elements, that make up this infrastructure have become essential to the course, and are carried forward and improved from year to year. While some pieces of a similar infrastructure existed at the SJC, certainly sufficient for the cultural and language education that takes place, there was very little there that was specific and necessary for a design projects course. This presented both a challenge and an opportunity. The challenge of course was to reduce the scope of ME210—in terms of both time (from 9 months to 10 weeks) and infrastructure required—while retaining as much of its value as possible for both students and sponsors.

But more than taking them as a challenge, we took this set of limitations as an opportunity, in part to begin to develop such an infrastructure in Japan, so that similar courses could be offered in the future. And perhaps more importantly, we took it as a chance to strip the course of many of its technological trappings, and increase the visibility of the crucial role of human skills and culture in design education and design work. This transformed the course in some sense to one that focused on a set of core social and creative essentials that all team design work must involve, regardless of whatever supporting technology might be used.

This stance on creativity and education in design—that the skills, habits, and abilities of the people involved in a design project are significantly more important to a good outcome than any particular technology—reflect a theoretical bias, an hypothesis with nearly axiomatic status, found in much of the design research conducted at Stanford. 'Design is a social process' is an oft-repeated maxim in the ME210 design course, emphasizing this stance. This is not to minimize the obvious value of the technical knowledge and skills that are necessary for design but to balance it. Such a balance is especially needed by engineering students whose education is usually dominated by training in mathematics, models, and well-defined problems sets. At the core of creative teamwork are such things as developing good relationships and communication skills among team members and between the teams and their mentors and sponsors, and developing an awareness of the cultural context in which the problem is being addressed, and into which a solution might be introduced.

WHAT MADE THE COURSE WORK

The primary unique characteristic of ME110K is, of course, that its participants were US university students, but it was taught in Japan. This unique arrangement was made possible by the following essential pieces:

- a collaboration among several people and organizations, and attention to the importance of communication between the students, the sponsoring corporations, and the students' advisors both in Japan and the US;
- a careful choice of a small but effective collection of support infrastructure;
- a small but effective cluster of principles for design education, rooted in product-based learning (PBL).

COLLABORATORS

This course would not have been possible without the support and collaboration of several

parties, and a convergence of multiple interests and purposes. These interests included:

- the Stanford Japan Center in Kyoto, Japan, part of the Stanford Overseas Studies Program, each of which has an interest in attracting students with technical training and giving them experience with Japanese life and culture, which they ordinarily wouldn't have time to gain;
- the Stanford Learning Lab, which is engaged in researching ways to reform higher education into a more involving activity, applying technology where appropriate, and doing so with a global outreach;
- the Stanford's Center for Design Research, which has focused on studying and supporting engineering design practice and education;
- several Japanese universities and corporations, particularly Osaka University and Prof. Itsuo Ohnaka's research laboratory, whose interests include design education, and increasing collaboration and exchange between themselves and American universities;
- a number of individuals in these organizations who came to the table prepared in unique ways to contribute to the collaboration.

The latter included:

1) a course supervisor with contacts in Japan, and a long track record of international work and managing international collaborations;
2) a Japanese coordinator, who was familiar with design education and who arranged contacts with Japanese sponsoring corporations;
3) the director and staff of an overseas studies program who were committed to attracting and educating students in all fields, and making it possible for students in technical fields to keep pace with their US peers in their technical coursework;
4) an instructor who had engineering design experience, expertise in coaching design teams, and knowledge of Japanese language and culture.

As anyone with experience in academic circles is aware, aligning the high-level interests of several such groups and people can be a daunting task. The significance of this course from the point of view of collaboration is that it provided a concrete focal point where the groundwork of collaborative patterns could be developed, trust could be built, and each parties' interests could be furthered in a small way. It reminds us that good collaborations often start not with an overarching framework and high-level goals, but in joining together for limited goals, with a tolerable, limited degree of uncertainty in terms of time, resources, and money for all parties. The collaboration, in a sense, is being built bottom-up, rather than top-down.

DESIGN EDUCATION PRINCIPLES

There were four main lessons or pedagogical principles that made particularly strong contributions to the way the course was run. These were:

1. Learn to 'see and resee' at will

The students were encouraged to take advantage of their new environment (Japan) to learn how to see the world around them from new perspectives. They learned to understand the relationships between seeing the world around them in a new way, communicating about it in new languages, and being able to come up with new and creative approaches to design problems.

Studies in design, and textbooks and handbooks for design education, consistently refer to a strong connection between 'seeing', in some sense of the word, and design [2, 3]. Stanford University's design courses have long emphasized this connection by requiring that students in design courses work using sketches and notebooks. (The first author's own research draws from a variety of sources, including philosophical [4], linguistic [5], psychological [6], and anthropological [7], to investigate the basis for why this is so, and of what use it can be in design and design education.) One point on which these researchers tend to agree is that, while culture and language are not the same thing, they are each (paradoxical as it may sound) inextricably a part of one another. This point directs us to consider culturally-embedded language and communication—visual as well as verbal, conceptual as well as physiological—and the roles that culture and language play in our ability to see, understand, communicate about, and respond to design challenges.

2. Make solid connections among situations, questions, and answers

The students were required to repeatedly come up with their own questions, and learn to answer them, so that the answers were more relevant to their own circumstances and thus better understood [8].

An old saying points out that we don't really understand the answer to a question that we haven't, on our own, genuinely asked. This idea serves well as a principle for education. One of the keystones of project-based learning is this principle—to learn to tackle a project, students can't be spoon-fed problem sets, exact requirements, and other kinds of ivory-tower questions [9]. Students are better off learning, under guidance, to ask their own questions, then being guided in dealing with them. They then are able to make their own 'connections' among the situations they are faced with, the questions they find relevant about these situations, and the various answers that they have a hand in developing and evaluating. These connections enable them to better understand real-world projects and apply what they have learned. By 'connections' we mean such things as an understanding of what kinds of questions are likely to be useful in a given situation, what the value and limitations of a given way of answering

these questions are, how to 'see' (in the sense described in the previous section) situations in terms such that questions can be asked—questions that are both useful and answerable.

3. Creative judgement usually develops in concert with creativity

The students were given exposure to a large variety of ideas, to develop their ability to creatively judge the applicability and relative value of these ideas to their design problems.

A lesson that is often lost in literature on creativity, we believe, is that this ability to judge value, potential, or creativity—to sense 'what works'—is almost always a prerequisite for the ability to be creative itself. A few people display this kind of judgement at an early age, and seem to need little guidance. But the majority of us learn this judgement over a long period of time. If so, then engineering design education should begin with students learning creative judgement.

While it may be true that an experienced designer can benefit from taking a fresh, unspoiled, even uninformed approach to an unfamiliar problem, we claim that this is not always the best approach for engineering education. We have seen again and again situations where a design project sponsor, mentor, or manager gives novices a design challenge, and then walks away. The novice designers then flail about, not knowing where to start, unable to distinguish the value of one of their own ideas from another, and finally, at best, coming up with the bare beginnings of a design that the sponsor has already thoroughly researched. Our approach in ME110K, and the one we advocate in any course involving novice designers, is to do just the opposite of this: rather than withholding ideas from design students, we should inundate them with as many different ideas as possible, and then their sponsors, coached, mentors, etc. should work with them so that they learn to ask good questions and make good judgements about these ideas.

4. Design is social, founded on communication

We stressed to students the need for being diligent and frequent in communicating with sponsors, mentors, and other people outside their team, so that their various understandings of the design problem and potential solutions can be kept in alignment. An adage (illogical on the surface) was reiterated several times in the course: 'Design is half design, and half communication'. That is, the technical work that is usually associated with design is ineffective if left uncommunicated. Effective communication often takes about half of a designers' effort. (Some simple technologies, like computer-based shared sketching media, were experimented with and used to help with the communication.)

A fundamental stance in design research at Stanford is that design is a social process. This doesn't mean that designers need social lives; rather, it means that design takes place in socially constructed contexts, is moved forward by methods that have a significant social component to them, and is done to meet needs that are largely perceived as needs by social actors [10]. It follows then, that we can also say that design is founded on communication—communication is the means by which social awareness and action are possible, after all.

A variety of things were done in the course to emphasize the need to communicate well, to make the students aware of the social side of design work, and so on. First among them was to point out the relationships that needed to be established and nurtured by regular communication. Guidelines and activities that supported this lesson included:

- Students were grouped into teams.
- Students were introduced to sponsors and coaches early, in face-to-face meetings.
- It was stressed and reiterated throughout the course that the students only had one customer, and this customer was the sponsor, not the instructor.
- The students were required to keep their work and communications toolsets simple, so complex tools don't distract from their purpose.

COURSE DETAILS

Each of the above four learning principles or goals—learn to see and resee, make connections, develop creative judgement, and understand design as social—was supported by the course activities, requirements, or guidelines. Table 1 lists the main supporting activities, etc., against the four education principles just listed.

The activities, etc. in the left column OF Table 1 have been given a further classification into four areas to communicate some of the structure we developed in the course, and are marked with (A), (R), or (G), for Activity, Requirement, or Guideline, again to reflect the course structure. (We realize that arguments could be made for a fully-connected matrix; however, here we emphasize only those connections that played a significant role in ME110K.)

CONCLUSIONS

In ME110K, we were able to offer the students an experience that stressed the importance of being aware of cross-cultural issues that might inhibit or enhance communication creativity. The experience helped them begin to uncover their own cultural 'blindspots', thereby improving their chances of seeing new ways to approach the design problems they worked on. Emphasis was also placed on teamwork and the social aspects of design work, something that individually-oriented problem sets

Table 1. Matrix of four design principles, or lessons, to be learned from the ME110K course, and significant activities, requirements, and guidelines that were used to introduce and reinforce these lessons. A '**P**' indicates that we see an activity/requirement/guideline as being **p**rimarily aimed at certain lesson; a '*' indicates a secondary connection.

Course activity, requirement, or guideline	Lesson 1: learn to 'see & resee' at will	Lesson 2: connect situations, questions, and answers	Lesson 3: creative judgement comes before creativity	Lesson 4: design is social, founded on communication
Culture				
(A) live in Japan, study language & material culture	P	*	*	*
(A) early face-to-face mtgs.		*		P
(A) fieldtrips, walks	P	P	*	
(A) find team 'uniforms'	*			P
Course organization				
(R) students graded as a team	*			P
(G) inundate team with ideas	P		P	*
(R) quickly iterate designs	*	P	P	
(R) students develop questions as well as answers	*	P	*	*
(G) design is half design, half communication	*			P
(G) sponsor is main customer		*		P
(R) weekly contact with sponsor & coaches	*	*	*	P
Reports & notes				
(R) all illustrations are hand sketched	P		*	*
(R) reports are half text, half illustration	*			P
(G) new reports build on, rework prior reports	P	*		*
Working media				
(R) build prototypes	P	*	*	P
(G) see all available media as potential part of project	P	*	P	

of the kind found in traditional American engineering curricula give little training in. Capable, motivated students were vital to the success of the course. We were especially impressed by the high levels of motivation the students developed when they had realistic problems to work on and by how confidence and willingness to consider new ideas was inspired when they had regular communication with their sponsors. The PBL framework contributed substantially to this outcome.

We regard the ME110K course as having been a successful first step towards creating engineering design PBL opportunities at the Stanford Japan Center, and towards creating opportunities for educational and research collaborations in Japan. We also see it as a valuable early look, for us, at how creativity and innovation can be learned in cross-cultural contexts, and indeed how this learning can be enhanced by such contexts. The course, now called ME113K, is being taught again in the Spring quarter of 2000.

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