INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED'09
24 - 27 AUGUST 2009, STANFORD UNIVERSITY, **STANFORD,** CA, USA

ACTIVE LEARNING PROJECT SEQUENCE: Capstone Experience for Multi-disciplinary System Design and Management Education

Ishii, Kosuke[1], de Weck, Olivier[2], Haruyama, Shinichiro[3], Maeno, Takashi[3], Kim, Sun K.[1], and Fowler, Whitfield[1],
(1) Stanford University (2) Massachusetts Institute of Technology (3) Keio University

ABSTRACT

Whereas team project-based learning of engineering design has attracted wide acceptance, it is still rare to see a curriculum that addresses high level societal needs involving diverse students with technical and non-technical backgrounds and a wide range of practical experience. This paper describes collaborative curriculum development among one Japanese (Keio University) and two US universities (Stanford and MIT). The Active Learning Project Sequence (ALPS) is a capstone experience for Keio's new Graduate School of System Design and Management (SDM). The faculty team combined their experience to use the System Development "V-Model" as a roadmap for the curriculum. ALPS set a high level "Voice of Society," from which the project teams generated solution scenarios, identified requirements, and described the proposed system using appropriate prototypes of not only hardware, but other amorphous means. The theme for 2008 was "Enhancing Senior Life in Japan," which led to project foci on more specific scenarios. This paper illustrates the design of the workshop sequence, in particular, two key learning modules: a) scenario development and prototyping and b) cross-team project evaluation.

Keywords: System Design and Management, System Development V-Model, Active Learning, Team Project-based Learning, Voice of Society, Scenario Development, Project Evaluation Scorecard, Cross-team Project Evaluation, Multi-disciplinary Teams.

1. INTRODUCTION

1.1 The World Challenges in System Design and Management

Keio, the oldest university in Japan, has been promoting talents in a variety of fields such as politics, economy, culture, education, medical treatment, and science and technology since 1858. Keio has made diverse contributions to the industrial world and in academia in Japan. However, the globalization of these inter-related fields in a rapidly changing world necessitates the education of talented people who can contribute to society world-wide in a complex community.

The international community in the 21st century must address diversity in race, language, culture, and economic systems, and relationships among them. Decision makers in every field must understand a very complex system, or "system of systems." This requires collaboration among the stakeholders and the ability to incorporate and adapt to unforeseen changes. Such challenges have always existed in industries dealing with large systems such as aerospace and defense. However, complexities are becoming evident in other industries such as automotive, transportation, energy, information technology, medical, welfare, tourism, and logistic services. Coordination among stakeholders and sound trade-offs must occur as the scale of the enterprises becomes larger. Conventional approaches exist, the so called "legacy systems engineering," established during the Apollo space project. However, such an approach no longer suffices, since in the past several decades, systems have become far more complex. Most complex systems require attention to not only engineering matters, but address other issues such as organization, economics and finance, environmental regulations, and political factors.

As for Japan, the level of systems engineering is not as advanced as other economically developed countries, despite its advances in technology. The country needs urgent action to disseminate and mature systems-oriented thinking and decision skills. Many systems-oriented problems have received national attention in the past decade. Some were the results of technical causes, such as the 2005 Japan Rail West's derailment accident, nuclear power plant problems, spacecraft failures, and frequent elevator accidents. By contrast, many systems-oriented, social problems have been observed, such as the export of restricted arms and the collapse of healthcare and insurance services. We believe the lack of systems-oriented thinking has contributed to these otherwise avoidable mishaps. Once we institute such thinking through "System design" and "System management," not only will we be able to mitigate social problems but also translate the approach to products and services in the marketplace.

1.2. Motivation for Graduate School of System Design and Management

The current state of Japan requires people with state-of-the-art information technology skills, the ability to communicate through multiple media. In addition, they need people to understand policies such as law and regulations, have financial aptitude, and can create new systems and manage them. Keio established the Graduate School of System Design and Management (Keio SDM) in April, 2008 with the goal of educating such people. Keio SDM seeks to produce systems-oriented leaders who can effectively create safe and environmentally sound systems in an age of globalization (Security, Safety & Symbiosis: S3). The typical skills of SDM aims to produce two types of people; 1) Creative system designers who can propose new technical systems compatible with a rapidly changing environment that includes diverse interests and requirements, as well as in transnational frames, create new markets, and manage new businesses. 2) Project managers who can manage complex, large-scale systems and who have a deep insight into all processes of the life cycle including planning, design, assembly, operations, and recycling.

Many agree that industries that have large scale infrastructure such as, aviation, and space systems require of their decision makers the skills noted above. More recently, the same requirement holds true regardless of the size of business to industries such as consumer products. People who graduate from Keio SDM must be able to make correct judgments utilizing effective communication in the organization and take a leadership role in the enterprise. Moreover, SDM aims at new value creation based on interactions of people with various backgrounds. Therefore, the program welcomes not only engineers and scientists, but people with backgrounds in marketing, consulting, journalism, law, management, public policy, research, and academia.

1.3. Capstone Design Experience ALPS (Active Learning Project Sequence)

Over the 2-year degree program, Keio SDM covers not only technical skills but also human skills such as the ability to communicate in English in order to respond to societal demands. In particular, the capstone design experience, Active Learning Project Sequence (ALPS), aims at enhancing presentation, teamwork abilities, leadership skills, technological knowledge, and creativity. Furthermore, it aims to produce students with strong simulation aptitude utilizing the newest information technology. Of special emphasis is the ability to visualize new ideas, to share value, to analyze value from various aspects, and to discover creative solutions. The design project ALPS emphasizes group projects to create plans for new systems.

Initially, Keio faculty requested that the authors from Stanford and MIT, two institutions on opposite coasts of the U.S., contribute individually to the SDM program through a series of lectures. Stanford and MIT had prior research and curriculum information exchanges over the past decade, so we agreed to join our efforts. The main goal was to expose SDM students with conventional and emerging methods and tools that cover the whole life cycle of system development using a unified project topic as a vehicle for team-based learning. Initially, we had in mind a topic that would yield a functional prototype using modular toys such as LEGO, and a relatively narrow function such as home healthcare robots.

Upon learning that the class was to be made up of about 60 students, about 30% of whom were non-engineers such as economists, journalists, policy makers and healthcare specialists, the authors quickly decided upon a much higher level societal needs for the project topic, encompassing the project challenge to specialties beyond engineering. In fact, the US collaborators were stunned with the diverse background of the class, far broader than what we were used to at Stanford and MIT. The experience gained through the truly multidisciplinary system design project sequence is already making a significant impact on our own courses in the United States, in dimensions that are very difficult to create in traditional engineering schools. The remainder of the paper describes the following

a) Design and planning of Keio SDM ALPS, class of 2008
b) The projects defined by student teams and their characteristics
c) New educational modules and tools that came out of ALPS: Scenario Prototyping and Cross Team Project Evaluation
d) What we learned and future outlook.

2. Designing and Planning ALPS

2.1 Team formation

Upon establishment of the Graduate School of SDM in April 2008, Keio faculty designated ALPS as a required capstone course for all students in the SDM Masters program. Along with a few students in the Ph.D. program, the initial class of ALPS 2008 began with 60 students. The class included about 30% students with social science background and 70% with technical background. Over 70% had extensive practical experience, most of who were in the degree program while working for various companies and organizations. Over 20% of the students were female. The student mix is shown in Figure 1.

The Keio, MIT, and Stanford teaching team formed 12 teams based on the mix of following factors: 1) length of practical experience, 2) area of prior education and/or experience, and 3) gender. We did not employ any structured methods in this process, such as personality typing or utility-function optimization. Faced with a very diverse audience, we wanted to keep the formation process simple, yet leverage the wealth of talent attracted by the new SDM program.

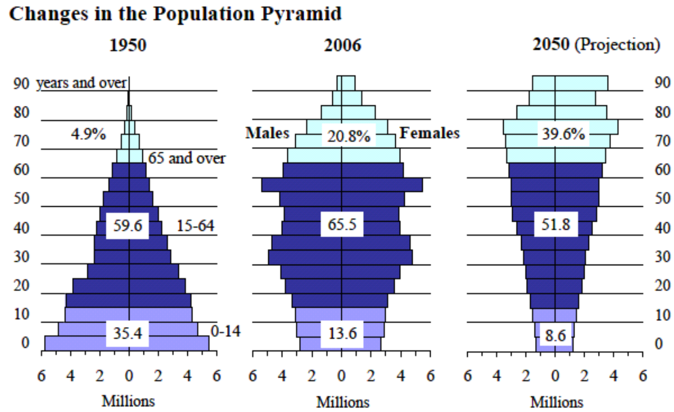
2.2 Project Theme Selection

The faculty had simple goals in defining the topic for the capstone project course: a) the project experience should allow the teams to exercise key methods and tools covered in the SDM program, b) the program should yield some form of “prototypes” that the teams can showcase at the end of the project, and c) every team would ideally share a high level project theme so that they can learn from each other (thus, “Active Learning Project Sequence.”) and d) the chosen theme should be of benefit to society at large.

In particular, the third goal differed significantly from project-based classes that the US authors were teaching at their home institution. The unified theme presented a challenge. First, we wanted to utilize the unique diverse talents in the class. Second, the theme should be broad enough that would result in different character and focus in the actual project topic defined by the students. Third, and perhaps most importantly, we wanted the theme to be timely and of currently importance.

After extensive discussion, in mid April 2008, the faculty agreed on a high level theme, or what we eventually called the VOS (Voice of Society): *“Enriching Senior Life in Japan”* (de Weck, 2008) As many people know, the Japanese population is rapidly growing, with an inverted age pyramid (Fig.2).

Yet, many elderly people are still healthy and want to (as well as need to) contribute to society. We wanted the class to observe seniors and the society around them to identify the issues that challenge mature individuals, the people around them, and organizations and society in general. The teams would then deploy system engineering methods to develop innovative solutions: products and services, to be demonstrated by appropriate forms of “prototypes.” An extensive white paper on the topic of Aging in Japan was prepared and provided as a pre-reading material before the start of the course.



Source: Statistics Bureau, MIC; Ministry of Health, Labour and Welfare.

Figure 2. Japanese Age Demographics

While being a critical societal challenge economically, currently and in the near future, this theme was also close to home for the entire class. Most students had aging grandparents, parents or relatives, many of whom had health issues as well as motivational challenges to live a happy senior life as an important segment of the community. It was not difficult for ALPS students to gather the voice of the primary customers, i.e., seniors or elderly. In fact, most project teams actively sought the opinion of seniors as well as care givers in commercial and public sectors. From the teaching team perspective, students had no excuse regarding access to the source of customer voice.

2.3 Key methods, tools, and workshop schedules

Authors wanted to introduce the essentials of key methods and tools that integrate into the basic SDM process: the product development V-Model (Fig. 3). In selecting the learning modules to be covered in a limited number of workshop sessions, the teaching team brainstormed to understand the background and needs of ALPS as well as our own competencies.

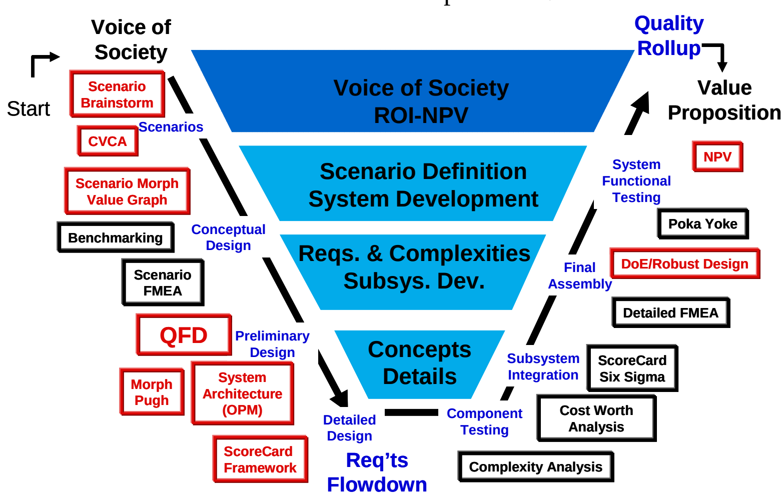


Figure 3. System Development Process: the V-Model and associated tools.

Figure 3 shows the major methods and tools that the U.S. authors incorporated in our respective project-based classes at MIT and Stanford. In particular, we focused on the planning and concept development stage. While we were not fully aware of the coverage by other lecture courses at Keio SDM, we tried to focus on tools that have a track record in industry and are compatible with team project-based learning (Dori, 2003; Donaldson, 2005; Beiter et al, 2006a; Kim et al, 2008).

The authors gave the following lectures during the five workshop sequence. Each lecture included homework assignments to be applied to each team's project topic. For each workshop, we defined at least one method/tools for the team to initiate (e.g., develop a skeletal QFD Matrix) over night of the first day, and report back on the second day.

1. Identification of Voice of Society and defining the project focus
    a. Customer Value Chain Analysis,
    b. Scenario Generation by Brainstorming
    c. Object Process Methodology (OPM Level 0)
2. Requirements Flowdown and Concept Development
    a. Quality Function Deployment (QFD)
    b. Concept Generation (Morphological Analysis)
    c. Concept Selection (Pugh Method)
    d. Prototyping Rapidly
3. System Architecture and Evaluation
    a. System Architecture (OPM Level 1)
    b. Scenario-based Amorphous System Design
    c. Quality Scorecarding
    d. Net Present Value (NPV) Analysis
4. Design for Robustness and Variety
    a. Design of Experiments
    b. Design for Variety
    c. Decision Analytical Scorecarding
    d. Project Definition Assessment
    e. Design for Changeability
5. Communicating the Proposed Idea
    a. Elevator Pitch
    b. One Page Advertisement
    c. Showcasing the Idea

The lectures were mostly in English with translation provided by Keio faculty and staff as needed. The Stanford instructor often delivered his lectures in Japanese. Each lecture module included varying levels of interactive sessions as well as homework assignments for the teams to work on immediately after the lecture, or in between workshops for those tasks that required ample time.

2.4 Workshop Schedules and Activity

To cover the lecture modules as well as allowing the teams to have ample time to apply the methods to their project, the ALPS instructional team scheduled five (5) two-day workshops (Figure 4). Every workshop involved at least two members of the teaching team on site.

May, 2008 (Mita, Tokyo): MIT Faculty, Stanford Teaching Assistant (TA)
June, 2008 (Mita) : Stanford Faculty and two Stanford TAs
Sept., 2008 (Hiyoshi, Yokohama): MIT faculty and TA; Stanford faculty and TA
Nov., 2008: (Hiyoshi) Stanford faculty and two TAs, one MIT TA
Feb., 2009 (Hiyoshi): MIT and Stanford, all hands

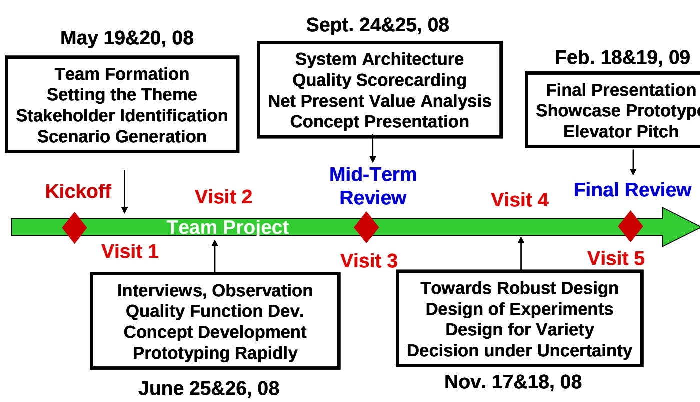


Figure 4. Workshop Timeline and Learning Modules

The US authors, when not present on site in person, participated part of the time through video conferencing (Figure 5). A majority of the 10 full time Keio SDM faculty participated, with one representative faculty (Prof. Haruyama) taking the lead.

Figure 5. Video Conferencing: Yokohama-Boston

3. Team Projects

3.1 Project Scenarios and their Grouping

The high level definition of the project theme posed a challenge for the teams to define representative scenarios of seniors' life for which they could use an innovative solution. The class used a form of brainstorming based "scenario morphological analysis" described in the next section. The teaching team was quite impressed with the diverse project focus each team generated. Below is the list of project titles and team names, some of which are more descriptive than others.

A1 Team "It's my life": Post-retirement life planning and guidance
A2 Team "Keiro University": Continuing Education for Seniors
B1 Team" Garlic and Yoke" The Last Mile Transportation
B2 Team "Township Troopers" Motivating Youth to Activate Seniors
C1 Team "PILO": Personal Intelligent Travel Assistant
C2 Team "Honey Reminder": The Memory Lane
D1 Team "Action Planner": Motivating Bored Senior Men
D2 Team "Nabla-tool": Heartful Communication
E1 Team "Lun Lun Walkers": Pedestrian Safety
E2 Team "Kame Sennin": Want to go any where, any time
F1 Team "P-Volula": Connecting Volunteers
F2 Team "Sing and Play, So, Hahaha": Healthy teeth the fun way

Upon reflection, the teaching team affinitized the project topics in the following groups (Figure 6.): 1) staying in touch, 2) mobile, 3) healthy, 4) fun.

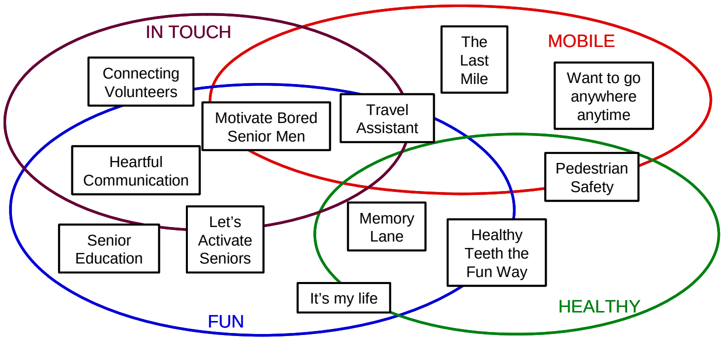


Figure 6. Grouping of "Enhancing Senior Life" Scenarios

The teaching team initially anticipated that more projects would be related to health or mobility issues and was surprised that eight out of the twelve projects addressed being active and socially connected or having fun. In retrospect, the class responded to our guidance to ask “why” whenever they started to converge to a specific solution too early. We then realized that the objective of being healthy or to be able to communicate is to have fun! Also, the interviews conducted by the students uncovered a strong linkage between the level of activity and happiness of seniors (i.e. their mental state) and their physical state. Japanese men in particular are known to be very tied to their jobs, and sudden retirement is often a difficult transition for them. A number of projects tried to address this issue in direct or indirect ways.

3.2 Sample Projects

Each team identified scenarios and generated solution systems that were eye-openers to the entire class as well as the instructors. This section describes the summary of two representative categories of the voice of customers (VOC) exercise.

3.2.1 Personal Intelligent LOvely Travel Assistant Bird (PILO)

This team focused on the need for information and assistance related to travel, in particular, sightseeing with family and friends. Japanese people are known to travel in groups abroad, but expressed a preference for individual mobility during interviews. The team held focus group meetings at local community centers through which they collected various customer voices and formed a scenario that called for innovative solutions. The VOC they addressed, in verbalized form is as follows:

> ***Voice of Customer: I would like to travel to Kyoto with my grand kids and friends, but always end up bothering them. I need to go to bathrooms often, but you cannot find them in busy areas very easily. I cannot find restaurants that serve my favorite food either. Some times, I get lost with grand kids, and their parents get really mad at me. Younger people seem to use mobile phones and other gadgets that help them navigate, but I don’t know how to use them. I can’t see small text anyways. I’m too old to have fun traveling… Sigh…***

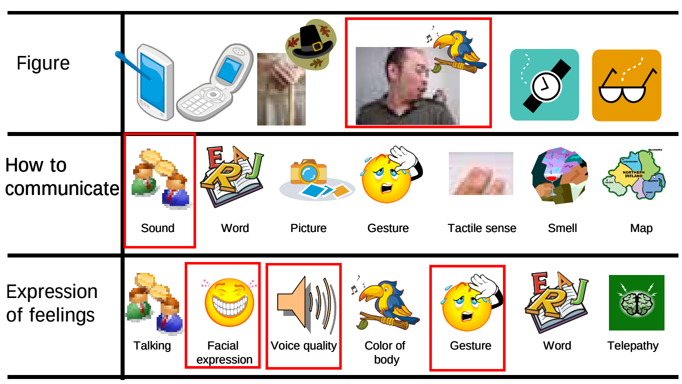


Figure 7. Scenario-Function-Form Morphology for Travel Assistant
(From ALPS 2008 Midterm Presentation, Team C1, Sept. 2008)

From this scenario statement, the team listed the necessary functions that enable the solutions for such scenarios. The morphological concept generation method guided them to several alternatives (Figure 7). Pugh concept selection helped them further refine the idea and hone into a pet robot or clothing accessory called the Personal Intelligent LOvely Travel Assistant Bird or PILO. The team further developed a business model in which travel agents or Japan Rail can rent PILO on which local information can be updated at train stations and other travel points. Interaction with PILO would occur mainly via voice commands. The student team created a functional prototype of PILO and demonstrated it at the final review (Workshop 5, see Fig. 4). PILO received very favorable ratings from other project teams and classmates.

3.2.2 “The It’s My Life” Game

The scenario setting for this team was “pre-seniors,” several years before retirement from their full time primary career. As mentioned earlier, many retirees (particularly Japanese men) are at a loss as to how to enjoy senior life after decades of being a member of a large company or organization. Declining help from their friends and family members, some even commit suicide. Members of this team conducted surveys and interviews among their own organization, and collected the voice of pre-seniors nearing retirement.

> ***Voice of Customer: I am really nervous about retirement from my current job. I have dedicated my entire productive life to company XYZ. I found joy in developing XYZ Robot's Electronics, so that's all I can do. But, since I did not become an officer of XYZ, the company will forcibly retire me next year. I have savings, so money is not an issue. I also don't want to bother my kids and grand kids. I won't have any purpose to live… Sigh…***

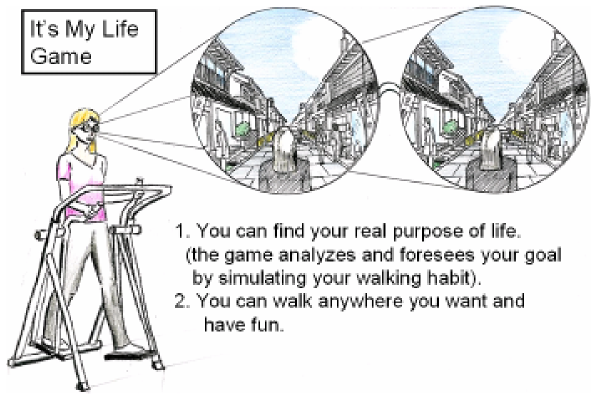


Figure 8. Scenario Prototype for the "It's My Life" Game
(From ALPS 2008 Midterm Presentation, Team A1, Sept. 2008)

Responding to this VOC, the team focused on "motivating pre-seniors for post-retirement life." After a preliminary scenario morph (scenario generation), they selected an environment that helped pre-seniors make plans for a fun and enjoyable second life, while staying healthy. The scenario led to functional elements of a second-life simulation environment, coupled with interest and aptitude matching, and education and training guidance. For example, some pre-seniors may want to learn dancing with their spouse, some may show interest in public service. Some may want to open up a pro-bono language school. Figure 8 shows a schematic of how the second-life simulator may work. The second life-game received very favorable response from older members of the class as well as Stanford and Keio faculty who were nearing retirement.

The next section describes two ALPS experiences that were a significant enabler in generating these innovative "sky-high" ideas.

4. New Approaches to Project-based Learning of SDM System Design

4.1 Scenario Morphology and Prototyping

Concept generation techniques and quick prototyping have been key components of system design curricula for decades. At both MIT and Stanford, we have covered these modules in project-based courses. However, when starting the course with high-level societal needs as we did in ALPS, the project focus was still fluid and uncertain of which functions the system should provide. This type of cooperation meant that the solution sets should be amorphous enough to encompass not only hardware and software, but also infrastructure, regulatory policy, and funding mechanism. (Beiter et al, 2006b).

As a result of the broadened scope, the projects became more complex, requiring multidisciplinary cooperation. Therefore, the design teams needed a more structured approach for designing and developing system-oriented products that were open-ended, or what we defined as "amorphous." To address the ambiguity of amorphous projects, we used Scenario-based Design for Amorphous Systems (Kim et. al, 2007), an approach that helps multi-disciplinary design teams visualize, organize and communicate high-level idea elements that lead to the formation of tangible concepts.

Representative methods for generating scenarios were Scenario Graph and Scenario Morph (Figure 9). By generating the four elements of a scenario, *Who, What, Where,* and *When* and then grouping them to form multiple scenarios, the design teams were able to grasp the setting of their project and identify the functions and requirements of the system they were trying to build.

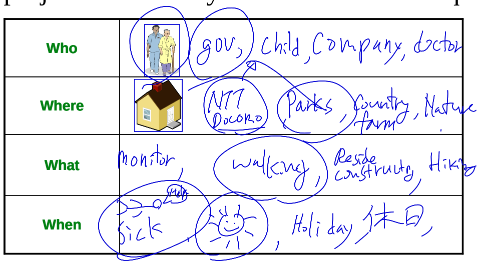


Figure 9. Iterations of Scenario Morph helped deal with ambiguity by dividing the elements of a scenario and then grouping them to form multiple scenarios.

Figure 10. A simple prototype for mobilizing seniors helped the design team to generate new ideas, test them and show their concepts.

The importance of early and simple prototyping during the conceptual phase of product development is well understood in the design community. We emphasized its equal importance in the scenario domain and introduced our method, "Scenario Prototyping Rapidly" (Ishii et al. 2009) and examples of prototyping scenarios to the design teams. Techniques such as storyboarding, making videos and movies, role-playing and body-storming played a key role in helping the design teams to generate new ideas, test them and show their concepts to other teams and the teaching staff. Figure 10 shows a scaled-down town prototype for mobilizing seniors. The design team generated new ideas by interacting with this town model, tested their ideas by simulating the operation of their transportation system and discovering failure modes, and finally demonstrated their concept by walking the other teams through their mockup and telling a story.

4.2 Project Cross-Team Evaluation Game

Throughout ALPS, the authors wanted each team to track the clarity of their project definition. At the end of each workshop, we asked the teams to complete a 14 point product definition checklist that has been in use at Stanford's Design for Manufacturability Course for the past decade (Wilson, 1993; Beiter et al, 20007)). The authors asked each team to evaluate their team's understanding and accomplishment in a list of categories including alignment of the project theme with corporate strategy, customer and stakeholder needs identification, core competencies, and business models. After three workshops, we noticed that 1) there were too many questions at a level of detail not compatible with ALPS, and 2) self evaluation was quickly turning into a "fill in the blanks" exercise. The intention of tracking the project was sound, however, the implementation was resulting in non value added "busy work."

To simplify the evaluation process and increase the learning achieved in the experience, we made the following changes for workshop #4: a) streamlined the criteria list to six that were pertinent to amorphous systems, b) made the exercise a cross-team evaluation, c) conducted a friendly competition with a Robust Design foundation. Table 1 shows the revised checklist.

After each team gave their project update presentation in an open session during day 1 of workshop #4, the teaching team assigned each team three other projects to evaluate in addition to their own. Then each team went in a breakout session to conduct the evaluation during the evening. At the end of the second day, during the workshop reception, the entire class shared the results.

Table 1: ALPS Project Definition Checklist

	Topic: Question	(not good) strongly disagree				strongly agree (good)
1	Scenario: team agrees on target VOS and scenarios?	1	2	3	4	5
2	Stakeholders: team captured and agrees on customer / stakeholder chain?	1	2	3	4	5
3	Customer Value: team understands CRs & EMs, innovation opportunity?	1	2	3	4	5
4	Complexities: team understands the complexities (cost, time, etc.)?	1	2	3	4	5
5	Concept Architecture: team selected and proposed (described) an amosys?	1	2	3	4	5
6	Business Model and Risks: team has evaluated cash flows & uncertainties?	1	2	3	4	5

Table 2: Instruction for ALPS Cross Team Project Evaluation

1	Please pay attention to every team during WS#4, and consider the 6-question Amorphous System Definition (Amosys) checklist.
2	Monday at end of day, each team will be given three other teams to evaluate.
3	Please evaluate all 3 teams based on the “Amosys” Checklist.
4	Please also evaluate your own team. And bring all forms to class Tuesday morning
5	We (Stanford coachs) will tally up the scores. We will do this after ALPS schedule is over, but before the konshinkai.
6	During the konshinkai, each team will announce their own self-assessment of the same checklist, write them on the whiteboard, perhaps say a few words about the low scoring items.
7	Stanford team will write the averaged scores of the "external" score for each team.
8	The team with the least difference between "self" and "external" scores wins a prize! The teams which perform the evaluations of the team that wins also receives prizes.
9	Each team will have 1 minute to announce to everyone the biggest risk or the biggest challenge for their team + 3 tasks they will perform before workshop #5 to address the challenge and deliver a great project.
10	Please have fun!

In considering the evaluation scores data , the teaching team considered two metrics to be important: 1) The Error Score (Equation 1) which sought to capture how accurately each team had evaluated themselves. (Equation 1) and 2) The Over Under Score (Equation 2) which sought to capture whether teams were on average over-confident or under-confident in their project. The evaluation results are shown in Table 3 for all teams a1 through j1.

$$ErrorScore = \sum_{6categories} \left| Selfscore_{category} - average(Externalscore_{category}) \right| \quad (1)$$

$$OverUnderScore = \sum_{6categories} \left(Selfscore_{category} - average(Externalscore_{category}) \right) \quad (2)$$

Table 3: Error Scores and Over Under Scores by team number

team	a1	a2	b1	b2	c1	c2	d1	d2	e1	e2	f1	f2	j1
Error Score	4.0	4.7	4.7	5.0	5.3	4.0	4.3	5.3	4.0	3.7	5.3	0.7	5.3
Over Under Score	0.0	-4.0	4.0	-2.3	3.3	0.7	1.7	1.3	-2.0	-0.3	5.3	0.0	0.7

Figure 11 shows that one team had the lowest Error Score by far (Team f2). Despite this score, however, dishonesty seemed unlikely for several reasons including: the 3 teams that evaluated team f2 would have had to knowingly put themselves at a disadvantage, the teams were aware that these scores did not impact the grading for the course in any way, and the teams with the higher error scores learned more about how to improve their projects. The teaching team later found out that this team deliberately subtracted a full unit of score (-1.0) from their own self-scores in order to account for the inherent bias of their self-evaluation. They were the only team to do so.

The results also indicate that teams generally tend to over-estimate their project achievement. Figure 11 clearly shows that 4 teams underestimated their performance while 7 teams over estimated their performance. The winning team (f2) used a strategy where once they had scored themselves, they took one full point off of each category before tuning in their self-evaluation as described above.

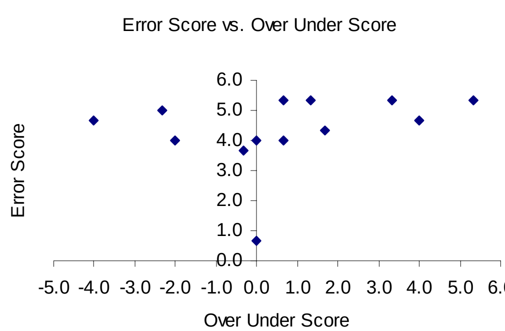


Figure 11: Error Scores and Over Under Scores

The authors believe this event was a success for several reasons: 1) the students paid more attention to each other during the presentations, 2) the students had both context and motivation to evaluate themselves honestly, 3) the students learned where they should focus their preparations for the final, 4) the students had fun, and 5) the entire process was time effective for the teaching team

By comparing the self evaluations to the external evaluations, teams learned where they should focus their preparations for the final project presentations in workshop #5. Teams could easily see where the external evaluation was lower than their assessment, and could use this *lesson* to channel their energy for the rest of the project. Teams could also see where the external evaluation was higher than the internal evaluation, and could use this *surprise* to identify areas where they had achieved more than they thought. The total process took less than 15 hours and the authors believe the benefits far outweighed the costs of the time spent.

5. Reflection, Conclusions, and Future Directions

5.1 Feedback from faculty members and students

The authors collected course evaluations and comments from each student and participating Keio faculty member at the end of each workshop. The summary of their reflections, comments and suggestions as of December, 2008 are as follows. All respondents commented that they learned many things from the ALPS experience. Notably, many appreciated the opportunity to exchange opinions with project teammates with diverse background and different ideas, as well as the learning experience of the methods and tools to promote discussion. Japanese students typically do not receive skills and training on how to effectively conduct group discussions since project-based learning is relatively new and still rare in Japan. In this respect, they rate that ALPS exceeded their expectations. Moreover, they responded positively to the lectures that created new value through innovative ideas, instead of simply teaching how to construct new systems. Having to present and critically discuss their team products in English was also challenging and rewarding for many participants.

Recognizing that 2008 was the first year for ALPS, they had many suggestions for improving the capstone experience. The sequence placed substantial weight on conceptual design, however, they also wanted to learn skills needed for detail design. There were also opinions that the relationship between ALPS and other SDM courses were not clear, and that it would be beneficial for the teaching team to coordinate the entire SDM curriculum with a clear positioning of ALPS. The students also expressed the need for more detailed ALPS syllabi of lecture modules provided by Stanford and MIT. Some students pointed out the diverse motivation level towards team project-based learning and the hours dedicated by each member. Keio faculty also pointed out that the planning of the cooperation between ALPS and other lectures was inadequate. Lack of preparation time between the establishment of the SDM program and ALPS kick-off led to the mode of “trial and error,” using the first year students as guinea pigs. Some thought that the duration of ALPS was somewhat too long, and could be shorter and more concentrated. One primary motivation for a more intensive sequence is to allow the students to apply their ALPS experience to their Masters thesis projects. The US teaching team felt that we could have used a more thorough planning. However, some level of “trial and error” was inevitable and even welcome, since the situation was quite uncertain at the beginning. The two main factors were: a) we did not expect such a diverse audience, and b) it required time to learn the subtle differences between Stanford and MIT teaching modules and styles.

The authors truly appreciated the frank comments from KEIO faculty and students, and intend to incorporate improvements in the future offerings of ALPS. The next section summarizes the changes under consideration.

5.2 Conclusions and Future Outlook

Team project-based learning of engineering design has attracted world-wide attention in the past decade, although it is rare to see a curriculum that addresses high-level societal needs involving diverse students with technical and non-technical backgrounds and a wide range of practical experience. This paper described a joint curriculum development effort among Keio University, MIT, and Stanford. The initial running of the project (2008) involved five (5) two-day workshops spanning nine months. KEIO positions this Active Learning Project Sequence (ALPS) as a capstone experience for their new Graduate School of System Design and Management (SDM). The initial year of ALPS included 12 teams of 5 students, with 70% part time students with extensive practical experience. About 30% were of non-technical background such as economics, law, journalism, political science.

The faculty team combined their experience from their respective institutions to introduce lectures and assignments that guided the System Development "V-Model," and complemented the SDM overall curriculum. ALPS set a high level "Voice of Society," from which the project teams generated solution scenarios, identified specific requirements, and described the proposed system using appropriate forms of prototypes and showcasing methods of not only hardware, but other amorphous elements such as software, infrastructure, regulatory framework, and business models. The teams also applied project evaluation scorecards and a preliminary life-cycle financial analysis. The theme for 2008 was "Enhancing Senior Life in Japan," which led to project foci on more specific scenarios about healthcare, fun activities, mobility, and communications. The authors also described the planning and design of the workshop sequence, in particular, two key learning modules: a) scenario development and prototyping and b) cross-team evaluation of project progress.

Planning for ALPS class of 2009 is already underway. The theme for the next edition of ALPS will be "Sustainable Community" and we expect that sustainability will be broadly interpreted by the student teams to encompass aspects such as environmental sustainability, social harmony and economic stability amongst others. In response to critique and suggestions from the students, as well as SDM faculty member's self assessment, we intend to make the following enhancements:

1) ALPS Duration: Many felt that the workshop sequence was strung out too long. We will shorten the overall ALPS cycle from nine months to five months, five workshops to four. The planned dates for the workshops are mid June, early August, late Sept., and late November.
2) Workshop Learning Modules: In concert with the shortened cycle, we will streamline the learning modules. The ALPS modules will continue to focus on early planning stages and topics not covered by other Keio SDM courses.
3) Linkage with other aspects of SDM curriculum: We will clarify the relationship between ALPS and other SDM courses, in particular, methods and tools for the detailed stages of the system development V-model.

Simultaneously, the authors intend to leverage the learning from ALPS to our own courses at Stanford and MIT. For example, the two new approaches described in Section 4 (scenario morph and prototyping; cross-team project definition evaluation) are an integral part of our curriculum. We expect to gather more information and insights into these teaching methods in the coming year.

Acknowledgements

We thank all Keio faculty and students for making ALPS a successful teaching and learning experiment. This paper is written in memory of Prof. Kosuke Ishii, the lead author and Stanford faculty member who was the leading force behind the creation of ALPS.

References

Beiter, K, Ishii, K., Karandikar, H. (2006a) "Customer Requirements Management: Methodology Selection and Deployment Guide," Proceedings of IDETC/CIE 2006 ASME 2006 International Design Engineering Technical Conferences, Sept. Philadelphia PA. Paper No. DETC2006-99630, ISBN 0-7918-3784-X.

Beiter, K., Yang, T., Ishii, K. (2006b) "Preliminary Design of Amorphous Products," Proceedings of IDETC/CIE 2006. ASME 2006 International Design Engineering Technical Conferences, Sept. Philadelphia PA. Paper No. DETC2006-99680, ISBN 0-7918-3784-X.

Beiter, K., Ishii, K., and Karandikar, H. (2007) "Making Design Reviews Count," Proceedings of ASME 2007 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference, September, 2007, Las Vegas, Nevada, DETC2007-35848, ISBN 0-7918-3806-4

Donaldson, K., Ishii, K., and Sheppard, S. (2006) "Customer Value Chain Analysis" Research in Engineering Design, Vol. 16, pp. 174-183

Dori, D. (2002). "Object Process Methodology – A Holistic Systems Paradigm", Springer, 2002

Kim, S., Ishii, K., Beiter, K. (2007), "Scenario Graph: Discovering new business opportunities and Failure Modes," Proceedings of ASME International Design Engineering Technical Conferences, Las Vegas, NV, Sept. 2007. DETC2007-34967, ISBN 0-7918-3806-4.

Kim I.L., de Weck O.L., Nadir W., Young P., Wallace D. (2008), "Innovative Modern Engineering Design and Rapid Prototyping Course: A Rewarding CAD/CAE/CAM Experience for Undergraduates", Session 332, *American Society of Engineering Education (ASEE)* 2004 Annual Conference & Exposition, Salt Lake City, Utah, June 20-23, 2004

de Weck A. L. (2008) "Enhancing Senior Life in Japan." White Paper, Keio University, Graduate School of System Design and Management Program, April 2008

Wilson, E. (1993) "Maximizing Designers' Impact on Market Success," Design Management Jnl., Fall, 1993.