SynThesis: Integrating Real World Product Design and Business Development with the Challenges of Innovative Instruction

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Introduction

The present workshop was particularly well timed. We have just completed the first year of a new graduate-level course emphasizing product design, business development, and team process. In this course we implemented and tested many of the published ideas of the engineering design community. We report on the results of the course, our experiences and the feedback from the students, industry participants and faculty (and interactions at the workshop) which are enabling the teaching team to develop the strategies, discussed herein, to improve the course.

Creating SynThesis

The Faculty of Engineering has introduced a new 4+1 Select Program in Engineering, which yields a Bachelor of Science degree in an engineering field, applied physics, or computer science (CS), and a Masters of Engineering (or Science, for CS) degree. The program requires that a student achieves a prescribed grade-point average, take an adequate course load in design, supplement his/her undergraduate degree program with courses in the management sciences, economics, ethics, and environmental engineering, and gain six months of practical experience in industry (through internships after the junior and senior years). In the graduate phase of the program students take advanced courses in engineering and management-related courses, and a full year product design and business development course called SynThesis, bringing engineering, computer science, and business students together into teams. This project requirement differs from many traditional theses in its themes of integration of experience and in the emphasis on team building and performance. The course design responds to input from our industry advisory board and the inadequacies in engineering graduates reported by industry.

In conceiving of SynThesis, a team of faculty met for a good part of a year and addressed a number of fundamental questions. How can one preserve the realistic, real-world experience of product design and business development, which helps to motivate students, while weaving a web of information, support and wherewithal into the process? What are the critical differences between the educational experience and the real-world context? What pedagogical approaches encourage team enthusiasm and cohesiveness, and give the teams the building blocks necessary to conceive and create within the context of real world needs? What preparatory design exercises draw the non-engineers into the design activity, and when do the business considerations motivate engineering students and impact the design?
Educating students in product design and development involves addressing several contexts of the professional practice of product design: working within large corporations, working in design firms, or working as independent entrepreneurial teams (Kaplan, 1998). The teaching team chose to focus on providing the experience of the last of these, i.e. entrepreneurial teams, rather than the more traditional focus on design engineering for clients or the detailed engineering involved in iterative innovation typical in corporate product development. The reasons for this choice were:

1) independent entrepreneurial teams produce more ‘discontinuous’ innovation;
2) the university environment cannot simulate the corporate or design firm context, and while industry participation is invaluable, it can conflict with the students’ control in problem definition and implementation;
3) the skills involved in self-managing entrepreneurial innovation are applicable to these design contexts of corporations;
4) an explicit commitment to educating leaders in technological innovation predisposes the teaching team to give the students leadership experience.

Consistent with research examining the background of contemporary technological innovators, while most have engineering educational backgrounds, they actually work in non-engineering roles. Providing students with the experience and confidence to entirely self-manage a project gives them experience in the multiple roles involved in product development. Since product development is cross-disciplinary (even anti-disciplinary) involving matters that transcend engineering, it was essential to introduce instruction related to management, finance and social sciences. Lectures on marketing, business planning, and group processes were essential components of the course. For these lectures, we turned to faculty and graduate students from the Yale School of Management and the Psychology Department.

The nonlinearity of product development, involving feedback and concurrent engineering, required the instructional process to mimic this process. The students are more accustomed to linear courses and the compartmentalization of subject matter and grading. Most students want to receive an assignment and a deadline and will independently complete these. Within product design and development, individuals have to depend on their fellow team members to finish an assignment. Cooperative learning can improve the success of solving difficult design problems. However, it is critical that the assessment reinforces the team responsibility and performance over the individual’s performance, and the project outcome over the individual assignments in product-based learning. To this end,

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i Studies that have examined the educational background of contemporary technological innovators including Kaplan 1998 show that while a great majority of innovative technology companies are founded by engineers, most of these successful engineer-entrepreneurs lament the lack of introduction to financial, marketing and management issues in their formal education.

ii Coined by Leifer, this adapts the virtues of project based learning (PBL) educational reforms to the specific requirements of design engineering.
involving students in defining, scheduling and prioritizing the assignments and milestones reinforces the team's autonomy with respect to the faculty. Portfolios, team and individual grades, and jury assessment were initiated in SynThesis and will be further developed in the future.

Curriculum Elements

The full-year course was structured loosely in four parts (although each of the topics was returned to several times): 1) Introduction to the product design and business development process (including mini projects, team and product selection); 2) project definition and prototype development in the context of needs assessment; 3) business planning; and 4) product refinement and manufacturing planning.

Initial Phase: The preliminary design exercises were intended to give the students rapid feedback from their peers and the chance to produce 'quick and dirty' design, jolting the students into the hands-on development required in the course. The peer feedback, made anonymous by web-based feedback forms, was delayed by database problems. This information is very time sensitive, and we learned that if delayed, the value of this information diminishes immediately.

The most successful of the initial exercises was the voice chip project. The student designs, given only two weeks to design and implement a fully functional voice chip-based application, were all successful and potentially viable products. The designs were innovative, widely varying and fully functional. We suspect that one reason for the success of this design exercise is that while the hardware was simple and modular, it also provided students tangible functional prototypes that verified the usability and feasibility of the products. Another exercise, 'benchmarketing', that combined product benchmarking with analysis of marketing issues was less successful. The exercise built on the pedagogically proven 'product dissection lab' activity, but the actual synthesis of the marketing information into the product picture did not work very well. The results were similar to the findings of Altman et al. in that students tended not to source the appropriate range of information (as compared to experienced designers or interested parties) or to bring this information to bear on the product. Engineering and management students need extra support in searching non-technical information and in sorting through the many types of marketing information. The teaching team will address this issue in the future by developing several exemplar benchmarketing cases that will demonstrate the scope of analysis required and will break down the information components the students are required to find. A forum for ongoing product analysis by individual students ('Product of the Week') will build a rich portfolio of products throughout the year.

Product Conceptualization Phase: This phase was the most critical in that it had enormous impact on the team performance throughout the rest of the year. The successful part of this process was that each student had to attract a team for his/her product idea. This meant that the product ideas were peer-evaluated and teams were self-assembled. When this works, it seems to guarantee the enrollment and enthusiasm of team members; however, for one team this process did not work. There may inevitably be a team of 'leftovers' who are
not able to attract persons to their proposal. In trying to preserve a valuable educational experience for the students, we are trying to explore strategies that will preserve the high motivation associated with assembling teams in this manner while not compromising the learning experience of the teams that were not able to converge on a product in the timeframe given.

Business Planning Phase: The metaphor for business planning was writing a good story, where ‘good’ story means that it is believable (supported by solid marketing research and product definition), and there is a happy ending for all involved (including the team, its investors, and the consumer). The ‘product story’ forced the students to revisit the engineering design problems and present them as ‘word problems’, which encouraged new approaches. The fact that there is a major Connecticut Venture Group Business Plan competition for academic institutions that overlaps with the time of this phase, was an extremely effective motivator. Although our teams performed very well in this phase, we believe that they need additional support in financial analysis tools. This shortcoming was indicated because none of the designs were actually revisited in the light of the financial analysis, and no tradeoffs were effected, demonstrating that the students did not ‘believe’ their own financial stories.

In each of these broad phases, we adapted to the changing circumstances in an involuntary practice we call “just-in-time-instruction.” The two class periods each week were divided into lectures and design studio time. The latter period enabled the students to work together, and to present material to their peers, faculty and invited guests. Without the organized studio space to promote the independent team activity (students used their own residences in lieu of this) the class time during the studio period was too short to accomplish actual building and prototyping activities.

The assigned deliverables, once student teams began their major projects, are listed in rough chronological order below. The list of deliverables was kept to a minimum so that the teams preserved independence to manage their own activity within the framework in which they were assessed.

Next to each category, we have abbreviated three categories: Project Conception Phase (C), Design and Design Documentation (D), and Business Planning (B).

product definition assignment ..................................................................................................... C
define user and appropriate interface and look and feel of product....................................... D
critical function review ................................................................................................................. C
define critical functions of product; and all functional parts
initial financial feasibility assignment – ..................................................................................... B
determine thumbnail of financial market, initial cost estimates

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iii See Delson discussion in this issue regarding the polarizing effects of project based courses.
iv A useful comparison is the performance of SynThesis teams vis-à-vis the performance teams constituted entirely by business school students. The entries were predominantly from business student teams and the proportion of Synthesis teams (2/3 vs. 1/15 at our institution) that made it to the finalists stage validates our approach.
and general feasibility of the product
look and feel prototype .................................................................C
design requirements document .....................................................D
   post the design requirements document on the web
functional prototype review - demonstrate critical functions in hardware ..........D
scheduling assignment ...............................................................D
methodology review ....................................................................D
1st user test results presented ......................................................D
alpha prototype .............................................................................D
   functional and look and feel ...................................................D
vendors list ...................................................................................B
   resources and vendors and material
parts drawings ..............................................................................D
present budget ................................................................................B
financial analysis ..........................................................................B
final business plan .........................................................................B
manufacturable prototype ..........................................................D
design review ................................................................................D
design requirements document .....................................................D
deliverables contract
assembly drawing ..........................................................................D
final specifications .........................................................................D
beta prototype ................................................................................D
final pre-market user tests ...........................................................D
final prototype ...............................................................................B
final presentation
final design document ....................................................................D
CT Venture Group competition entries ........................................B
course assessment

The Team Projects in 1998-99

- The Ola-Factory, a computer peripheral that delivers scents from a multi-scent cartridge, either for computer gaming or aroma therapy applications.

- The STAR Sprinkler Co., which developed a sprinkler system for conformal and programmable lawn area coverage.

- Safe Overhead Storage, which designed a new pull-down overhead system for accommodating the growing storage needs of homeowners.

Each team had at least one engineering student and one student from Yale’s Professional School of Management. There were four engineering students (three seniors and one masters student), three computer science students (two seniors and one graduate student), one biology/economics major (a senior), and three graduate student in the School of Management.
Pedagogical Challenges

The major pedagogical challenges revolved around maintaining a real world context, while assuring a supportive learning environment. Some of the steps in this effort included: requiring students to use resources beyond the academic community (e.g. vendors, fabricators; focus groups of potential end users); coordinating an appropriate external jury for each presentation and for many of the deliverables; deciding when the industry voice should be brought to bear on the student projects; encouraging company participation more generally so that students had opportunities to improve the way they presented themselves to non-academics; and other internal team management issues that replicate real world issues such as the preparation of appropriate documentation for manufacturing.

How are instructors to be viewed by students in this nonlinear product design process? As lecturers, graders, bosses, mentors, pests? Since students respond to deadlines, instructors must somehow have a set of gradeable deliverables; at the same time, instructors want to instill in students the sense of the excitement of the process that transcends individual assignments. At times this process is akin to the “conditional chaos” that is inherent in the creative process. Rather than allowing anxiety to be the result of this uncertain process, the competencies developed in this course will enable students to engage product development and negotiate the productive tensions and tradeoffs in the process.

External Validation

External deadlines are superb motivators and act as useful milestones. In addition partaking in a number of design competitions (e.g., Aspen Student Design competition and ID Magazine Design competition), the course structured the business plan deliverables around The Connecticut Venture Group’s Business Plan Competition for academic institutions. At the point in the course when the preparation of each team’s business plan was to commence, the CVG competition began, first with an initial phase entry (to the number of statewide entries), and then two months later a full business plan was due. Each of the three SynThesis teams participated as a course requirement. Two made it into the finals, and one group—The Ola-Factory won the $20,000 first prize. The competition was timed so that the winning team would be able to participate in Connecticut’s annual Venture Fair, where venture capitalists and others are invited to hear entrepreneurs “pitch” their company’s new initiatives. Several hundred attended, and our winning team performed exceptionally well.

Outcomes

Students and faculty in SynThesis were immersed in a creative process: the creation of a new course. The ingredients were all there: good design materials, sound business planning, good interactions with a diverse faculty and with experienced industry leaders, etc. Of course, the ingredients do not always guarantee a good meal. The methods of preparation are crucial. In many respects there were many lost opportunities for coherency (exacerbated by the diversity of the projects undertaken). For example, many of the
materials about the design process and the course expectations will be assembled in a loose leaf notebook and provided to each student beginning the course to provide them a shared set of references to build upon.

Probably our biggest shortcoming in the past year was not having a formal design studio space and adequate class studio time. This approach would allow instructors, acting as mentors, to observe and facilitate a regular weekly activity of each team, reduce organizational overhead and provide the stage for the many diverse interactions that constitute design activity (understood as a social process).

Timely feedback by students (both self-assessment and team assessments) and by faculty is essential. This process can be web-based and anonymous, with some quantitative data going into a database for analysis of longitudinal trends.

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References


Other relevant papers include:


