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Enabling and Characterizing Twenty-First Century Skills in New Product Development Teams*

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This paper outlines a New Product Development (NPD) class designed to enable 'flat world' skills—multidisciplinary teamwork, rapid prototyping, creativity, business, entrepreneurship and human-centred design. This course aims to develop the skills necessary for successful product development in today's competitive global marketplace. To accomplish a truly multidisciplinary dimension, the graduate course draws students from UC Berkeley's Engineering, Business, and Information Systems departments, as well as from the Industrial Design programme at the California College of the Arts. Students from all of these programmes and colleges join forces on four to five person product development teams to step through the new product development process in detail, learning about the available tools and techniques to execute each step along the way. Each student brings his/her own disciplinary perspective to the team effort and must learn to synthesize that perspective with those of the other students in the group to develop a sound, marketable product or service. Students depart the semester understanding new product development processes as well as useful tools, techniques and organizational structures that support new product development practice. In recent years, we have added material on social entrepreneurship and have encouraged socially-conscious design projects. This paper presents quantitative and qualitative data gathered to evaluate teams and project-based learning outcomes along with case studies of three socially responsible ventures from our class that took the next step in regards to further developing their product or service after the end of the semester. Third party structured interviews and post mortem analyses of these teams provide a window into what enabled them to move their products to the next stage beyond the semester course. The three cases covered are: AgLinx Solutions, Revolution Foods and Seguro. All of these successful teams had a core group of dedicated student leaders who worked with teams having a diverse mix of skills.†

Keywords: New product development; socially-responsible design; entrepreneurship; project-based learning; design education

INTRODUCTION

THE NATIONAL ACADEMY OF ENGINEERING recently released two reports that identify the 'flat world' [1] skills that engineers will need in the increasingly interconnected environment of the twenty-first century. The 'engineer of 2020' reports [2, 3] were motivated by industry projections of the forces that will frame the future environment for engineers and the requisite key attributes that will support the success and relevance of the engineering profession in 2020 and beyond. The reports described the drivers that will shape engineering in the 'flat world':

- The pace of technological innovation will continue to be rapid (most likely accelerating).
- The world in which technology will be deployed will be intensely globally interconnected.
- The population of individuals who are involved with or affected by technology (e.g., designers, manufacturers, distributors, users) will be increasingly diverse and multidisciplinary.
- Social, cultural, political, and economic forces will continue to shape and affect the success of technological innovation.
- The presence of technology in our everyday lives will be seamless, transparent, and more significant than ever.

The reports argue that in addition to maintaining strong analytical skills, engineers of the future will increasingly require practical ingenuity, creativity, communication skills, high ethical standards, a strong sense of professionalism, leadership, busi-

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ness and management skills as well as higher level abilities to be able to engage in lifelong learning and to respond quickly to unpredicted market and society needs with dynamism, agility, resilience and flexibility.

Individual students must be taught these 'flat world' skills, and we believe the best way to do so is through a multidisciplinary and multicultural team context. Project-based learning is thus an appropriate pedagogical approach to teaching these skills [4]. Creating and encouraging entrepreneurship in project-based courses is a challenging task, and it is even more challenging to assess the learning outcomes in innovation and entrepreneurship courses [5]. Encouraging students to pursue socially relevant or responsible businesses in class is also a challenge [6] but is an important part of helping future designers and engineers develop successful products that are responsive to human needs in a global context. Mikic *et al.* [7], after embedding socially conscious projects in a freshman level engineering course at Smith College, report that students claim that the projects taught them not only the value of working in teams, but also the value of socially responsible design in engineering practice.

Looking at entrepreneurship and innovation education more broadly, Hamilton *et al.* [8] teach a technology-based entrepreneurship course at Brown University, with the goal of giving undergraduate juniors and seniors a 'real-world' entrepreneurial experience. The course focuses on helping engineering students experience team work and develop the business skills necessary to succeed as a technology entrepreneur. SynThesis [9] is a product design and business course offered to graduate students at Yale University. Similar to our New Product Development (NPD) course, the course at Yale embodies a project-based learning approach and places students together on multifunctional teams, drawing from the engineering and business schools on campus. Evans *et al.* [10] discuss a broader entrepreneurial programme that is in place at the University of Texas at Austin, called I2P. I2P helps foster entrepreneurship and technology commercialization by educating students and providing them with resources necessary to promote team development and a product concept. This is achieved in part through courses and business plan competitions. The program draws students from diverse backgrounds as well: Law, Engineering and Business. Feland *et al.* [11] at Stanford University also acknowledge the importance of integrating business, engineering, and user-centred curricula and discuss a proposal to extend the current Product Design programme, an integration of art and engineering, into a more comprehensive design programme.

Teaching 'twenty-first century' skills, especially social entrepreneurship, potentially enables students to be successful in their work beyond the university, and in particular to form ventures that have a positive societal impact. How can a new product development course at the University of California, Berkeley help students develop the 'flat world' skills necessary to create innovative products for a competitive marketplace. Because the NPD course at UC Berkeley is similar to multidisciplinary courses taught at other colleges and universities, such as Arizona State University, Carnegie Mellon University, Massachusetts Institute of Technology, University of Michigan, University of Illinois, the results of our research are broadly applicable.

RESEARCH SETTING: NPD CLASS AND ITS IMPACT

The NPD course is part of the graduate-level Management of Technology (MOT) programme at the University of California, Berkeley. Graduate engineering, information sciences and business students from Berkeley and undergraduate industrial design students from the California College of the Arts joined forces in small product-development teams, using a project-based learning approach [4, 12], to step through the new product development process in detail, learning about the available tools and techniques to execute each process step along the way. Although the course focuses on the application of these principles to new product development, they are more broadly applicable to innovation in general—of products, services, organizations, business strategies and governmental policies. Our project- based learning approach sensitizes students to the key issues of new product development in a global market, with the goal of developing 'flat world' skills through peer learning and the development of shared understanding of 'flat world' issues. In short, we expose students to the knowledge they need to work effectively in multidisciplinary high performing teams. Our graduate course is unique in that it accommodates a balanced representation of both faculty and students from across the business, engineering/information science and industrial design disciplines.*

We recently completed a longitudinal study of the impact of the course content on the development of 'twenty-first century' skills by students who have graduated from our course and are pursuing careers in industry [13]. In Fall 2006, teams of business, information science and engineering graduate students conducted 21 in-depth interviews with alumni who took the course between 1995 and 2005. The alumni were asked to rate topics covered in the course (identified by students in the course as important) on a scale from 1 ('not important') to 5 ('very important') to assess how important the topics are to them in

* More detail on the NPD course and lists of project topics over the last decade can be found at the course website at: http://best.me.berkeley.edu/%7Eaagogino/me290p/me290p.html

Table 1. Summary of ranking of NPD methods and skills valued by alumni [13]

Rating of Course Topics/Skills/Methods	Averages (1–5 scale)	Standard Deviation
Working in teams	4.75	0.55
Concept generation / creativity	4.35	0.93
Prototyping and testing	4.25	1.12
User needs identification	4.20	1.28
Setting goals & working with a mission statement	4.10	0.91
Effective meetings & scheduling	4.00	1.08
Concept selection	4.00	1.03
Project management	3.70	1.03
Financial, economic & business	3.40	1.31
Design for assembly/manufacture/environment	3.00	1.62

their current job. As summarized in Table 1, on average all of the topics were rated 3 or higher, suggesting that all were of value to the alumni, but alumni most valued what they learned about team work, concept generation/creativity, understanding user needs, prototyping and concept testing. The next most valued were setting goals and developing a mission statement. This work confirmed the value of engaging students in multidisciplinary design projects to develop the skills needed in today's competitive new product development environment.

FOSTERING INNOVATION AND SOCIAL ENTREPRENEURSHIP

There is no doubt that interest in social entrepreneurship has grown steadily since its identification and definition in the early 1970s [14]. We start this section with some definitions of social entrepreneurship, and then present an analysis of the types of projects our students have chosen to work on in the NPD class, and how their choices have changed over time.

At the most fundamental level, an entrepreneur is defined as 'a person who organizes and manages any enterprise, especially a business, usually with considerable initiative and risk' [15], and entrepreneurship as 'the organization, management and assumption of risks of a business or enterprise, usually implying an element of change or challenge and a new opportunity' [16]. Social entrepreneurship has not been quite so specifically defined to date; some suggest that it exclusively refers to not-for-profit ventures, while others include large for-profit businesses that address some socially responsible agenda [17, 18]. Dees [17] synthesizes the various definitions found in the literature to characterize social entrepreneurs as those who adopt a 'mission to create and sustain social value' and engage in a 'process of continuous innovation, adaptation and learning'.

Although social entrepreneurship is most often viewed as a not-for-profit business, we adopt a wider definition, and analyse our class projects independent of their profit or non-profit goals. We adopt a working definition of social entrepreneurship from Mair *et al*. [18]:

> a process involving the innovative use and combination of resources to pursue opportunities to catalyze social change or address social needs.

Using this definition, we consider projects in our NPD class representative of social entrepreneurship when they have missions that sustain some social value and are relevant to society's most pressing social needs.

Since 1995 there have been 139 NPD projects in our course. We captured all student deliverables for these projects, including the original project proposals and the project mission statements, as well as detailed survey data from each of the students and teams about the focus of their

Table 2. NPD project categories

Project Category	Total No. of Projects (1995—2006)	No. of Socially Responsible Projects (excluding 2005)	No. of Projects in 2005 (All Socially Responsible)
Comfort & Leisure	30	0	0
Outdoor Recreation & Sports	24	1	0
Communication/Software Technologies	24	0	2
Food Experience	16	2	0
Health & Safety	13	6	5
Energy, Environment & Agriculture	7	5	1
Children	7	2	1
Computer Accessories	6	0	0
Home Technologies	4	0	0
Disabilities	4	1	3
Students & Education	3	1	0
Total	139	18	12

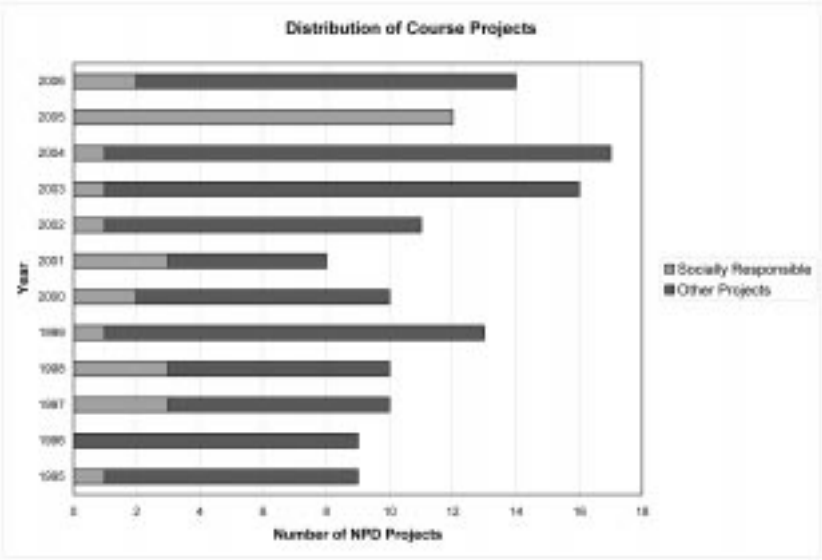

Fig. 1. Distribution of NPD projects by year.

projects and the values they felt their projects represented. We used these documents, and more specifically the descriptions of the projects as represented by their mission statements, to iteratively cluster projects into the categories shown in Table 2 based on both the primary markets served and the needs addressed by the projects. Many of the projects could be categorized under more than one category, but we selected a single category for each based on its primary mission. By definition, because students propose projects that address an unmet market need, all of the projects were entrepreneurial in nature. Thirty of them were specifically classified as socially responsible, or as addressing a pressing social need.

Table 2 shows the range and types of projects students have chosen to work on over the years. A large number of projects are dedicated to Comfort and Leisure (e.g. alarm clocks, travel bags), Communication and Software Technologies and Recreation and Sports; however, very few projects in these categories are classified as addressing pressing societal needs. The large number of projects in these three categories is largely due to the fact that students often propose and choose projects to serve unmet needs of immediate interest to them, and for which they have easy access to a user community to do interviewing and concept testing. Due to the limited 15-week duration of the projects, students also often limit themselves to projects they feel can be accomplished within the semester; only a few form projects with a broader vision that can extend beyond the class.

In 2005, we required students to select a socially responsible project, so all projects in that year are categorized as such. Figure 1 shows the relative proportion of projects that were considered socially responsible in each year of the class.

These data suggest that, with the exception of 2005, the number of socially responsible projects per year has been relatively stable over time, ranging from one to three per year. There is no clear indication of increased interest by the students in socially responsible projects over the ten-year period of this research.

TEAM COMPOSITION AND GENDER DISTRIBUTION IN CLASS

The NPD projects typically have a diverse mix of gender and disciplines. We examined the proportion of women students who take the NPD class relative to their presence in the general population of students from which they are drawn, and checked whether or not there is a relationship between types of projects chosen and the proportion of women in the class.

The process of selecting projects and forming teams for the class starts with each student presenting a project proposal, preferably around an unmet market need, to the class in both written and oral forms. Based on that information, students submit their preferences for the top five projects on which they want to work. The faculty takes that information and creates teams with at least one MBA, one engineer, and one industrial design student, attempting to place students on their first or second choice project. Some students request to be on a team with specific peers; that information along with gender and strength of students' skills is considered when making the teams.

Six hundred and fourteen students took the project-based NPD course between 1996 and 2006, 184 (30 per cent) of which were women and 430 (70 per cent) were men. Table 3 shows the absolute numbers of students by gender and year as well as the percentages for 1996–2006. The NPD class from 1995 was not included in the gender

Table 3. Gender percentages by year

Year	Number of Females	Number of Males	Total Number of Students	% Female
1996	13	32	45	28.9%
1997	11	34	45	24.4%
1998	14	37	51	27.5%
1999	16	45	61	26.2%
2000	11	38	49	22.4%
2001	15	24	39	38.5%
2002	17	35	52	32.7%
2003	26	47	73	35.6%
2004	18	60	78	23.1%
2005	21	43	64	32.8%
2006	22	35	57	38.6%
Average	16.7	39.1	55.8	30.1%
Standard Deviation	4.7	9.4	12.2	5.9%

Table 4. Gender distribution in NPD course by discipline*

Discipline	Number of Females	Number of Males	% Female in class	% Female in local campus pool
Industrial Design (1999–2006)	28	62	31.1%	30.0%
Engineering (1996–2006)	71	162	30.5%	22.4%
Information (2001–2006)	16	12	57.1%	49.8%
Business (2001–2006)	36	100	26.5%	26.5%

* Numbers of females in the general population were gathered from departmental administrative offices. Numbers were not available for all years from all programs, so comparisons are made only for the years in which numbers were available.

analysis since this data were not available at the time of the writing of this paper. The percentage of women in the class has fluctuated from as low as 22.4 per cent in 2000 to as high as about 39 per cent in 2001 and 2006.

As the graduate NPD course is an elective that students may chose to take, we examined gender for evidence of whether or not there is a bias in who selects this course. There appears to be some selection bias by discipline as shown in Table 4. On average, graduate students from UC Berkeley's College of Engineering are 22.4 per cent female, but the NPD course has 30.5 per cent female engineering student participation. Information Sciences students also have stronger female representation in the NPD class (57.1 per cent) than in the general Information Sciences program (49.8 per cent). In contrast, business students are equally represented in the NPD class (26.5 per cent) when compared to their representation in the general population (26.5 per cent). The CCA industrial design students were required to take the NPD course as part of their curriculum, so their gender distribution in the NPD class is the same as that of the general CCA population (roughly 30 per cent women). We should note here that all three of the faculty teaching the course have been female in six of the ten years covered by this study, and two of three have been female in the other four years, which may affect choice of the class by female students. We could not find a statistical correlation between the percentage of women in the course and the percentage of socially responsible projects completed in the course, implying that gender does not appear to impact the selection of socially responsible projects.

STUDENT AND TEAM VALUES

Each team member arrives at the early phases of a design project with his or her own set of assumptions that guide his or her interpretations and actions, sometimes referred to as a frame [19]. Frames are 'underlying structures of belief, perception and appreciation' [20] comprising implicit assumptions about what issues are relevant, what values and goals are important, what criteria can be used to evaluate success. Designers' frames work in concert with their professional knowledge to influence the decisions they make and actions they take [21]. Frames form the basis upon which designers pair problems with solutions [21, 22, 23]: the selection (or assumption) of a desired end state or goal implicitly includes the identification of a problem or need and conversely, the identification of a problem or need implicitly implies some desired end state or goal. In the context of this paper, we expect that students working on socially responsible projects would have different personal frames, and that the teams would develop different shared frames than students on less socially responsible projects.

In 2005 and 2006 we surveyed the NPD students to better understand their personal values as well as

Table 5. Summary of personal and team values

Class Year	Top 3 Values (Personal)	Top 3 Values (Team)	Lowest 3 Values (Personal)	Lowest 3 Values (Team)
2005	CREATIVE LEARNING FUNCTIONAL NEEDS	FUNCTIONAL NEEDS CREATIVE MORALE	PARTNERS PROFIT TECHNOLOGY	PROFIT PERSONALITY TECHNOLOGY
2006	EMOTIONAL NEEDS MORALE PROFIT	EMOTIONAL NEEDS PROFIT MORALE	EVALUATION COST PARTNERS	BENEFIT EVALUATION PARTNERS

what they perceived to be the shared values of their teams.* The values survey was administered at mid-semester and semester-end to see how the students' perceptions of their values changed. The students were given fourteen values including: benefiting a specific group or society without regard for profit, completing project deliverables on time and with efficient use of resources, and building a profitable, self-sustaining business. We asked the students to (1) select the three most important and three least important values to them personally and (2) select what they perceived to be the three most important and three least important values to their team as a whole. There was little change between the mid-semester and end of semester results, so we report here on the end-of-semester results. The results are shown in aggregate form in Table 5 and are also discussed in depth below.

Not surprisingly, the students in 2005, who were all focused on socially responsible projects, held different values both personally and as teams than did the students in the 2006 class where only two of the projects were focused on socially responsible objectives. The top three most highly ranked personal values in 2005 were: developing a creative, unique and innovative product/service (CREATIVE), learning about the NPD process and teamwork (LEARNING), and satisfying users' functional and technical needs (FUNCTIONAL NEEDS). The top three most highly ranked team values in 2005 were: satisfying users' functional and technical needs (FUNCTIONAL NEEDS), developing a creative, unique and innovative product/service (CREATIVE), and working in a way that supports group cohesion and morale (MORALE).

The three most highly ranked personal values for the students in the 2006 class were satisfying users' emotional and social needs (EMOTIONAL NEEDS), working in a way that supports group cohesion and morale (MORALE), and building a profitable, self-sustaining business (PROFIT). The three most highly ranked team values for the 2006 class were the same, but ordered as EMOTIONAL NEEDS, PROFIT and MORALE.

On the other end of the ranking, the 2005 students least valued items personally were taking all business partners, supply chain and institutions into account (PARTNERS), building a profitable, self-sustaining business (PROFIT), and developing an exciting new technology (TECHNOLOGY). Their lowest ranked team values were PROFIT, creating a final project that reflected their unique personalities and values (PERSONALITY) and TECHNOLOGY.

The lowest ranked personal values in 2006 were being evaluated positively in the class (EVALUATION), keeping the costs of the product/service low (COST) and PARTNERS. The lowest ranked team values in 2006 were BENEFIT, EVALUATION and PARTNERS. Some of the differences in highly ranked values between years seem obvious: that the students in 2006 would be more focused on PROFIT than the students in 2005 is not entirely surprising. What is interesting is the difference in focus on FUNCTIONAL NEEDS versus EMOTIONAL NEEDS, and the extent to which the students in 2005 focused on LEARNING from the class and being CREATIVE, perhaps as a result of working on projects that they did not necessarily see as having a profitable future.

Similarly, differences in low ranked values follow a similar pattern. The socially-responsible teams from 2005 ranked PROFIT low, while the 2006 teams ranked BENEFIT low, with the exception of the Seguro team, which ranked BENEFIT highest on both the personal and team values due to the socially-conscious nature of its project. We highlight Seguro as a case study in later sections of this paper.

This area deserves further exploration to better understand what role the values of the individuals on the team have to play, how those values are brought together to develop a shared set of values on the team, and how value differences play out with respect to social entrepreneurship.

TOLERANCE FOR AMBIGUITY AND NEED FOR CLOSURE

The intolerance of ambiguity (or low 'tolerance for ambiguity') is 'the tendency to perceive ambiguous situations as sources of threat' [24] and is associated with a high cognitive tendency and high motivation to seek certainty. It has been hypothesized that a low tolerance for ambiguity leads

* The surveys were developed by PhD candidate Caneel Joyce at the Haas School of Business. She is still in the process of validating them and analyzing the data in the context of her research on the role of framing in concept selection. We provide here a summary of some of the pertinent results to date.

people to cling to the familiar and arrive at the early selection of one solution in ambiguous situations. It is associated with dichotomous or 'black and white' (as opposed to probabilistic or 'grey') thinking.

The need for cognitive closure (NFC) describes both a personality-level trait, and a situationally-induced motivation. Related to the intolerance for ambiguity described above, NFC refers to 'the expedient desire for any firm belief on a given topic, as opposed to confusion and uncertainty' [25]. It has been shown to result in 'seizing' on the first information available that will provide closure in an uncertain situation, and 'freezing' upon closure once it has been retained, rather than remaining open to constant change. Laboratory studies indicate that a high NFC is associated with stereotyping, falling prey to 'impressional primacy' (pervasive first impressions), and the tendency/ability to resist persuasion [26].*

We assessed both tolerance for ambiguity and need for closure with a survey administered to individual students in the NPD class in 2005 and 2006. What we learned is that teams with higher diversity in need for closure and tolerance for ambiguity among team members performed better at the end of the semester. Thus, while it might be argued that good entrepreneurs have a high tolerance for ambiguity and low need for closure according to organizers affiliated with the National Collegiate Inventors and Innovators Alliance (NCIIA) [27, 28], our research suggests that successful teams have some representation on both ends of the spectrum. This allows them to explore widely during periods of divergence, and narrowly when convergence is required.

SUCCESSFUL PROJECT CASE STUDIES

We have examined some of the data from ten years of NPD classes to understand whether or not there is increased focus by the students on social entrepreneurship, whether or not gender makes a difference in the students' choices, how student and team values differ when students focus on socially responsible projects, and how tolerance for ambiguity and need for closure play a role in team success.

We now turn to a presentation of three case studies of entrepreneurial ventures—Revolution Foods, AgLinx Solutions, and Seguro—that developed beyond the projects in our class, all ultimately becoming socially responsible efforts. We used third party structured interviews and post mortem analyses of these teams to understand what enabled these teams to move their products to the next stage of entrepreneurship. The Seguro team attracted a high percentage of under-represented minority students. Both Revolution Foods and Seguro are women-led ventures. We first present the overall mission of each venture and then highlight what factors enabled these teams to grow into successful ventures.

Revolution Foods

Revolution Foods [30] was launched as a company in August 2006 and today provides nine schools in Oakland, California with 1,500 healthy lunches each day as well as breakfast and snack items in specific cases. In the words of the founders, their vision is:

> All children will have access to nutritious, tasty food to support the development of healthy minds and bodies. Our mission is to dramatically improve the food and food service experience in US schools in order to reduce obesity and improve health, education and well being for students in communities across the United States.

The group's mission statement targets childhood obesity, health and student health education. They are also expanding to educate parents about healthy food, potentially creating another set of customers for the company, and are launching a branded set of healthy food products with Whole Foods Markets.

The concept for Revolution Foods was conceived by a business school student before the NPD class and then proposed as an NPD course project in Fall 2005. She was joined by one engineering, one industrial design and two business students. Another team of students worked on a related project, developing a credit card mechanism for purchasing school lunches, in a different design course. The two teams communicated frequently about their work.

During the Fall 2005 course, Hey *et al.* [19] found that the Revolution Foods team had a very strong shared frame and vision for their project. This shared frame amongst the team members reduced the amount of conflict over the project direction. The team stated that they used their project mission statement as a guiding vision that reflected the team's values of providing a socially responsible solution.

In recent interviews with the former team members, they said that the NPD course gave them an opportunity to better understand their customers, but at the time they felt that they did not adequately address core elements of their business such as nutritional lunch composition, customer satisfaction with prepared food, and cost, to name a few, during the NPD course. The group initially focused its efforts on the design of a lunch tray, fearing they had limited time during the semester to prototype their design concept and perform multiple iterations and wishing to gain richer feedback from their customers.

* PhD Candidate Caneel Joyce is also working on research to determine how need for closure and tolerance for ambiguity relate to NPD success. The development and administration of this questionnaire was done by her as part of her doctoral research [29].

Fig. 2. (Left) NPD lunch tray prototype from Fall 2005; (right) elementary school kids enjoying healthy lunches provided by Revolution Foods in 2006 [30].

During the course, the founders felt that they did not fully utilize all of their members to the extent they could have. The three MBAs on the team had a tendency to focus more on the business aspects of the project rather than building a product. Team members also had differing levels of commitment; some were interested in the project for its potential as a real business and some were only interested in completing a project for the course. Within the constraints of the class, the team felt they did the best they could, but that their own design timeline for Revolution Foods was broader than the timeline of the fifteen week NPD course.

The three business school students launched the Revolution Foods concept after class along with one other business school student from the other class who serves on the company's advisory board. One of the original founders has since left the company. Revolution Foods works with Whole Foods as a supply-side partner and recently won the Global Social Ventures Competition at the Haas School of Business.

Consistent with the importance ratings from the alumni interviews in Table 1 above, the former team members cited the following as their main lessons learned from the NPD course:

- Learning how to work in multidisciplinary teams and how to leverage the strengths and weakness of the teams;
- Learning brainstorming and concept generation processes;
- Gathering and analysing user needs;
- Three areas the team felt they could have improved upon at the initial stages of the process are:
  1) Producing a more creative looking product and going beyond a basic 'Lunchables' appearance;
  2) Learning more about the logistics of providing meals in schools;
  3) Pursuing different funding options.

Aglinx Solutions

AgLinx Solutions, another NPD project, was successful in obtaining funding from the National Collegiate Inventors and Innovators Alliance (NCIIA) E-Team grant and winning a campus innovation award for social ventures to further develop their product. In their own words, their original mission was to:

> Improve the current solutions for protecting wine grapes from spring frosts and summer heat. We are committed to providing a complete monitoring solution for vineyards that is compatible with the existing infrastructure.

Their original product, called VinePod, focused on use of sensors and precision agriculture in wine vineyards. The VinePod concept was conceived by one of the original team members in Spring 2004 while enrolled in another Haas School of Business course where the student was discussing with a faculty member how vineyards currently deal with frost in the Napa Valley. The student wanted to develop a better way to solve the problem. The student enrolled in the NPD course in Fall 2004 where he, along with a team of business students and an industrial designer, had the chance to further develop the idea. The Aglinx team was one of the few to have a fully functional prototype for the final class tradeshow. After the tradeshow, the students thought there was more they could do to enable new farming techniques with their current design idea. They wrote a grant proposal and received funding from the National Collegiate Inventors and Innovators Alliance (NCIIA). They expanded their focus and entered the Haas Business Plan competition and made it to the semi-final rounds.

After further developing their product and market projections, they realized that protecting vineyards from frost was too limited a market to be profitable. In addition, a more thorough competitive analysis revealed that less expensive, easy to implement commercial options existed.

Fig. 3. VinePod prototype

Their market research, however, revealed an even bigger market for use of wireless sensors for precision agriculture to optimize water consumption and thus conserve its use. Aglinx is unique in that they originally did not start out as a social venture, but over the course of the year after the class, they refocused their efforts to turn their project into a more socially-conscious project. Their new mission became:

> This project aims to mitigate state water scarcity by increasing the effectiveness and efficiency of irrigation, increasing the stability the food supply. Optimal and effective irrigation can mitigate pollutant run-off, ground water contamination, soil salinization, pest infestations, disease outbreaks, and top soil loss. Reduced chemical use will also promote more sustainable practices and improve worker health.

Aglinx also won a 'big ideas' award from the Center for Information Technology in the Interest of Society (CITRIS) to further develop and market their product (Figure 3). One member of this team is also applying similar wireless micro-sensor technology to monitor air pollutants in remote homes in Ecuador.

The members of the current team stressed the difficultly of student retention as many of its former members moved on to other projects or graduated and pursued their careers independent of the initial VinePod project. They said their project lost momentum in December 2005 when the industrial design and business student team members left the project to focus on other commitments, reducing the team to three engineers. Team members lost their focus as they struggled to move their class project to a solid business.

Some of the lessons the students learned through their project are:

- Having an understanding of the required work effort and time commitment is recommended.
- Getting feedback early is important: The team made a lot of assumptions and only fully tested them after the class. Some of the assumptions turned out to be incorrect. Validating technology assumptions earlier in the process would have saved time.
- Team diversity was also important. While the engineering students were very passionate about the project, the diversity of the original team made it more successful.

Seguro

Seguro originated as a proposal by two of the NPD faculty with a grant from Proctor & Gamble and the Industrial Design Society of America (IDSA) to look at the underserved market of farm workers and migrant communities in California's Central Valley [31, 32]. Seguro began as an interdisciplinary design collaboration between NPD and design students from UC Berkeley and the California College of Arts in Spring 2005. The team involved students in a freshman design class at UC Berkeley and CCA Industrial Design and Graphic Design students taking an independent study. Graduate student mentors from UC Berkeley joined the project on a volunteer basis. Working with the Anita Borg Institute of Women and Technology [32], the student team ran an innovation workshop and performed user needs studies with farm workers in California's central valley and produced several rough concepts. This work was presented by the team to Proctor & Gamble at their headquarters in Ohio. Our graduate NPD class then adopted the project in Fall 2005 with one of the previous graduate student mentors as an advisor. The group investigated how technology can help improve the health and safety of farmworkers, their families, and the general community. From that initial needs analysis the group generated potential solutions to reduce pesticide harm to farm workers.

> Seguro's mission is 'to develop technologies that will protect farm workers and their families from pesticide exposure as well as increase awareness of the pesticide problem'.

The Seguro team developed a first generation of products that allows farm worker communities to both protect themselves from pesticide exposure in the fields, and track short- and long-term exposure levels in the fields and in the workers' homes. Their design consists of a protective suit with associated glove, face, and footing protection in order to prevent pesticides from entering the farm worker's body while working in the fields, and a network of pesticide sensors that can detect and record pesticide exposure levels from the field to the home. The Seguro student team won an NCIIA grant to further develop its product to the pre-commercialization stage. Although it originated as a faculty idea, the project was taken on by an evolving student team with one motivated graduate student leader to further refine the product working with the farmworker communities.

Unlike the other case studies, Seguro has been able to draw a large number of students after its introduction to NPD courses. The continual influx of students has helped to keep the project going, whereas many of the NPD projects which struggled to move forward had a difficult time maintaining a significant number of students. These students may work on the project at certain times and then leave to pursue other interests. But the main team leader, an African-American engineering graduate student, has been with the project since the beginning and views Seguro as a product which can have a great social impact.

> ''I was dedicated to Seguro and I decided to stick with Seguro . . . For me, I feel anything I aspire to do has to have a social impact, otherwise it's useless . . . we were not put here to satisfy the one percent that have the resources . . . We can produce great products for some great people.''

The team leader of Seguro emphasized that NPD tools facilitated the research and development of the solution, highlighting user needs analysis and concept selection techniques as the top two most valuable tools for the Seguro project. She also expressed the importance of team diversity in terms of individuality and expertise:

> ''It's important to have a multidisciplinary project . . . sometimes you may not, as an engineer . . . necessarily think of the social aspects sometimes and it's good to have someone in social science . . . come and bring their expertise into the group.''

The team leader for Seguro is motivated to continue with the project as she passionately believes in its social mission. Currently, the Seguro team has six students who work actively on the project. The student leader emphasized that working on Seguro has shown her the importance and difficulties of managing and leading two completely different projects (Seguro and her own graduate research) and maintaining a personal life and family at the same time.

> ''Bringing inventions to fruition is difficult . . . One of the characteristics of a group leader is time management . . . That was something I thought I was good at, but after becoming the team leader I felt that I needed to re-evaluate my idea of good time management skills.''

CASE STUDY FINDINGS

The common thread among the case studies is that having a project concept already defined before the NPD course increases the odds that students will pursue the project after class. Those who formed the concept outside of class already had a passion for and commitment to that area. The students who came into the NPD course with project ideas already in mind had preliminary business proposals or design concepts already laid out in some form, giving them the advantage of applying the NPD process more effectively. Although these students may have had a jump start on a project concept, the NPD course gave them the skills, methods, and tools necessary to begin turning their concepts into successful business or social ventures. Engaging in a strong human-centred design and innovation process supported these teams in helping them develop compelling social and business cases for obtaining funding to continue their work after the class.

In addition to the projects we expanded into cases, we are aware of one more project from Fall 2005 that is moving forward—Childhood Obesity. Childhood Obesity's mission is to develop activities and products that can help reduce the problem of childhood obesity. The team has been working on their project sporadically over the last two years. However, due to most of the team members' industry commitments, the amount of time they have been able to devote has been limited. Recently, the team has started to aggressively pursue additional funding sources with the goal

Table 6. Summary of case studies

Name	Mission	NPD Project Inception	Current Status	Success Enablers
Revolution Foods	Provide healthy and nutritious food to U.S. schools	Fall 2005	Collaboration with Whole Foods; Currently providing nutritious lunches to schools in the San Francisco Bay Area	Conceived idea before NPD class began Strong shared frame
Aglinx Solutions	Wireless sensor network solutions for precision agriculture	Spring 2004	NCIIA grant completed; One team member is working at a start-up using similar sensor technology for conserving and optimizing home energy usage	Conceived idea before NPD class began
Seguro	Protect farmworkers from pesticide exposure	Spring 2005	Several more generations of the design have been tested. The student team has expanded members to include students and faculty from Mexico; The goal is to manufacture in a joint venture between the U.S. and Mexico.	NPD Faculty initiated concept Constant influx of students

of turning their former project concept into a socially responsible business.

REASONS FOR NOT PURSUING NPD PROJECTS

The previous section examined three successful social entrepreneurship efforts that grew out of our class. To our knowledge, the majority of NPD student projects, however, do not make it beyond the semester-long course. It is important to note that our first priority is ensuring students learn the necessary NPD tools, team and process skills that are vital to succeeding in jobs in innovation and design. Our previous work on NPD lessons learned [33] and an NPD alumni study [13], helped us to confirm that the NPD course is indeed meeting its learning objectives, and students are now successfully practicing user-centered design and innovation processes in their current endeavours. Turning NPD projects into entrepreneurial ventures, is strongly encouraged in the course, but not required.

NPD graduate students and a teaching assistant from the 2006 course conducted in-depth semi-structured interviews with 21 alumni from 1995–2005 to better understand what factors prevented students from turning their projects into entrepreneurial ventures. Alumni were asked about the current status was of their former NPD project, if they had ever considered pursuing it further, and why they believe the project ended. The alumni were asked these questions as a way of guiding the interview, but each interviewer focused on drawing out the story each alumni had about their project and team dynamics to better understand their reasons behind not pursuing their project further. The interviews were coded in an iterative manner to draw out the major themes and categories and identify the factors that prevent students from pursuing both socially-conscious and non-socially-conscious projects further.

Many of the alumni considered, at least in passing, the idea of taking their NPD projects further once the class finished. Reasons for why the projects never made it vary based on the team project and individual. Some of these factors are described in Table 7.

Many alumni attributed the project ending to a lack of motivation or different goals and schedules amongst team members once the class was over. Alumni who felt they had a great idea and wanted to pursue it further often lost the motivation once one or more team members decided not to become part of the project. Many felt that they had a great concept, but realized that the final tradeshow results were far from being the final design. The amount of effort and work required to take the project to market did not seem appealing to the teammates involved. Most often, the problem with taking a product to market is that the team either did not fully understand their customer or only a few team members were interested in proceeding with the project beyond the class. In this case, a team often lost critical functional roles, and the team members left behind did not know how to proceed further with the product concept they had generated. The overall feeling among alumni was

Table 7. Alumni reasons for not pursuing NPD project further

Category	Description	Example Response	No. of Responses
Different commitment levels	Team members were interested, but had prior career goals and commitments before entering the course	". . . Team members decided to take different directions in their careers, and we did not have the time and money to further develop and refine the product."	9
Not fully understanding the customer	Misunderstood who their user was and what the salient needs were	". . . our user needs research wasn't thorough, [we] got good and bad feedback from judges."	4
Required more design iteration	Teams needed to iterate and do more research beyond the course	"Many students do not realize is that the final prototype presented at the tradeshow is far from being final."	3
Poor business model	Team did not understand the business aspects of taking a product to market	"The product we thought about did not offer viable business model."	2
Loss or lack of functional team roles	Core team members decided they did not want to pursue the project further	"The leadership wasn't there to keep product in the market."	2
Competitive market	Impression that one's product is already on the market or required large scale facilities and resources to be successful	"For a second, we considered taking it to market. . . We looked into it. The 2 geniuses in a garage idea is a myth—[the project] really needed to happen in the context of a large manufacturing outfit."	2
Technology not available	The necessary technology that would make the product a success was not easily accessible	"It was a little too early for the LED and lighting technology and market readiness."	1

that even though some of their projects has entrepreneurial potential at the time, most came into the class with prior goals and career plans in mind.

In the NPD course, the instructors help the students develop the team skills and human centred design process knowledge that is necessary to create new innovative products and services. Many of our course alumni have moved on to product manager, design, and innovation roles in companies, and some took the next step to form their own entrepreneurial ventures. In our sample of 21 alumni from 1995–2005, over half (twelve of the 21) indicated that they are strongly involved in an innovation role in their company. Two of the 21 alumni started and are still running their own companies: LightFull Foods [34] and PlaceSite [35]. LightFull Foods began as a concept in another business school class to create healthy smoothies. PlaceSite uses wireless networks to strengthen local communities and grew out of a Masters project at UC Berkeley. Although these ventures did not come from NPD projects, the alumni indicated that the tools, methods, and skills learned in the class—specifically, tools for concept generation and understanding user needs—have helped them in their current entrepreneurial activities.

CONCLUSIONS AND RECOMMENDATIONS

We started this paper by introducing the skills required for engineers to be successful in the 'flat world': practical ingenuity, creativity, communication skills, high ethical standards, a strong sense of professionalism, leadership, business and management skills and the ability to respond quickly to unpredicted market and society needs with dynamism, agility, resilience, and flexibility. We argued that a project-based, multidisciplinary approach is required to teach many of these skills, because it exposes students to a set of practical tools and approaches and enables them to apply those tools and approaches in a cross-disciplinary team setting.

We explored some of the contributions we have found our NPD class makes to students launching their careers in the 'flat world'; students in the class and alumni value the ability to work with others and the creativity tools the class has to offer. More specifically, we examined the extent to which students are interested in socially responsible projects, which was on average no more than they were ten years ago, and the extent to which the NPD class attracts more than a proportionate number of women in engineering and information technology.

We did find that students engaged in socially responsible projects support different values, both for themselves and for the project. This opens the door to additional research on the formation of values, both as individuals and as a team, and into ways in which students might be guided to select more socially responsible values in their work. We also reported on the need for diversity in tolerance for ambiguity and need for closure on a successful team.

With this relatively general backdrop, we then explored three socially responsible projects that have grown out of our NPD class and the enablers of their success. We also examined data from alumni interviews to determine the reasons why more projects do not go forward after the end of the semester. In short, we determined that moving a project forward requires passion and motivation on the part of at least one person, who often develops an idea well before the NPD course starts. Although most teams did not pursue their projects beyond the class, they found the content and lessons learned from the course valuable to them in their post-graduation profession; valuing most what they learned about team work, concept generation/creativity, understanding user needs, prototyping and concept testing.

In Fall 2007, we offered a version of the NPD course titled 'Sustainable Product Development' for students interested in the sustainable design of products and services. This course retained the components on multidisciplinary teams and the human-centred design process, but placed more emphasis on tools to better understand the social impacts of design, specifically in regards to the environment, which will be important skills for future designers to have. Students, who participated in the Green Product Development course, now have the option of pursuing their conceptual design further this upcoming spring semester in a continuation course on 'Green Manufacturing'. Several of the participants were encouraged by our external design judges to move their projects forward and one team submitted an NCIIA proposal for additional funding.

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