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SELF-REFLECTION: LESSONS LEARNED IN A NEW PRODUCT DEVELOPMENT CLASS

New Product Development (NPD) classes based around problem-based learning and mediated by design coaches from industry provide an effective vehicle for authentic learning and realistic design experiences within the constraints of academic settings. Little is known, however, about what students actually learn in these courses or whether the learning corresponds to what is required by industry. To address these questions, we: 1) analyzed data from a structured 'lessons learned,' or self-reflection, exercise performed by NPD students in a graduate, multidisciplinary NPD class at the University of California, Berkeley each year for the past six years; and 2) conducted interviews with our industrial partners who coached the students' projects. We present an analysis of over 2300 lessons learned and compare the students' views with the reflections of the industry coaches. In the lessons learned analysis, students highlighted skills for working in multidisciplinary teams as their most important learning experience, and secondarily, within lessons about the NPD process itself, identified the gathering and analysis of customer and user needs. Students commonly referenced skills that are not part of a traditional engineering design curriculum: listening, observation and performing research in context. The interviews with the design coaches largely confirmed the importance of both the realistic teamwork experience that accompanies NPD and user research skills. Our findings reinforce the importance of providing students with real multidisciplinary team experience for NPD projects and suggest that greater emphasis be given to the teaching and practice of 'softer' skills, such as listening, negotiation, empathy, and observation. The research also indicates that more guidance, tools and frameworks are needed to assist student product developers in the complex task of gathering, managing and applying user needs.

Keywords: Lessons learned, assessment, multidisciplinary teams, user needs

1 Introduction

Assessing what students learn during a new product development class is a difficult task [1-3]. There are shortcomings with most common assessment methods. A written test, for example, might assess content or process knowledge, but not reliably assess the practical and teamwork skills gained from a group design project. A textbook understanding of the design process itself does not guarantee that the student can successfully apply the process in complex design situations. On the other hand, grading the outcome of a design project, particularly with input from an industry jury, can provide a good indicator of how well a team has exercised the New Product Development (NPD) process, but give little sense of an individual student's learning. A project that is not highly rated could have been the vehicle for tremendous learning and, conversely, a team that generated stellar output may not have experienced the kinds of conflict or team interactions that are rich with learning opportunities. In short, design project ratings do not necessarily get at the salient learning experiences for individual students – the nuggets of experience they will carry with them to their jobs as designers, managers and innovators. Bailey and Szabo [4] sum up this predicament:

> *"Despite the ubiquity of engineering design in curricula, little is known about what students learn in engineering design courses." [4]*

One approach to assessing students' learning experiences in a NPD class is to ask the students themselves what they learned. This approach not only provides course faculty with some insight into the student experience, it also serves to build the students' skills in self-reflection, argued by Schön to be a critical tool for what he called the reflective practitioner [5]. We use this approach in a multidisciplinary graduate NPD class that uses a project-based learning approach. At the end of the course, students are asked to reflect on, write down, and share key lessons they learned throughout the course. Lessons vary in their specificity and content, but typically take the form of short phrases such as:

"Listen, listen and listen again."
"Proximity breeds productivity – working together helps you work better."
"Customers will surprise you – listen and watch closely."

Over the past six years, we collected more than 2300 individual lessons learned statements from about 350 students. In this paper we collate and analyze this data, discuss the themes, frequencies, and interrelatedness of lesson topics, and put forth some implications for NPD education.

In addition to analyzing what students say they learned in the NPD class, we examined how these lessons align with the skills industry NPD professionals deem important. The industry design coaches who are assigned to each team in the class are in the unique position of having industry experience, an outside perspective on the class, and first-hand experience with the student design teams. We conducted a series of surveys and interviews with them to find out what skills and lessons they hoped the students would get from the class. We present their perspectives and relate them to what the students reported as well.

2 Research Design

2.1 Research Setting

The graduate course, "Managing the New Product Development Process: Design Theory and Methods," at the University of California, Berkeley takes students through the front end of the NPD process, from initial team formation and problem selection to presentation of a tested prototype to a panel of professional designers at the end of the semester. Teams begin with an initial project proposal based around a 'bug' or annoyance that students have observed or around a market that interests them. Teams then perform "need-finding" through customer and market research that often results in significant changes in direction. They then engage in concept generation, concept selection, concept prototyping and testing, and financial analysis, largely as laid out in their textbook, Product Design and Development by Ulrich and Eppinger [6].

Teams are multidisciplinary, with representatives from Berkeley's Haas School of Business, the Berkeley College of Engineering, the Berkeley School of Information Management, and the California College of the Arts Industrial Design program. The group project makes up the majority of the class activity and 60% of the students' final grade. In class project work is supplemented by lectures, guest speakers and small assignments to gain familiarity with design tools.

Past teams have developed a wide range of products and services including: devices to improve the mobility of the elderly, emergency response systems for dealing with disasters such as Hurricane Katrina, lunch food service for inner city youth, mechanisms to protect grape crops from frost, toys to entertain toddlers at the dinner table, and clothing to protect farmworkers from pesticides. Although the class is titled "Managing the New Product Development Process," the process we teach can be more broadly termed an "innovation process." We teach a process of observation, framing, generating imperatives, and identifying solutions as put forth in Owen [7,8] and used in other project-based design courses [9,10]. At the end of the semester we have industry speakers describe the application of the process the students have learned to services, processes and other activities outside the product sector (e.g., to redesigning the education system in Singapore). Thus, we believe, the lessons learned by the students are more reflective of an innovation process, not necessarily focused solely on new product development.

The class uses a project-based learning pedagogy [9,10] that builds on the Kolb model of experiential learning [11] (see Figure 1). The Kolb model encourages integrated thinking by cycling the learning experience through concrete, hands-on activities, and experimentation sequenced between activities of abstract conceptualization and self-reflection. The active/reflective integration in the Kolb model allows the student to develop the self-reflective capabilities proposed by Schön in The Reflective Practitioner [5]. Thus, reflection and sharing are key pedagogical tools employed throughout the course to help students gain maximum benefit from their product development experience. We ask the students to reflect on their experiences after each assignment (e.g., their first customer interview), and to share their team reflections at each of three presentations to their peers. By the time they get to the final class assignment, generating the lessons learned that are the subject of this paper, they are well-experienced in reflection.

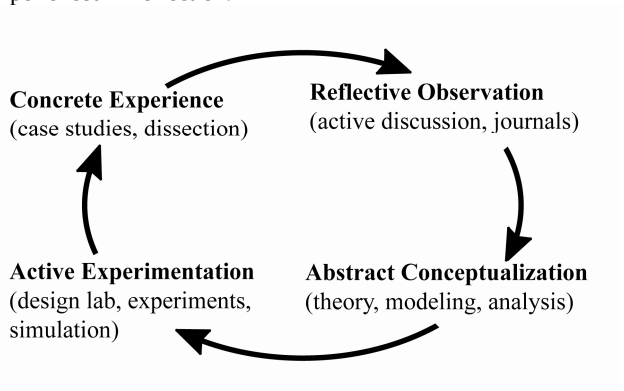

Figure 1. Kolb's model of experiential learning

2.2 Student Self-Reflection

Reflective practice involves thoughtfully considering one's own experiences in applying knowledge to practice while being coached by professionals in the discipline [12]. Schön refers to the 'learned intuition' of professional practice as 'professional artistry' or 'knowing-in-action'. He advocates reflective practice as critical to refining one's artistry, and recommends that novices use reflective practice to recognize consonance between their own experiences and those of successful practitioners. He suggests that it is the ability to reflect both during and after an activity that distinguishes the effective practitioner. Self-reflection is also a critical component of constructivist learning, which assumes that learners construct their own knowledge based on interaction with their environment [13,14]. Self-reflection is a means for learners to socially construct their understanding of a design process for themselves and for others [15,12]. Thus, it can be both a learning tool for the student and an assessment tool for the instructor.

'Lessons learned' exercises as a form of self-reflection in design classes provide insight into what students themselves experienced as the most salient parts of a course. Whereas a written assessment tests knowledge that the instructor thinks is most pertinent, asking for lessons learned focuses on the students'

experience. It reveals not what students were supposed to learn, but what they thought they actually learned and what they felt was most important about what they learned. A disconnect between the two – what students were supposed to learn and what they say they did learn – provides useful feedback for the instructor.

As a pedagogical tool, articulating lessons learned encourages reflection and reinforces key learning and meaningful experiences. It encourages students to reflect on their experiences and develop transferable lessons to be applied in other situations in the future. When conducted in a group, reflection helps students learn from the experiences and stories of others, as discussion of each lesson elicits anecdotes of actual project experiences. In turn, sharing also solidifies the individual's lessons learned. Hearing about others' experiences and analyses of similar processes or situations encourages critical thinking and discussion, as experiences and interpretation often differ.

Sharing lessons learned in groups other than the original project teams allows students to socially construct knowledge about their own team experience without worrying about their teammates' differing opinions or about hurting their teammates' feelings. Furthermore, since names are not attached to the lessons learned, and since the exercise is not graded, students are more likely to provide an honest assessment of their experience, positive and negative, without fear of consequences.

The data analyzed in this paper are elicited when the students are asked, in preparation for the final class of the semester, to:

"Reflect on the experience you have had working with your team in developing your product this semester. Capture 8 – 10 key lessons you have learned from the experience on Post-It™ notes (one per Post-It™). Bring those notes to class with you to share."

The wording of the assignment usually results in consistent interpretations by the students as to what to bring. Students are placed in groups with students from teams other than the one on which they participated during the semester to discuss the individual lessons they brought with them and to cluster similar lessons together on pieces of flipchart paper. At the end of the class, students share the most significant lessons from their conversations in a broader class discussion that concludes the class for the semester. We collect each of the flipcharts with the clustered Post-it™ notes, or what we refer to in this paper as 'lessons learned', from the student groups at the end of each year's discussion. This paper analyzes over 2300 direct student quotes as transcribed from the Post-its™ collected over six years of NPD classes – 2000-2005. The numbers of student and numbers of lessons learned by year is shown in Table 1.

Table 1. Numbers of lessons learned collected

Year	Number of students	Total number of lessons collected
2005	68	448
2004	76	427
2003	63	473
2002	52	448
2001	48	244
2000	49	308
Total	356	2348

After the collection and analysis of student lessons learned we listened to the experiences and perspectives of the industry design coaches to compare to the students' experiences. The coaches were not shown the results of the analysis of student lessons before providing their thoughts.

2.1 Design Coach Reflections

Design coaches – experienced designers from industry who are asked to coach and mentor the NPD teams – are used successfully by an increasing number of product design programs (e.g., [16-18]). The design coaches guide the students as they navigate the NPD process, helping them to explore and articulate what the problem space is and what the solutions might look like. Design coaches provide the benefit of an outside perspective on the process and help the team resolve issues with team dynamics. Interaction with industry professionals encourages learning by helping students connect class experiences with real-world constraints, priorities, and quality expectations. Design teams in the NPD class at UC Berkeley are encouraged to meet with their coaches as often as necessary to seek their advice and share their experiences, but at least three times during the semester. Student reflections show their appreciation of the coaches:

"Design coaches were invaluable. I wished we'd seen more of ours."

"Design coach was an excellent resource and was open and helpful. He was a great contact to the professional world."

"I have a new respect for people who do this professionally."

"Mentorship or outside consulting helps tremendously."

"Talk to the experienced professionals. They know what we have to improve!"

Over 60 design coaches have been associated with the NPD class in the last six years with over twenty of them coaching for more than one year. The design coaches have unique first-hand knowledge of the students' design experiences as they meet with the students and observe where the teams struggle and where coaching is most needed. Often they can elicit information from the teams that the faculty are not able to, as the faculty are seen as controlling course grades, while the coaches are seen as knowledgeable professionals who are offering their expertise. In addition to what the coaches learn and observe about how the student teams work, they have their own body of knowledge about the skills NPD professionals need to know to be successful. They are thus well positioned, with an outside perspective, to determine if the class does indeed develop these skills.

To make responding as easy as possible, we provided three options for the coaches: an email survey, a phone interview or a face-to-face interview. A seven question survey asked coaches to rank the clusters of lessons most commonly identified by the students in terms of both what they see the students learning, and what would serve them best in industry. While some coaches returned the survey form, other coaches preferred to share their thoughts and experiences in a short phone interview covering similar questions. Although the survey questions were used to guide the conversation, we encouraged the design coaches to share the stories and experiences that seemed most relevant to them.

Table 2. Proportion of lessons learned per category per year

Process (P) Team (T) Other (O)	% of lecture time	Lesson category	% of Total Lessons							
			Total	2005	2004	2003	2002	2001	2000	Standard Deviation
P	15	Customer and user needs	14	14	11	16	12	14	17	3
O	0	Meetings and scheduling	8	10	9	7	11	3	2	4
T	*	Roles, responsibilities and skills	8	9	8	6	9	7	4	2
T	*	Team diversity	7	9	4	9	8	7	4	2
P	26	General process learning	7	5	7	5	9	7	8	2
T	*	Communication	7	9	8	7	7	4	3	2
O	15	Other	7	5	6	15	2	5	5	4
P	5	Concept generation	6	6	6	6	8	5	6	1
O	4	Project management	6	3	7	4	8	7	8	2
P	16	Prototyping and testing	5	5	4	4	3	10	9	3
P	3	Concept selection	5	7	4	3	6	9	6	2
T	*	General team learning	5	3	9	2	5	7	8	3
T	*	Team building	4	2	4	5	4	6	2	2
P	2	Mission statement	4	5	4	3	3	3	4	1
O	0	Design coaches	3	4	2	3	3	2	4	1
T	*	Conflict management	3	1	4	3	1	2	5	2
T	*	Leadership	2	2	3	3	2	3	3	1
P	5	Financial, economic and business	2	3	2	1	2	0	2	1

* the total lecture time spent on team issues was 8%, or 1.5 lectures

3 Data Analysis and Results

In this section of the paper we first describe how we merged the lessons learned from the six different years, then present the summary data, and identify important results. We then dig into the lessons learned that focus on the NPD process itself, and analyze the "Customer and User Needs" category in some depth. Finally, we describe how we analyzed the data provided by the design coaches, and how it compares to what the students provided.

3.1 Merging Six Years of Lessons Learned

During the class exercise, the students clustered the lessons learned into categories of their own choosing and named those categories using a process commonly referred to as affinity diagramming [19]. The resulting categories reflected the particular mix of student experiences represented in each group. Each year, after collecting all the lessons learned, we used these categories as starting points for a high-level clustering exercise to integrate and re-sort all of the lessons from the class. In this step, Post-its™ from similar categories, such as 'milestones' and 'deadlines' for example, were grouped together into one category to make the list more digestible. We transcribed the new clusters of lessons learned to create a summary document which was returned to the students. Utilizing the students' category names as much as possible ensured that their perspectives and means of organizing their own experiences were retained.

The high-level clustering performed each year varied in both the naming and granularity of the categories, so to make the data comparable across years we performed yet another high-level clustering exercise. In this case, we amalgamated similar categories and broke larger categories down to form a uniform set of categories that spanned the six years. We carefully referred to each of the individual lessons learned within each category to ensure consistent application of category definitions. Each year there were several categories – such as "Effective Workspaces," or "Archiving Documents." – that did not show up in any other years; these were eventually folded into an "Other" category. Categories that consistently showed up across all six years remain distinct in all of the analyses that follow, and all of the final categories we present here were suggested by at least several groups of students throughout the six years. Table 2 shows the results of this organizing activity. Because the total number of lessons varied from year to year, the data are normalized to show the percentage of lessons each category represented in each year. (We also include in Table 2 the percentage of formal class or lecture time that was spent covering topics in each category.)

Three broad clusters of lessons learned categories emerged. Team-related categories (indicated by a T in Table 2) comprise 35% of the lessons learned, process-related categories (indicated by a P in Table 2) comprise 42% of the lessons learned, and other categories (indicated by an O in Table 2) comprise 23% of the lessons learned. 'Other' includes topics that were general and not specific to NPD, such as managing time and arranging meetings. We now examine the team-related and process-related lessons learned in more detail.

The categories of team-related lessons learned, ordered by decreasing frequency of mention, include: Roles, Responsibilities and Skills, Team Diversity, Communication, General Team Learning, Team Building, Conflict Management and Leadership.

Table 3. Team related categories with examples

Category	% of Team-Related Lessons	Example lessons
Roles, responsibilities and skills	*22*	*"Don't pigeonhole someone into a role based upon their background"* *"Utilize others' strengths. If they can do it better than you, let them"*
Team diversity	*20*	*"Each member of a team learns differently and approaches problems from different angles based on experience, personality type etc."* *"Involving others in your project is opening up to vulnerability, however having another expert take up the slack makes projects race where they would have crawled if you worked alone"*
Communication	*19*	*"Have regular meetings and communicate as much as possible"* *"Face-to-face meetings are best; don't always rely on emails"*
General team learning	*15*	*"Agree on process to get buy-in"* *"Allow for time to gather necessary information so that decisions are fact-based"*
Team building	*11*	*"Spending time outside of regular meetings can help build team chemistry and enable you to work more effectively"* *"An ideal balance between humor/play and serious work can be achieved"*
Conflict management	*7*	*"Be honest about problems early"* *"Just because someone says 'yes' does not mean they really agree"*
Leadership	*7*	*"Clear leadership is helpful to allocate jobs more efficiently"* *"A team leader is not really needed as long as the group can reach a decision. Otherwise, a team leader is needed to reach a decision"*

Three categories stand out by their frequency of mention (Table 3): Roles, Responsibilities and Skills, Team Diversity and Communication. The General Team Learning category includes a number of smaller categories that did not appear consistently across years, including Trust, Humor, Team Values, Team Flexibility and Decision-making, along with a large number of quotes commenting generally on the team experience (e.g., "Having fun together is key to acting as a team rather than a group, and Everyone is valuable.") To provide a clearer idea of what is included in each team-related category, Table 3 provides sample quotes from the students.

Table 4. Percentage of process-related lessons learned by category

NPD Phase	% of Total Lessons
Mission statement	4
Customer and user needs	14
Concept generation	6
Concept selection	5
Prototyping and Testing	5
Financial, economic and business	2

The process-related lessons learned categories identified by the students, not surprisingly, parallel the NPD model the class follows [6], including: generating the goals and mission statement of the team, customer and user needs research and analysis, concept generation, concept selection, prototyping and testing, and financial analysis. The largest category of process-related lessons mentioned by students, see Table 4, related to identifying and dealing with customer and user needs; the phases of concept generation, concept selection, prototyping and testing, and financial, economic and business were less significant to the students. As Customer and User Needs is the most significant process-related category, we more closely examine the breakdown of the 318 lessons learned in that category to understand what aspects were the most significant.

3.2 User Needs Lessons Analysis

Over the last several years, the need-finding process and a deep understanding of customer and user needs have become increasingly important, with both industry and design classes placing greater emphasis on them (see, for example,[20]). The need-finding activity poses the greatest amount of uncertainty to developers because customer and user needs are unknown and out of developers' control. Finding new or unknown customer and user needs has more potential to change the end result of the development process than any other activity [21,22]. Yet, arriving at a precise list of needs to address can be a difficult and time-intensive endeavor because consumers often have trouble articulating and prioritizing their needs when they are not responding to offerings with which they are already intimately familiar [23].

We took two approaches to understanding and analyzing the lessons relating to customer and user needs. One researcher placed each lesson on its own note card and then performed an affinity diagramming exercise [19,24] in a large open space. Rather than use the categories suggested by the students, which were not at the required level of granularity, the researcher independently identified natural relationships or clusters, named them, and let them evolve until all 318 lessons learned were incorporated. Separately, another researcher coded each lesson with an evolving set of codes that emerged from the data [25,26], first on paper and then using Nvivo [27], a software package supporting qualitative analysis. In both cases, individual lessons learned statements could be assigned multiple codes, to reflect the overlapping and subjective nature of the process, as well as some lessons learned statements containing multiple insights. As much as possible, the researchers let the content and wording of the lessons learned statements drive the natural development of the categories and codes. After both analyses were performed, the two sets of classified data were brought together and differences, discrepancies, patterns and similarities discussed. Table 5 identifies the major categories formed and provides definitions and examples in the students' own words for each.

Table 5. Breakdown of major lesson categories pertaining to customer and user needs

Category	Definition	Examples
Listening	The importance of listening to what people say and what they say they do.	*"Ask plenty of open-ended questions of users/customers."* *"Listen, listen, and listen again."*
Observation	The importance of observing people, as opposed to just talking to them.	*"What customers say doesn't always = what they do."* *"During interviews, watching is just as important as listening."*
Context	The importance of observing and talking to users in the context in which the product will be used.	*"Direct observation is essential. Experience use in the customer environment."* *"Get out of the office! Viewing customers in their natural environments is key."*
Perspectives	Understanding the users' perspective, resolving conflicting viewpoints, designer biases	*"Ground the conversation in on "individualization" to avoid the bias that each member envisions themselves as the end user."* *"Users' ideas can be very different than what you think"*
Sharing within the team	Sharing user research with other group members, getting and staying on the same page, group understanding.	*"Field trips are good. Going out together to get more info is better than just talking about it in a room."* *"The team could have done a better job compiling information"*
Scope	The variety of people to talk to, different people have different needs, broad vs. narrow, size/diversity of focal group.	*"There are many types of users, users are different, and you can't satisfy them all."* *"Make time in the planning phase to investigate the broader context for use. Don't narrow the scope too soon."*
Prioritization	Competing needs, prioritizing needs, contradictory needs, trade-offs among needs, balancing needs, focusing on a need, deeper versus big picture needs	*"Locating the "base" need is very helpful; gets thinking outside the box."* *"Hard to get at what truly matters to users (need prioritization)."*
Accuracy	Finding the "right," "real," "true," or "wrong" needs.	*"Find the right customer needs."* *"Accurate identification and prioritization of user needs is critical."*
Latent/ Implicit needs	Latent needs, those that many customers recognize as important in a final product, but cannot articulate in advance	*"Observation and past stories can give hints to latent needs."* *"Customer stated 'wants' might be very different from their real behavior."*
Ongoing/ Iterative	Continual feedback, constant communication with users, and the iterative nature of need-finding.	*"Contact with the customers should happen all the time, before, after, and during."* *"Need to revisit customer needs repeatedly"*
Quantity	The amount of need-finding that should be done.	*"Meet as many people as possible."* *"Learn as much about needs as possible early in the process. Time spent up front saves lots of time at the end."*
Need-centric	Focusing on user needs above all else.	*"Stick with user needs, not solutions."* *"The consumer's voice should be heard above all others."*

3.3 Design Coach Survey and Interview

Data from the design coaches was in the form of both written answers to the survey questions and transcripts of the interviews. As the number of coaches was significantly smaller than the number of students, no quantitative conclusions could be drawn. Qualitatively, however, the coaches' prioritization appeared to mirror that of the students and provided an outside validation of the students' self-assessments. The coaches' comments, however, were more nuanced and sophisticated, perhaps reflecting the form of input. Here are some representative answers to the questions concerning what they see the students learning that is of most value to industry practice:

"Negotiating a wide range of views – different people looking at the same set of information can come to different analyses – they have to work through this as a group."

"The initial ideation is easy when there's nothing at stake. But that second round of ideation, when people have different perspectives – that to me is the other real world learning. Working out who their team is and how to get it to work. That's huge."

"I think the most important thing is to clearly perform market research and market segmentation before tackling any design challenge. User research is also something that is lacking from most industries that I've worked in."

"User needs identification: Stressing use of observation - and story telling using visual will enhance the students' work, innovation and communication skills."

"Communication skills are at the heart of presenting ideas to team members, clients, end-users, etc., which is at the heart of the user-centered design process (getting ALL stakeholder inputs). Identifying user needs are again a heart of user-centered design. These skills will be at the heart of designer/analyst professional expertise."

4 Discussion

Our discussion is organized around two major findings. First, while only 8% of the total lecture time is devoted to working in teams, team-related lessons learned account for 35% of the total lessons learned. The design coaches also highlight team-related learning as critical. Second, of the process-related lessons learned, 14% concerned Customer and User Needs, which was at least twice the frequency of mention of any other process-related category.

4.1 Team Lessons

It is not surprising that the breakdown of lessons learned does not match the breakdown of lecture time in the class. Learning about working in multidisciplinary teams is best done by actually working in multidisciplinary teams. And, although we did not spend much lecture time on teams and team dynamics, we did conduct a mid-semester team review in which students were asked to evaluate their team's performance and provide individual reviews of their peers on the team. Feedback from this review was the focus on one "lab" meeting where students were encouraged to discuss the results. Let's examine some of the specific things that the students learned.

Of the team-related categories of lessons learned summarized in Table 3, the items in the top two categories – Roles, Responsibilities and Skills (22% of the lessons learned) and Team Diversity (20%) – are highly related to working on a *multidisciplinary* team. Clearly, a multidisciplinary team experience provides valuable lessons that a uni-disciplinary experience does not. A number of students cite this as a primary reason to take the class in the first place. For many, this is the first multidisciplinary project team experience they have had. While many students work on group projects in other classes, few are multidisciplinary, and even fewer require the students to conduct their work and make decisions as a team to the degree that new product development projects do.

Many of the lessons learned refer to the challenges and benefits of working with significantly different disciplines, citing the different motivations, thinking and communication styles of different disciplines as the primary challenges: *"It's great to have people who are good at different things;" "People with different backgrounds sometimes speak different languages;" "Variety of background helps with division of labor, but leads to more misperceptions and greater tensions."*

The harmony, difficulties, synergy and dysfunction that arise from working in teams impact the students' experiences throughout the entire product development process. Often making their team work is the biggest challenge the students encounter, which may lead to the emphasis on team-related lessons learned.

Communication was strongly represented in both the student lessons and the design coaches' comments, often as a solution to dealing with the diversity of the multidisciplinary team (e.g., *"The way each person communicates his thoughts has to do with his background,"* and *"Don't assume everyone agrees just because they don't speak up"*). Team members in this class not only have to learn to communicate across disciplinary bounds, but must deal with the challenges of not being co-located. The California College of the Arts campus is located in San Francisco, while the other students are all in Berkeley. Even the small distance between the cities creates a significant challenge for the students in scheduling time together and forbids the chance meetings that might happen were they in the same vicinity. The students also commented on the different choices for communications technology – e-mail, phone, instant messaging – that are chosen and the difficulties in choosing a common mechanism. These issues are not much different than those experienced in industry. See, for example, Allen's [28] work describing the effects of distance on communications.

Leadership, a common focus for entrepreneurship and innovation programs, is the least represented of the team-related lessons learned categories, accounting for just 2% of the total lessons learned. Leadership tends to show up more in comments about roles and responsibilities, as the students allow the leadership role on their teams to rotate (e.g., *"In the absence of an assigned/imposed leader, every team member has in one way or other assumed a leadership role, and Successful teams don't always have a clear leader or hierarchy."*), though this is by no means always the case (e.g. *"Assign roles and project leader. No rotation of roles!"*).

The students often split the leadership role into a project champion role and a project management role, acknowledging that the roles might best be played by different people. The project champion is often, although not always, the person who proposed

the project. The project management role is focused on keeping the team on schedule, making sure that deliverables are complete, etc. There is some fear among the students of taking on explicit leadership roles that might be perceived as hierarchical in some way, as they are working with their peers. Thus, they tend to use conversation, influence and consensus-building to reach decisions rather than allow one individual to drive them. Not all teams are successful with this approach; some get needed facilitative leadership from their coaches at crucial points in the process. Our design coaches told us that this is reflective of a more general trend in industry in which product development, design or innovation teams operate more on the basis of interpersonal influence than on the basis of strict hierarchical control. Leadership roles are more concretely described, and often shared among team members.

4.2 Customer and User Needs Lessons

Tables 2 and 4 show that the greatest proportion of NPD process-related lessons learned was in the area of Customer and User Needs. Several factors may contribute to this result. Perhaps the user needs category is a broader "bucket" than others, thereby encompassing a wider range of experiences and thus lessons learned. Perhaps students were biased to include those lessons, as the overriding philosophy of the course was customer-driven as opposed to technology-driven design, and the class placed significant emphasis on the product definition phases of the process. On the other hand, 15% of lecture time was spent on Customer and User Needs, which tracks with the lessons learned in this category representing 14% of all lessons learned. Examination of the data, however, suggests that this was a category of lessons that were learned by making mistakes (e.g., *"Analysis of customer responses and inference of potential product from these needs is time consuming and should be done by the entire team!"* and *"Spend more time developing your user survey/questions. You might have only ONE chance."*) or lessons that stood out as particularly positive or useful (e.g., *"Watching people is fun as well as informative; you find out some things you overlooked."*). In other words, the lessons learned were experience-based – positive and negative, and not something they could have learned from the lectures.

While no causal connections can be made from our post-hoc data analysis, there are sound reasons to suggest that the high number of lessons learned relating to user needs reflects both the importance of that phase within the NPD process and its impact on students' experiences. First, as we discuss further below, effective need-finding requires skills not traditionally associated with the disciplines of engineering, business, and information systems management. Effective need-finding requires designers to empathize with their users [20], drawing on their listening, observation and understanding skills as well as their intuition. Need-finding is a "fuzzy," non-linear, and inexact process, unlike the more analytical, linear processes often taught within these disciplines. Other phases of the NPD process that draw on more traditional skills may provide students with fewer salient learning experiences.

Second, requiring students to test their products with real users reveals to them the importance of effectively performing the need-finding stage. When a technically proficient design does not please users in the prototyping and testing phases, students may relate this failure to a gap in their understanding of user needs. It is possible, as a result of these experiences, that students associated lessons learned through the prototyping and testing phase with identifying customer and user needs, thus in some ways falsely inflating that category relative to the prototyping and testing category. This may help explain why Prototyping and Testing, while 16% of lecture time, only accounted for 5% of lessons learned. The emphasis on customer and user needs is reflected in the feedback from the design coaches as well.

We also analyzed the interrelationships between the subcategories within Customer and User Needs. The interrelationships suggest three interesting aspects of understanding customer and user needs for these student teams: the adoption of new skills, the need for framing and reframing based on user needs and the difficult task of managing and analyzing needs once collected. We discuss each topic below.

4.2.1 New Skills

There were many interrelated lessons learned relating to the skills required to do need-finding, particularly in the subcategories of Listening, Observation and Context (Table 5). Some students learned about the importance of effective observation skills (e.g., *"Observation is key for identifying user needs."*), others about the need for listening skills (*"Listen intently to consumers. Their needs should drive every step regardless of the developer's original intent."*), and yet others about the need to observe in the context of a product's use (e.g *"Direct observation is essential. Experience use in the customer environment."*) As the examples show, many of these lessons overlapped. Current design researchers and practitioners also emphasize the importance of these skills in uncovering users' latent needs: *"Today, the message is to observe customers working in context to find out what those customers need, not just what they say they need."* [29] The inter-relatedness of these subcategories indicates both their importance to an effective product development experience and how new these skills are to many students taking the course.

4.2.2 Frames, Perspectives and Sharing

Together with the subcategories relating to new skills, the subcategories of Perspectives and Sharing raised issues of framing the situation and negotiating frames within the teams. Frames are *"underlying structures of belief, perception and appreciation"* [30] and refer to the way designers and users structure their experience, deciding what are and are not the important elements of a situation, the boundaries of a situation and the criteria for success. Frames are a notion commonly employed in sociology (see for example [31] or [32]) to understand the way a group of people understand their roles and interactions within a context. We saw many lessons learned related to the importance of relinquishing the frames and viewpoints that students originally held and replacing them with the user's perspective (e.g., *"Customer needs can surprise you and change everything; Understanding issues, step into the shoes of your customer."*). Related lessons pertained to biases that product developers themselves bring to user research, often obscuring the user's perspective (e.g., *"Customer research may be biased by [the researcher's] hidden agenda."*). In this and similar cases, hidden

agendas or biases results, consciously or sub-consciously, from the frames that the developers themselves bring to the situation.

Students identified the resulting importance of developing shared frames as a team. They learned the importance of conversation to create shared understanding (e.g., *"Before surveying customers the team should survey itself to ensure a consistent understanding of responses; Analysis of customer responses and inference of potential product[s] from these needs is time consuming and should be done by the entire team!"*). And, they learned of techniques such as personas and grounding insights in real user data to assist in the negotiation of different frames within the design team [33] (e.g., *"Being in touch with the end user helps keep things in perspective - Make sure words are always attached to a face."*).

4.2.3 Identifying and Managing Needs

Finally, students recognized that figuring out what to do with the customer and user needs once they have been captured is non-trivial. These lessons learned show up in the highly interrelated subcategories of Accuracy, Scope, Latent Needs and Prioritization (Table 5), with many lessons fitting into two of the subcategories. Students emphasized the importance of finding the 'right' user needs, or those that resonated most with the users (e.g., *"It's important to get true customer needs and do a good job early on so that you pick the right direction in the end."*). However, there was also a tension between finding and prioritizing the 'right' user needs to address and limiting the scope of users from which to draw insights. Several lessons learned emphasized the notion that *"Initial customer needs assessment has to be broad with input of several sources,"* while others favored a narrower scope: *"There are many types of users, users are different and you can't satisfy them all,"* or *"You can't please everyone."* Though students found it valuable to study a diverse range of users, interactions and scenarios, there was also a feeling of being 'bogged down' in the amount and variety of data that resulted, often revealing conflicting needs. In short, they found that managing divergence and convergence is a delicate balance.

Understanding, managing and prioritizing needs once they were identified also seemed problematic. There was an emphasis on the importance of identifying latent, hidden or implicit needs (e.g., *"Locating the 'base' need is very helpful; gets thinking outside the box;" "Ask why – find out what's behind customers certain behavior;" "We are not only designing a new physical product, but a part of people's life;" "Users' latent needs are hard to define but it's extremely useful."*) However, deciding where to focus appeared difficult partly due to the different 'levels' of user needs (e.g., *"Many times customer needs are all over the map, making it difficult to judge which needs to focus on;" "User needs/wants are often contradictory;" "Hard to get at what truly matters to users (need prioritization)."*).

Together, the lessons learned in these four subcategories typify what is hard about need-finding and what is so important about doing it well. It is not easy to identify hidden needs that a customer cannot articulate themselves; designers must learn effective observation, listening, and empathy skills. Once needs are identified, it is then difficult to manage and prioritize these needs for the range of users studied. Perhaps the most important underlying lesson the students learned is the highly iterative nature of the need-finding and product development processes. To effectively identify, analyze and prioritize needs, the students had to revisit conversations and other forms of customer needs multiple times. The design coaches also highlight the importance of iteration in getting at core customer and user needs.

5 Limitations, Conclusions and Future Work

5.1 Limitations of Self-Reported Data

While we find these conclusions compelling, we also recognize that our study relies upon self-reported data from the students. In contrast to other research methodologies, such as a written assessment of learning or direct observational data, our use of self-reported data introduces some uncertainty in our conclusions. Students may be biased towards recalling only certain types of lessons learned. When asked, they may be more likely to recall those things that stood out as unusual or unexpected, or had an associated emotional charge, thereby excluding more mundane, but equally important learning. They may not appreciate the importance of some lessons until they have had experience working on a professional NPD team. Or, according to the well-documented recency effect, they may place disproportional weight on recent events when making their evaluations.

Academic or peer pressure may also introduce bias in student responses. Students may, for example, identify what they perceived they should be learning, or what they thought would make a suitable or interesting lesson to share with others. There could be a tendency for students to focus on what they thought the instructors wished to hear, and not on what was actually most salient to them. We attempted to minimize this bias by making the lessons learned exercise both anonymous and ungraded and by encouraging sharing among peers rather than with the instructors.

The limitations of self-reported data can be reduced, as Denzin [34] recommends, through triangulation of data, methodologies, researchers or theories. We used multiple researchers to analyze the raw lessons learned data, collected data from the industry design coaches, class questionnaires, document analysis [35], and also tested the results of the lessons learned analysis with the course instructors whose knowledge has formed over many years of teaching. This increased the number of perspectives we had on the data and its interpretation and, in turn, increases our confidence in our conclusions.

5.2 Conclusions

We have presented an analysis of over 2300 lessons learned from over 350 students collected from six years of a multidisciplinary new product development class and comments from the design coaches that support that class. We found that team-related lessons learned are nearly as significant for the students as the lessons learned associated with the NPD process. Clearly, team and process development complement each other, yet many of the textbooks on new product development, such as the one we use in this class [6], focus almost exclusively on the NPD process with little discussion on what makes an effective team. In fact, it is not unusual for design textbooks and design classes to have virtually no formal content on teamwork. Yet, team issues are hard to learn, as our data from both the students

and design coaches suggest, and are clearly critical to NPD success.

Our results also suggest, perhaps not surprisingly, that there are some things that are best taught through experience rather than through formal lectures. Team dynamics is one of those topics. We spent only two lectures or 8% of the total lecture time in the course on team-related topics, yet 35% of the lessons the students learned were on these topics. Of course, we might argue that more lecture time be devoted to team-related topics given that they are so important to the students. There is no doubt that there are other tools and techniques we might formally teach to help the students in their teamwork. As for many schools, we are left with the question of how and where team-related topics should be taught. To what extent should a class focused on the new product development process teach teamwork? To what extent can students learn teamwork in a unidisciplinary class (e.g., within the business or the engineering school) or in a lecture-based class? Given the importance of teamwork in industry, and the fact that the students emphasize learning about team skills, this is a question with which many institutions must grapple.

A general theme emerging from the process-related lessons learned is that need-finding is neither formulaic nor entirely methodological. Instead, need-finding is better represented by Schön's metaphor of a reflective conversation [5] and Horst Rittel's view of design as an argumentative process [36]. Direct, spontaneous interactions with users, within design teams and around prototypes make these early stages of design appear as a form of improvisation (see for example [37]). The 'back and forth' between developers and users, and within the teams themselves, was clearly evident as the teams negotiated need-finding and iterated toward final prototypes. In addition, there was also the realization that the designer's own viewpoint and expertise remain valuable within the user-centered design process, as eloquently voiced in this lesson from a student:

"While asking the customer what they want sounds so simple and logical, someone still needs to interpret. Even following the best process around, if there is not insight/empathy/ intuition – it's all for naught."

Deeper analysis of these lessons learned identified the importance of new skills for product developers in empathizing with users, including observation, listening and the importance of context. We suggest that greater emphasis be given to the teaching and practice of such skills, traditionally associated with the social sciences and qualitative research. Further, the lessons pointed to the importance of practicing and applying these skills within the context of the design process, for although the instructors of the class cover the basics during class lectures, application still provided many learning experiences. Tools like interviews, observations, and real-world interactions rarely follow predictable scripts; there are simply too many variables and possible outcomes to sufficiently prepare students in the classroom alone. It may be that if part of the benefit of working in multidisciplinary teams is learning from teammates, then incorporating team members with these skills, such as anthropologists and other social scientists, may prove beneficial to teamwork and overall team performance.

Finally, analysis of the lessons learned indicates a need for more explicit tools and techniques for understanding, analyzing and prioritizing customer and user needs. While it is clear that teams must engage in a messy and iterative process of gathering and interpreting needs, and that some of that process is an art form, there are certainly other tools that might be developed to help with the framing and re-framing of customer needs. These tools rarely show up in textbooks on new product development.

The "lessons learned" exercise allowed us to better understand what our students are learning, and how we might fine tune the class in future years. We believe that the students also gain from being required to reflect on what they have learned and by sharing their lessons with one another, particularly in cross-team groups. We thus advocate this pedagogical tool for multidisciplinary NPD classes. The reflection and sharing of lessons among class members appears to be a useful learning experience, as well as a valuable window for instructors into students' real design experience.

5.3 Future Work

We plan to extend our work by analyzing data collected throughout the semester on lessons learned. We hope to determine how far through the process students must go before the lessons become apparent to them. If possible, we would also like to compare our data with similar data from another institution. Finally, we plan to collect data from alumni of the class to determine which lessons learned stuck with them, and what they believe is most important now that they are applying what they learned in the real world.

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