

# Teaching Integrated Product Development: *Educational Innovation at Carnegie Mellon University*

**I**N AN ACADEMIC WORLD that thrives on departmentalization, Craig Vogel, Jonathan Cagan, and John H. Mather buck the trend with an interdisciplinary course on product development that brings together industrial design, engineering, and marketing. Student teams put theory to the test as they respond to consumer research by designing and prototyping new products. The creativity-focused lessons in this exercise include developing effective communication skills, interpreting customer needs, and integrating issues of materials and production.

*by Craig M. Vogel, Jonathan Cagan,  
and John H. Mather*

**The 20th century** has been a century of specialization. It was a phenomenon begun by industry: Companies were growing dramatically in size and scale, and heads of emerging corporations responded to the change by developing various specialized departments. This was deemed essential if companies wished to stay competitive in the development and production of mass-manufactured products. Colleges and universities followed suit and developed a variety of new departments and majors to complement industry. Today, even more specialties are emerging; it's a trend that won't go away. Ironically, however, some of the very industries that began the trend are now calling for a new movement toward reintegration, especially where product development is concerned.



CRAIG M. VOGEL



JONATHAN CAGAN



JOHN H. MATHER

Bob Blaich noted in his book *Product Design and Corporate Strategy*:

The division of tasks and turf battles of earlier decades were recognized in the 1980s as a major obstacle to innovation, quality achievement, and reduction of development-to-market time... The serial product process, it was understood, had to be replaced by the parallel process... Corporations need to address this issue by specifically developing a process and procedures for achieving product creation and integration.<sup>1</sup>

As Karl Ulrich and Steven Eppinger state in *Product Design and Development*,

1. Blaich, Robert, and Janet Blaich, *Product Design and Corporate Strategy: Managing the Connections for Competitive Advantage*, (New York: McGraw-Hill, Inc., 1993), p. 36.

“Product development is an interdisciplinary activity requiring contributions from nearly all the functions of a firm.”<sup>2</sup> And, they go on to say, successful products require the involvement of a minimum of at least three core competencies: engineering, industrial design, and marketing.

The authors of *The Wisdom of Teams* have observed that when asked, managers tend to agree that integrated teams are the right approach to product development.<sup>3</sup> However, they feel that in practice, there is still resistance to the concept, due in part to beliefs in the value of individualism.

We believe that industry and management will have to learn some new practices in order to support this new approach. We also believe that professionals need to be exposed to interdisciplinary team experiences before their first employment. That’s why at Carnegie Mellon University (CMU), we have developed a course in which industrial design, engineering, and marketing form a triad—a team of equal partners in which the success of the product in the marketplace depends on the integration of contributions from each discipline. This approach has evolved during almost a decade of planning and teaching into a unique course that prepares design, marketing, and engineering students to start their careers with a clear understanding of the value of an integrated approach to product development.

Carnegie Mellon University is one of the few universities in the United States that has strong programs in industrial design, engineering, and business. CMU is also small enough (7,500 students) to make it relatively easy to develop interdepartmental initiatives across colleges. It is this context that has fostered the development of our Integrated Product Development (IPD) course, which is one of many interdisciplinary initiatives currently featured at the university. The course focuses not only on product development but also on the growth of functional, integrated, interdisciplinary teams. The process is as important as the product.

### Course Overview

The goal of the IPD course is to have teams develop products that are perceived as useful, usable, and desirable. The team process and the resulting product receive equal emphasis. Students choose their own teams and determine their own product opportunities. All teams are interdisciplinary and require shared leadership and a climate of mutual trust and respect.

The course runs for 15 weeks and is cross-listed in three colleges: engineering, business, and design. An optional (elective) course, it usually includes 25 to 30 students, who form four or five teams. All three disciplines must be represented on each team.

Three faculty members, one from each discipline, plan and teach the course and are active participants in all lectures and course meetings. Additional expertise is brought in for particular team support, as needed.

The course is divided into four phases (figure 1), beginning with a search for an appropriate product and ending with design prototypes. In each phase, the team gathers data, develops multiple options, and refines those options down to one or two alternatives. The goal in phase one, for example, is two-fold—identify as many product opportunities as possible, then choose one. Teams initially use qualitative methods of decision making and then, as the issues become clearer and more refined, they switch to quantitative methods of analysis. For instance, teams start with simple nonweighted matrices to choose a product opportunity; by phase four, they are employing the house-of-quality method to refine product attributes.

Our methodology focuses on approaches that seek to gain as much information as possible, as early as possible, throughout each phase. We do this with tools and methods ranging from diagrams, sketches, and 3D models to consumer databases developed around economics and values. Ethnography studies help us gain early insight into customer needs; continuous testing of concepts against potential users keeps the teams on track; we also use Pugh charts to consider trade-offs and to discuss technical issues, and house-of-quality to map the market to the technology. We have found that matrices work well as an organizational tool for integrated group decision making, especially the product value matrix, which helps to identify and recognize the needs of potential users. Students are taught team-meeting protocols and role assignments; they are asked to rotate roles in meetings. They are taught decision-making methods and when to use them.

“The IPD class is an excellent compressed version of the product development process in real life. In a big company, an engineer works on a small part of the process, but this course gave us an appreciation for our contribution to the big picture. More important, it gave us an appreciation for the other contributors to the development process: design, marketing, and, of course, the customers, who are really the ones who define the product. The course also gave us practical experience in teamwork, leadership, and working under time and budget constraints, skills that are very valuable to employers.”

—Anne-Claire Markl, MA, Mechanical Engineering

2. Ulrich, Karl T., and Steven D. Eppinger, *Product Design and Development*, (New York: McGraw Hill, 1995), pg. 3.

3. Katzenbach, John R., and Douglas K. Smith, *The Wisdom of Teams: Creating the High-Performance Organization*, (Cambridge, Mass.: Harvard Business School Press, 1993), p. 9.

Throughout, we insist that each discipline—marketing, engineering, and industrial design—be actively engaged in decision making.

As figure 1 illustrates, the course moves from qualitative to quantitative methods of analysis: Teams work with simple nonweighted matrices before they reach the house-of-quality stage.

Students are not allowed to start with preconceived product concepts. Instead, we start the teams with a blank slate on which to apply the integrated development methodology from conception through product introduction. The teams gain a sense of their own control in directing content from the beginning. Each team must submit a report and make a presentation at the end of each phase. The students are graded for each phase; the grade represents a combined evaluation of the report, presentation, and team process. Teams do not in any way compete against each other.

As the IPD course has evolved, one of the critical needs the teams identified was a resource describing the economic status, value system, and purchasing

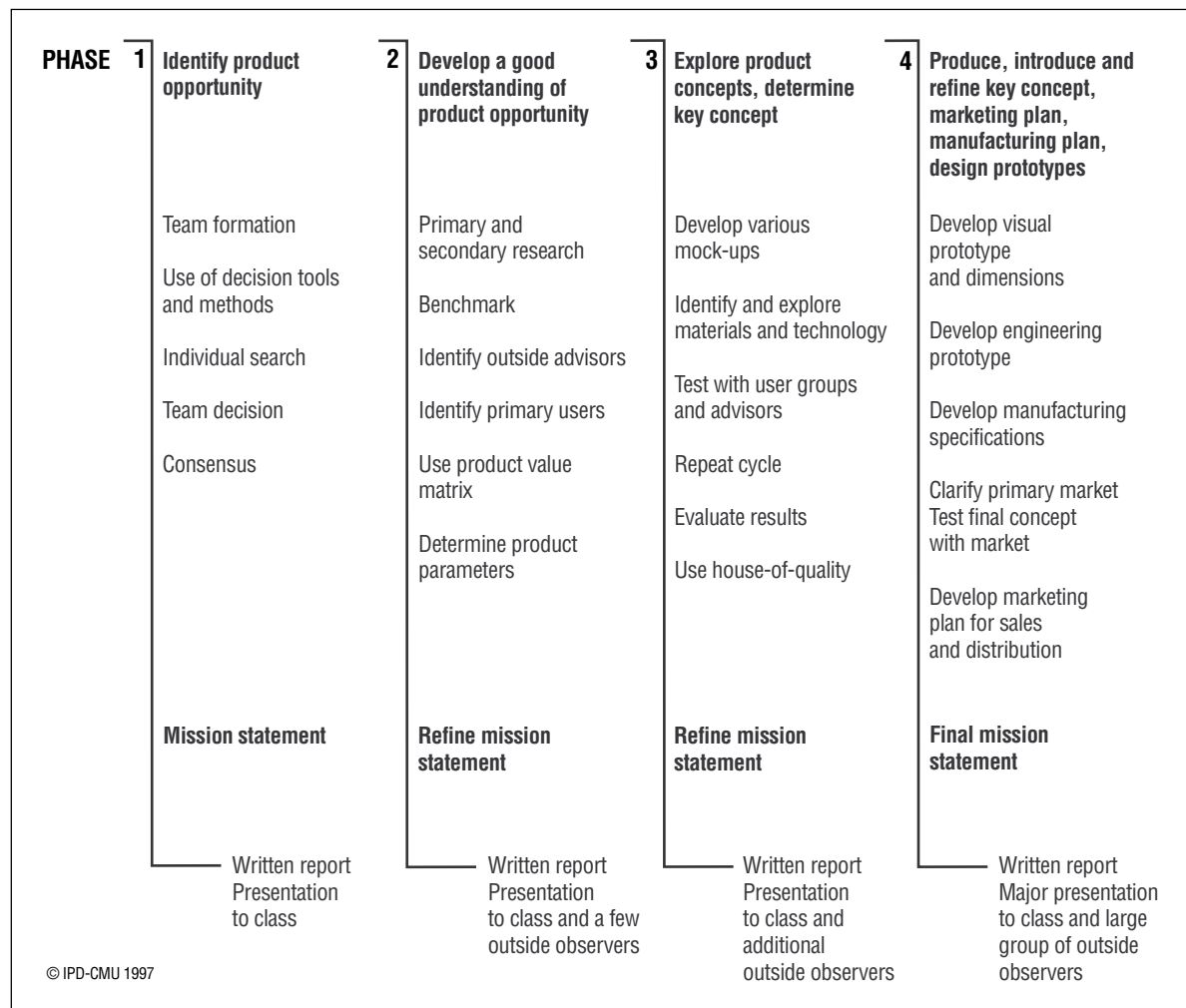
profiles of the intended end user of the product.

It was observed that the sooner this information was available, the sooner the focus, excitement, and commitment of the student teams occurred.

We found that the VALS 2 (values and lifestyles) segmentation framework provided by the Stanford Research Institute provided the necessary user information for teams examining product ideas. Each team is given a manual that offers an overview and instructions for accessing the framework's large data bank, which consists of several volumes of raw data on consumer profiles.

The VALS 2 system is based on the psychological foundations of consumer decision making. It was developed against a background of a changing society and marketplace. Consumers are classified not just by what they purchase, but also by why they make purchase decisions—how their attitudes affect their purchases. The MBA and ID students have found VALS 2 to be an excellent database for determining marketing profiles and as a point of departure for product characteristics.

Figure 1



Integrated Product Development course schedule

## Teaching the IPD Process and Managing IPD Teams

The IPD course has been offered for nine years, and the current faculty team has been together for three of them—the longest period of time that teachers from all three disciplines have been together. We have been able to make constant improvements on the course's structure, building on the base established by previous instructors. During the last nine years, nearly 40 teams have completed the IPD course, 15 of them in the last three years alone.

The faculty team meets throughout the year to plan, evaluate, and improve the course, which requires significant maintenance and planning. The class meets twice a week, with the weekly course schedule split into discrete days for lectures and team meetings, allowing the faculty to teach and manage in parallel. As the course develops, we act more as coaches and less as teachers. The teams become the experts and require support and information that is more particular to their products.

We have established several course objectives. First and foremost, we hope to produce industry leaders who will understand an interdisciplinary approach to product development. We also emphasize that students must learn to work effectively in horizontal teams. Additional objectives include taking students through a cycle of the product development process (from concept to prototype) and teaching them to present their ideas clearly and concisely using carefully chosen visual support. Last, we try to teach students to identify product opportunities based on human interactions and needs—a natural fit when managing IPD, which capitalizes on the synergies achieved by melding the three disciplines.

The IPD course continues to evolve through the efforts of long-time friends like Dan Droz, president of Dan Droz and Associates, who still plays an important role. Droz was one of the course founders, and he continues to share his insights on design with the current faculty and students. The course has also benefited from the help of recognized experts who have taken an interest in its development. For instance, Dave Smith and Patricia Moore, visiting faculty at the School of Design, have made significant contributions. Smith, cofounder of RichardsonSmith, provided insights on interdisciplinary product development based on his experiences with Crown Equipment Company. Moore, who is cofounder of Guynes Design, is a respected expert on universal design and has helped to support the course's focus on user-centered issues.

Sam Farber, founder of OXO Good Grips, has also been an advisor for the course. In attendance at this year's final presentation, he said:

"I was overwhelmed by the quality of the various projects. The products and presentations were very professional. I was particularly pleased with your ability to make use of all three disciplines—design, business, and engineering. I have never seen it work so effectively... I also liked the fact that the concentration was on user-centered design... There seemed to be a very easy give and take and a deep respect for the abilities and accomplishments of the students on the part of the faculty."

Farber has worked with a number of other schools in new product development courses, and we value his assessment and participation in the course.

## Insights Gained

In *The Wisdom of Teams*, Katzenbach and Smith have defined four levels of teams. The most successful is what they call a "high-performance" team, which they define as "a small number of people... equally committed to a common purpose... for which they hold themselves personally responsible." In addition to these attributes, the team members "are also deeply committed to one another's personal growth and success."<sup>4</sup>

It is our contention that well-managed IPD teams can develop more effective comprehensive product programs than can teams from individual disciplines working in sequence. However, we have found that our teams vary in their use of methods, ability to work comfortably together, and effectiveness depending on which phase of the course they are experiencing. On a scale of "functionality" whose high end would be occupied by high-performance teams, the most functional teams have success in both product and process. They epitomize the phrase: The whole is greater than the sum of the parts. They bond early and experiment with tools and methods comfortably. They take maximum advantage of each phase and provide clear criteria for decision making. They leave a logical trail to retrace and help them understand their decision processes. Strongly supportive and trusting of one another, they have a healthy and confident relationship with the faculty/management team. Every team experiences stress of one sort or another, but successful teams absorb stress more effectively. They often use humor as a way to release stress.

"The best things I took from the course were its multidisciplinary approach and the real-world focus of product development. The overall experience was fun, and the team experience of working together was great. It was the most valuable and enjoyable course I took at CMU."

—Eric Close, MBA, member, Home Entry team

4. Ibid, p. 92.

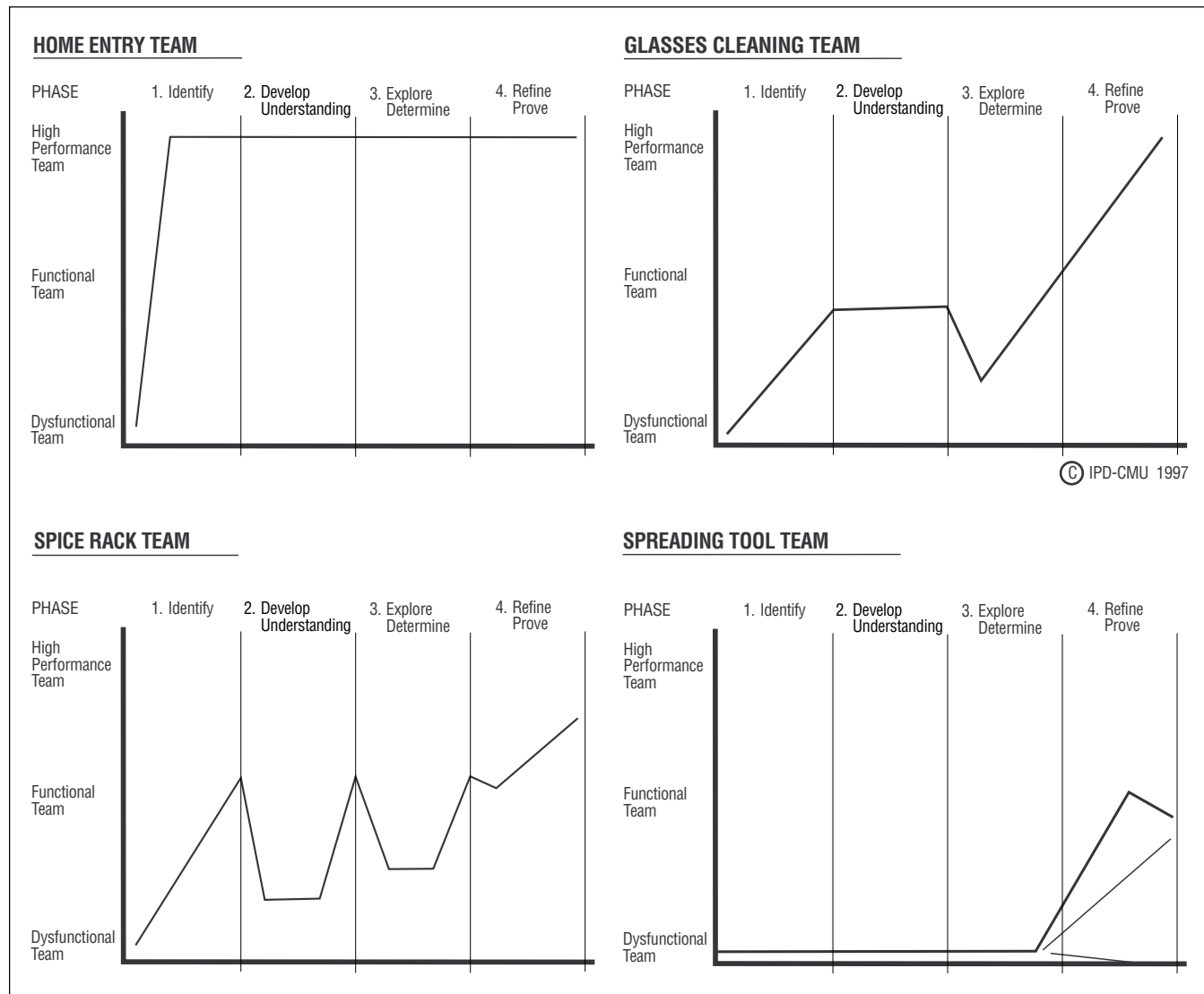
Our goal in the IPD course is to have every team reach the high-performance level and reach it as quickly as possible. We have noticed that teams behave very differently over the four phases of the course. They develop their own personalities and performance profiles. The art in managing IPD teams is knowing when to modify and when to allow a team to keep its eccentricities.

We have found that all teams start as “dysfunctional” teams. They question the value of team decision making; they question the validity of the viewpoints of the other disciplines; and they jockey for position in the team as active or passive participants. Eventually, they become “functional” teams, accepting the process and becoming committed to a common purpose. The third stage, the level of the “high-performance” team, is not attained by all teams and is not always sustained across all four course phases. In figure 2, we profile four teams,

which we’ll name by the products they produced: Home Entry, Glasses Cleaning, Spice Rack, and Spreading. These teams exhibited four different performance paths and required equally different management approaches.

The product developed by the Home Entry Team—whose goal was to improve the way people opened their front doors (see figures 3 and 4)—was one of the most complete product systems developed in this course. Home Entry started strong and stayed at a high performance level throughout the course. Marketing provided early insights through focus groups; industrial design and engineering students worked seamlessly to produce prototypes for evaluation. The team actually got ahead of schedule. Team members developed a high degree of trust in the course and in each other; they quickly became committed to the product. Their ease of communication and depth of commitment allowed

Figure 2



Team performance profiles across four course phases

them to effectively use the methods introduced in the course. We have come to realize that teams who work well together use tools and methods more effectively. They focus on the product, not on the smaller issues of team decision making and leadership.

The Glasses Cleaning Team was searching for a product that sterilizes eyeglasses during the night. They did not catch on as a team until the third phase, when they quickly improved and had the best overall presentation of the year. These students showed us that once a team achieves a high performance level, it can quickly make up for lost time. We also learned not to give up on a team too early.

The Spice Rack Team wanted to develop a way to dispense spices that would allow measured amounts of spices to be dispensed with one hand. This team peaked for all the presentations, then quickly lost momentum. They wasted the time between presentations and relied on their talent to save them. Eventually, they had to reduce the scope of their final product. This group helped us to learn that we had to put more emphasis on weekly team meetings in order to prevent teams from losing momentum between major presentations.

**Figure 3**



The Home Entry Team's functional prototype: the Xpedient remote door lock, designed to provide consumers with a convenient and safe method to enter the home. In addition, the lock complies with the requirements of the American Disabilities Act. When the remote is activated, the door briefly unlocks; all that is required to open the door from the outside is to lean on the curved metal panel. In the case of a power outage, the door can be unlocked using a conventional key.

**Figure 4**



Home Entry Team, left to right: Noah Brinton, Eric Close, Robert Suarez, Sanjay Vora, and Jay Chu.

The Spreading Team hoped to develop a product that was comfortable to hold and could spread hard and soft condiments without destroying the surface of the bread or toast. This team presented the worst performance profile we have seen. The team process suffered because one negative member constantly destroyed team momentum and consensus. We learned from this experience and have prevented it from occurring again by screening students for any history of negative team experiences. The faculty advisors now intercede immediately if any team member shows signs of monopolizing the project.

#### SOME STEREOTYPES DO HOLD TRUE

Much as we try to avoid stereotypes, there are patterns of behavior we've observed for students from each discipline. The engineers, for instance, are the most comfortable with secondary research; they're used to conducting literature searches in technical areas. They tend to know more than others about the specifics of mechanical and electrical systems. Many engineering students have an interest in industrial design and quickly learn to physically model their ideas.

On the minus side, products developed by engineers always involve human factors and ergonomics; however, engineers are not educated to observe consumers or to analyze context of use. They design from the inside out. Engineers also like to focus on a single concept rather than on several. They tend to have the weakest verbal and visual presentation skills, and they are least likely to take leadership roles in a team.

MBA students are usually proficient at defining markets, determining product criteria from a verbal perspective, and understanding cost to market. Many MBA students at CMU have technical backgrounds; they often have undergraduate

degrees in engineering. This gives them a clear connection to the engineers on the team, who can help them learn how to translate user needs into physical product attributes.

MBA students like to take the role of overt leadership more consistently than do students from the other two disciplines, and they tend to be the best at verbally presenting ideas, which sometimes translates into a certain aggressiveness. Marketing

students are the only ones educated to translate consumer needs to market criteria: an emphasis on competition that is a fundamental difference between business education and the other two disciplines.

Industrial design students are excellent at primary research (field observation and modeling ideas), exploring multiple concepts, and visualizing product concepts in two and three dimensions. Designers tend to take less overt leadership roles; however, they often lead in more subtle ways, by syn-

thesizing the team's ideas into visual representations of the product. By directing the visual evolution of the product, they can keep the project progressing. This visualization through drawing or models helps students from the other two disciplines: Marketing students use the models to interact with consumers and garner feedback, and engineers can thereby understand how a product's technology needs to develop. The visualization process literally leads team development and serves as the focus for much of the feedback and decision making.

The design students are often the strongest consumer advocates, because of their awareness of ergonomics and human factors. Industrial designers are the only ones educated to translate consumer needs into actual product criteria from a visual, material, and human factors perspective.

The designers often shine at visualizing and constructing presentations; they vary in their ability to articulate their ideas verbally. Most of them have not been taught how to conduct secondary research, nor have they learned how to conduct quantitative analysis in marketing, material performance, or technology. They know about cost of materials, but little about cost to market.

At the same time, within our three disciplines, certain generalizations have become clear. They overlap in a number of areas. They also focus on

very different aspects of product development. Learning how to find overlap and develop consensus where there is conflict is a core part of integrated product development. As figure 5 shows, for example, human factors and market criteria overlap for design and marketing. Materials selection, manufacturing, and concept generation are natural overlaps for design and engineering. Consumer desires and product function form a natural overlap for engineers and marketing. The challenge for team members is to see the three disciplines as an integrated whole—learning that human-centered product development favors no one discipline; rather, it focuses on the overlap of all three.

As the course evolves, the team members often exchange and share their methods. In the Home Entry Team, for example, engineering and design worked together to develop a prototype that was integrated in function and appearance. Design and marketing worked together to conduct marketing surveys and focus groups. It is not uncommon for marketing students to get involved in making blue foam models or in assisting in the production of final prototypes.

#### MENTORING THE TEAM

Although we are all experienced teachers in our own disciplines, it took us all some time to learn to teach this type of course. We have integrated our lectures more effectively; sometimes we lecture together, giving complementary perspectives on the same themes. As we have gained experience as managers of the process, the products resulting from the class have consistently improved. The increased confidence level gained by our *integrated* mastery of the subject has increased the teams' buying into the process. We surmise that there are many lessons here for managers in the "real" world, who should learn how to manage integrated teams, no matter what core discipline they come from.

We believe the course has had as much impact on the instructors as on the students.

#### Conclusions

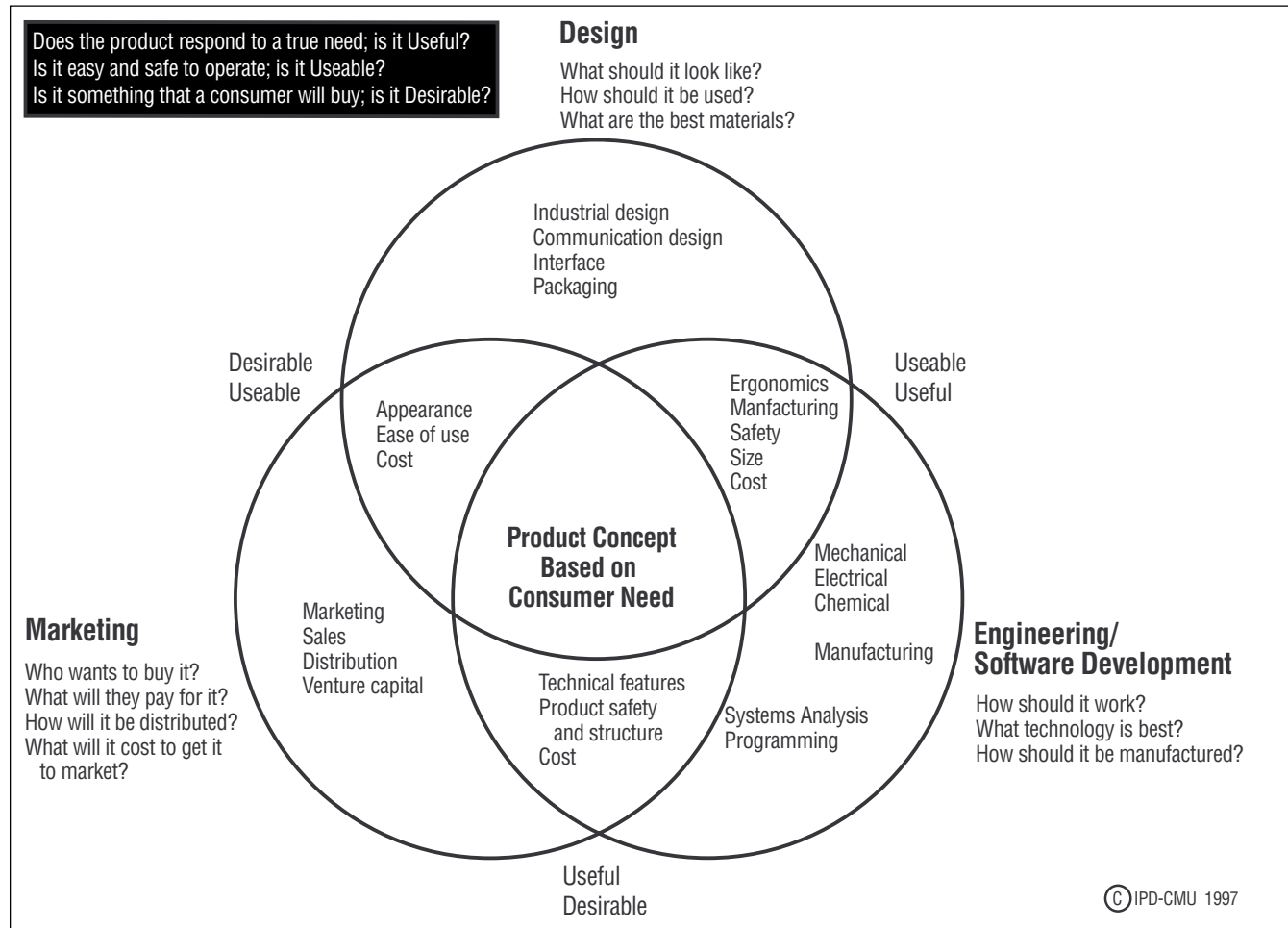
Carnegie Mellon's IPD course certainly affirms the notion that new products can be developed in a shorter time period, given an integrated approach to team composition, thinking, and execution. Industry, take note: New practices in management must develop to support interdisciplinary product development teams. By teaching this approach, we are developing both the team and the management methods needed to make integrated product development a core practice in corporations.

The most obvious, yet difficult, challenge we face is the need to abandon the semantics of individual disciplines and reorient all information to

"My experience in the Integrated Product Development class was invigorating. Learning how the engineers and business students think and work, as well as teaching them what design is and why they need it, was a small step in finding a common language. With that common language, we were able to be a positive, open, and productive team. Our product was cool, too, but it was learning and interacting as an interdisciplinary team that really made the experience."

—Francine Gemperle, MFA, Design

Figure 5



Overlap and tension in developing the optimum product for an identified user need

the common knowledge base of a group built around the intended product user. Once achieved, this new common language reduces the time required to reach an understanding of the opportunity, develop a response to the opportunity, and finally market the product. ♦  
(Reprint #9784VOG58)

#### Suggested Readings:

Farson, Richard. *Management of the Absurd: A Paradox in Leadership*. New York: Simon & Schuster, 1996.

Kao, John. *Jamming: The Art and Discipline of Business Creativity*. New York: HarperCollins, 1996.

McGrath, Michael E. *Setting the Pace in Product Development: A Guide to Product and Cycle-Time Excellence*. Boston: Butterworth-Heileman, 1996.