Developing a New Breed of Engineer – Integrated Product Development at Carnegie Mellon University

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The Integrated Product Development (IPD) course at Carnegie Mellon provides a state-of-the-art education in new product development while exploring the role of interdisciplinary teaching and learning. The IPD course has been in existence for over a decade and has evolved from an experimental course to a class at the center of the strategic plan of the university. The course takes teams of engineering, industrial design, and MBA students and, in one semester, leads them through the product development process to the program approval stage of the process. Patentable, and often patented, products are developed for corporate sponsors in 16 weeks. A fundamental philosophy of the course, and the Carnegie Mellon education, is that engineers must function within an integrated environment that supports both hard and soft attributes of a product. This "New Breed of Engineer" is addressed within the core mechanical engineering curriculum. The IPD course has resulted in several by-products that include a book, a new professional degree, and a model for other courses within and outside the university. Details of the course, the methodology, the new master's degree, and student, university, and faculty implications are discussed.

Introduction

There is often a lack of connection between the education that engineers receive and the expectations and demands on engineers who lead, or for that matter participate in, the product development process in industry. The educational constraints imposed upon engineers by segmentation into engineering classification (mechanical, electrical, chemical) or even sub classification (fluids, solids, controls) closes the world of possibilities for the practicing technical engineer. But worse, many engineers who practice their trade and produce new products are isolated from the many disciplines that all contribute to the creation of a breakthrough or even revised product. It is our contention, supported by best practices in industry, that engineers must participate in a team that not only includes other engineering disciplines (of many classifications, the better of which have a broader understanding than their own narrow educational focus) but also includes industrial designers, marketing researchers, financers. In particular, mechanical engineers must have a higher level, systems understanding of the product and the process necessary to develop it. Thus most mechanical engineering curricula neglect preparing their graduates for the realities of engineering design and its role in product development programs in the corporate world.

The Integrated Product Development course at Carnegie Mellon University meets this challenge by teaching students a best-practices product development process that is team based and has equal contribution from engineering, industrial design, and marketing. The class brings truly interdisciplinary teams together to create new products that are patentable, and often patented. The course was developed within the unique culture of Carnegie Mellon and is a model of the type of education that the university provides in philosophy and practice. In terms of the mechanical engineering curriculum, we believe that the time has come to educate a new breed of engineer. The engineer of today must actively and comfortably participate in this competitive, exciting, and challenging interdisciplinary design process. To do so there is a new paradigm of what a mechanical engineer needs to understand and believe. For example the successful mechanical engineering product developer must be as comfortable with the soft quality visual, brand, usability and lifestyle aspects of a product as the hard quality manufacturing and technology that is traditionally of focus. By bringing the IPD understanding to the capstone mechanical engineering design course, we are graduating engineers who have a better understanding and association with this broader context of their discipline.

This paper will discuss the IPD process taught in the course and developed by two of the instructors and authors. Next the course will be described showing example projects from the course and also insights into teaching such a course. The course's broader influences will then be described including the development of a senior design course for Carnegie Mellon's BioMedical

Engineering department, a new professional degree offered by Carnegie Mellon – the Master's in Product Development, and the influence of IPD on the mechanical engineering capstone design course. This latter influence is part of the basis of creating a new breed of engineer, one that we will describe below.

IPD Process: Creating Breakthrough Products

Before discussing the IPD class itself, we will introduce the reader to the IPD process. The process has been developed by authors Cagan and Vogel and is described in detail in their book *Creating Breakthrough Products: Innovation from Product Planning to Program Approval* (Financial Times Prentice Hall, 2002). The process begins with and focuses on the earliest stages of product development, what has been coined the "Fuzzy Front End" of the process, and brings the process through to the "program approval" stage where a company would make the decision to commit the resources to bring a product to production and to protect the Intellectual Property.

Most engineers are uncomfortable with the uncertainty and chaotic nature of the early product definition stage. Instead they prefer to take a product definition and quickly move it from function to form/mechanism. Unfortunately, all too often, the early definition and purpose is not well understood which leads to an ineffective or at least sub optimal solution downstream. Engineering analysis and parameter optimization tools then take a bad idea and work to make it acceptable, or quality manufacture processes produce very well made but undesirable products.

We have studied the very early stages of product development where the product opportunity is just being formed as a vague description of intent. We have studied industrial product development processes in a variety of industries identifying the best practice tools that we have found in the best product development firms. In our investigation we identified holes in the process; a lack of organization and focus for the early stages of the process. The primary research that we have conducted with large and midsize companies helped us to develop new tools and perspectives on the process that were woven into a formal method for product development. Each year we used the IPD class as an in-house laboratory where we could modify the process and introduce new tools and evaluate their effectiveness. We have also consulted with consumer, medical, and business-to-business product and services companies where we have introduced our process and confirmed its efficacy. This cycle continues today where the syllabus of the course is dynamic and modified year to year based on new findings from our work.

Our approach uses four phases that brings each team from product opportunity identification through to the point of program approval where a company commits to patenting and manufacturing costs. The method and tools integrate with current processes within companies, or can serve as the basis to develop a new process for those companies looking to develop their own.

The IPD Process

The IPD process is summarized in Figure 1[1]. The goal is to create a product or service that is considered useful, useable and desirable to the target market. In Phase I product opportunities are identified. In our book we introduce the SET factors (the Social, Economic, and Technology factors), which interact in a dynamic way to create product opportunities. By constantly scanning these factors, trends in culture and lifestyle can be identified. This leads to gaps in the marketplace we call POGs (Product Opportunity Gaps). Initial customer-based and secondary literature-based research lends credibility and insight into the opportunity, transitioning to the second phase.

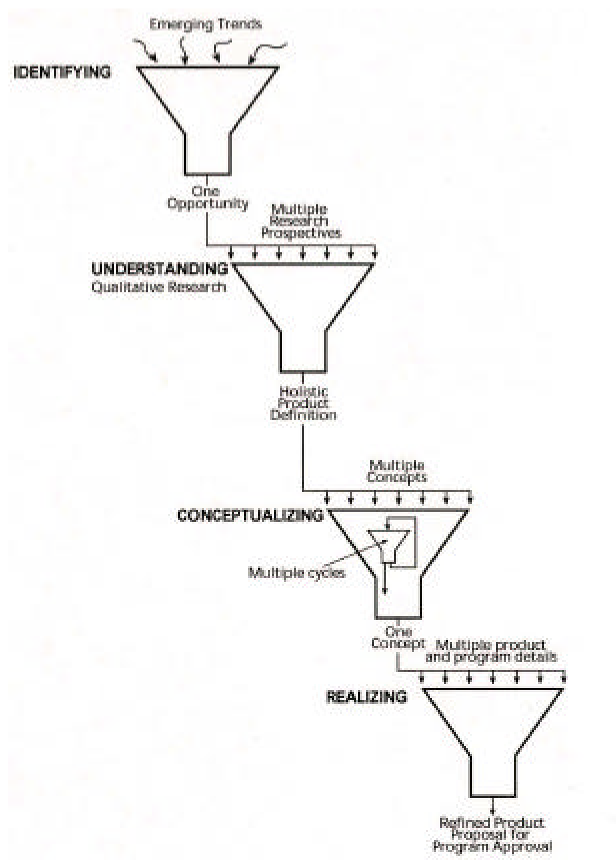

Figure 1. Four Phase Integrated Product Development Process (adapted from *Creating Breakthrough Products*).

[1] In *Creating Breakthrough Products*, the IPD process is referred to as the iNPD (integrated New Product Development) process; IPD is used here to be consistent with the Carnegie Mellon terminology, and also because theprocess is applicable to product redesign as well.

In Phase II, qualitative research focused on a deep understanding of the key stakeholders leads to actionable insights that provide a framework for product form and feature development. This phase is often missing from an engineer's tool kit, and differentiates an insightful process from the standard approach of minimal change and innovation. The challenge is to identify, understand, and articulate the key attributes of value to be developed into the product and use those attributes to create a value proposition.

We have broken value into seven categories, each with distinct attributes. We call these categories Value Opportunities (VOs). A product development team can use them to assess the current state of products in their category and to determine where improvement is possible. Many companies consider aspects of these attributes, but no company that we know of has used so formal or complete a breakdown of value attributes into descriptors that can be applied directly to characterize the early design criteria for a product.

Each of the seven Value Opportunity classes—emotion, aesthetics, identity, ergonomics, impact, coretechnology, and quality—contributes to the overallexperience of the product. In *Creating Breakthrough Product*s, we map the VO attributes onto a ValueOpportunity Chart. The VO Chart forms the basis for a qualitative tool—a Value Opportunity Analysis (VOA)— that helps a product development team analyze the current state of products on the market (be they theirs or competitors), the ideal state of a product, or the realistic expectations of what attributes of value a new or next-generation product can achieve. These value categories make sense for all disciplines involved in the product development process and help teams to develop a shared understanding of their goals.

The Value Opportunity attributes are determined from in depth qualitative user research using techniques such as ethnography (using observation and in depth interviews), lifestyle reference, and ergonomics/anthropometrics. An in-depth stakeholder analysis indicates which stakeholders must be considered in the early stages. The VO attributes are then defined for the opportunity resulting in an initial product description that indicates who the target market is, and what characteristics the product will articulate.

Phase III is a more traditional part of product development that takes the insight from Phase II as a basis for generating concepts. The difference between IPD and other methods, however, lies in having conducted the research in Phase II. This makes the conceptualization more effective and meaningful; the initial product criteria developed in that second phase, in addition to serving as the point of departure, also serves to direct and confirm each concept developed. In order to reach an optimum conclusion at the end of Phase III it is important to use an iterative conceptualization process. This requires multiple cycles (ideally three) of quick, interactive prototypes tested or discussed with the key stakeholders to help direct the conceptualization process. At the end of this phase the basic product is now designed, setting up the fourth phase.

In Phase IV, the concept is detailed to the point that the company can make a go/no go decision as to whether to move the product to production. In our class, for example, students have a complete and accurate form model, technical proof of concept usually shown through a functional prototype, a marketing plan with complete financials and roll out strategy, and a manufacturing plan. Even in Phase IV the basis for success lies in the eyes of the stakeholders as identified by the team.

Our IPD class ends after the fourth phase at the point of program approval. However, in industry the process continues. After the fourth phase the product goes into the refinement phase toward production and launch. These steps are well understood, but the challenge is to protect the innovation created in the earlier phases.
Because the product was developed with a good understanding of the customer, that knowledge provides the argument of how to protect the features and prevent cost reduction that reduces feature quality as well.

An important aspect of the process is the integration of an interdisciplinary product development team. We have seen teams of talented people fail because they have not developed into a high performing team and have focused only on their own discipline (and promotion). We focus on discipline integration and partnership and introduce tools to help with this process. In addition, author Weingart joined the teaching team two years ago, after participating with the team on research for three previous years. Coming from the field of organizational behavior, she brings a focus on effective teamwork by helping teams build bridges across disciplines and learn techniques for effective communication, conflict management, and coordination.

IPD Class

The development of the class, process and book were all done in parallel. The course began 16 years ago when it was introduced as Design, Manufacturing, and Marketing of New Products, and each discipline participated in the process, but did so in an individual, rather than integrated, way. Cagan and Vogel began teaching the class nine years ago and, along with Prof. John Mather from the business school, integrated the class and changed the name to Integrated Product Development. Weingart joined the team two years ago, replacing Mather, and brought a formal approach to team interaction to the process.

The course has four main goals:

- Learn a state of the art product development process;
- Learn how to work in diverse but integrated teams;
- Learn how to communicate ideas in both written and oral form;
- Create potentially patentable products.

The course is offered every spring at Carnegie Mellon. Six teams of undergraduate and graduate engineers (mostly mechanical), industrial and communication designers, and MBA students are formed. Each team ideally has two students from each discipline. The 16 week course follows the process outlined above; Chapter 5 of *Creating Breakthrough Products* is the syllabus for the class. The students are given a broad topic of focus and within that topic they follow the four phases to identify an opportunity, understand it, conceptualize a solution to it, and realize the opportunity. At the end of the semester the student teams deliver a functional prototype, a form prototype, a manufacturing plan, and a marketing plan with complete financials and roll out strategy.

At the beginning of the semester, students engage in a broad exploration within an open ended but defined topic area (provided by the company sponsor). Examples include aftermarket products for the bed of a pickup truck, wearable body monitoring, sleep enhancement, interior lifestyle features for an SUV. Student teams explore the topic and, in the first phase, identify 100 opportunities before weeding them down to one. Social, Economic, and Technology factors help the teams identify the Product Opportunity Gap. In the second phase extensive primary research with lead users and experts couples with secondary research to provide an in-depth understanding of the needs, wants and desires of the target market. The Value Opportunity Analysis and a Positioning Map looking at style and technology help the teams articulate the value proposition and early product definition. In the third phase, the teams explore multiple potential solutions, using early prototyping and focus groups to provide feedback to the process. In the final phase the product concept is detailed to prove function, aesthetic and market feasibility.

The 16 week course provides just-in-time material to the student teams. It also recognizes that generic lectures are not very meaningful in a design course (or likely other engineering courses as well). The course balances lectures with team-based activities and individual team meetings between the student and faculty teams. The course meets on Tuesdays and Thursdays. Tuesdays are typically lecture days, though "lectures" often include interactive working groups. On Thursdays the faculty meet with each team for half an hour. The goal of the meetings is to help the teams apply the concepts in lecture to their particular project. The meetings also ensure that the teams are set to meet the deadlines of each deliverable. Toward the end of the course, when the teams are focused on refining and bringing to closure their design, lectures are replaced by team meetings with the faculty in every class.

At the end of each phase the teams deliver a written report and an oral presentation to the faculty and corporate sponsor. Detailed feedback helps the teams develop their communication skills. The goal is for teams to be prepared to make succinct, powerful, and rich presentations in an organizational environment, and in particular to prepare them to make such presentations in their future employment. Prior to the final presentation the faculty review and critique the presentation to help the teams maximize its content, visualization, and script. The final presentation takes place in a formal setting before an audience of university faculty and administration and representatives from the sponsoring company that include project managers and vice presidents. Initially the theme for the projects was to develop products for use in and around the home. After realizing that quite interesting and potentially successful products were being created but never further pursued once the semester ended, the faculty began to seek corporate sponsorship of the course. With a sponsor the topic needed to remain broad, but also needed to pertain to the business focus of the sponsoring company.

The corporate sponsor not only financially supports the course, but also provides expertise, often proprietary marketing data, equipment, feedback, and lectures. In exchange the sponsor gets limited IP rights.

Ford Motor Company sponsored the course twice, patenting 5 of the 12 projects created by the teams. Industry participation has greatly increased the value of the course to the students by providing a real world experience and expectation, and providing incentive to the students for the corporation to deem the project desirable and viable.

IPD Projects

Many exciting projects have been developed in the class, each following the process laid out above. Here a few are highlighted:

The "Grab'n Do - Poison Response System" (Figure 2), developed by students Dave Aliberti, Drew Degentesh, Rick Hoobler, Brian Nakai, Erik Royse. This system is a complete poison antidote for the home, targeting families with children. This system alleviates the fear and consequences of children ingesting poisons in the home. The system has a sippy cup with the correct dose of syrup of Ipecac and a container with charcoal embedded in foam, much like "Cheese Wiz", and a flexible straw to help parents inject the charcoal into their kids. The package is shrink-wrapped with an 800 number to allow parents to determine which antidote to give, and a magnet to keep it prominent on the refrigerator.

The "Dionysis Wine Chiller" (Figure 3), developed by students George Chow, Scott Kopcho, Dan O'Brian, Jamie Rugnetta, Jared Schneider, Jennifer Sutherland. The accomplished homeowner with discretionary resources would desire this product that allows any wine to be chilled to the proper temperature within five minutes using a phase change material. The contemporary chiller meets the aesthetic requirements to sit on a dining or buffet table in any upscale home, and would likely be purchased at Williams-Sonoma.

Figure 2: The “Grab’n Do” emergency response system.

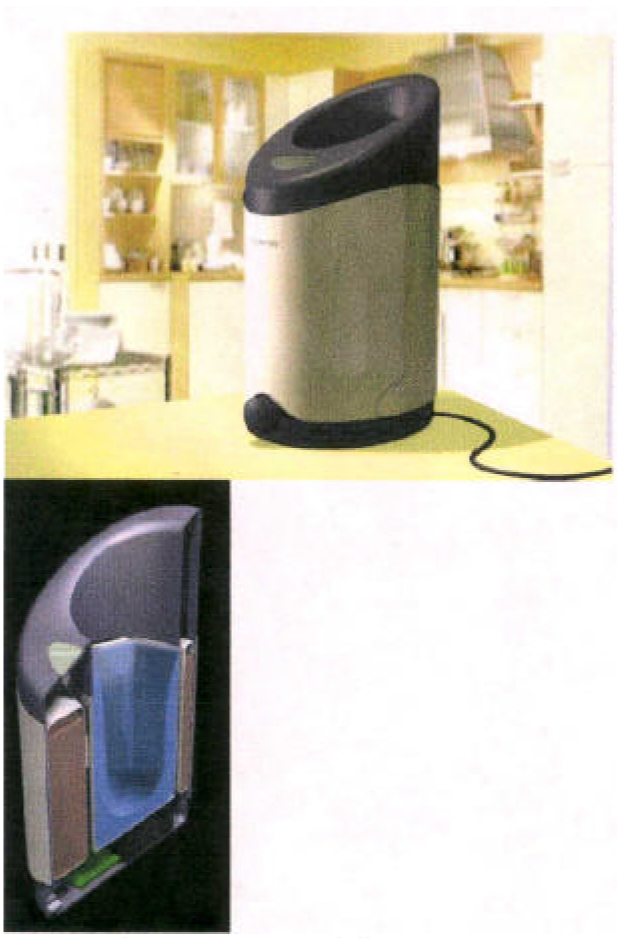

Figure 3: The Dionysis Wine Chiller.

The “Apotheca” system for managing medicine in thehome (Figure 4), developed by students Freddy Anzures, Cormac Eubanks, Eric Hoffmann, Kristo Kriechbaum, Matthew Modell, April Starr. This product targets families with kids whose medicine cabinets or kitchen counters look like disorganized pharmacies. This system allows for pills (prescription and over the counter) to be efficiently stored with minimal footprint. The system locks and each container is removable. Each container is ergonomically designed to be held, fits in a shirt pocket, has an alarm to remind the user to take the pills, and an indicator of the last time a pill was taken. Up to seven medicines can be stored in the system, and pharmacies can fill the containers directly.

Figure 4: “Apotheca” system for medicine manage ment.

The “MasterRack” storage rack system for a truck bed (Figure 5) developed by students Jeff Beene, Linda Bliss, Kat Cohen, Lauren Icken, Samuel Ferraro-Pollak, Sree Vijaykumar. This project was sponsored by Ford Motor Company and now has an issued patent (US Patent 6481604). This reconfigurable storage system for the truck bed targets the “Workhorse” who uses the truck for work during the week and family during weekends. To allow for quick organization, storage, and exchange of tools for personal belongings, the rack system has custom-designed pegs that fit and lock into an extruded aluminum frame to secure modules, frames, or dividers. Containers are purchased that are fitted with the pegs and can easily stack in a garage.

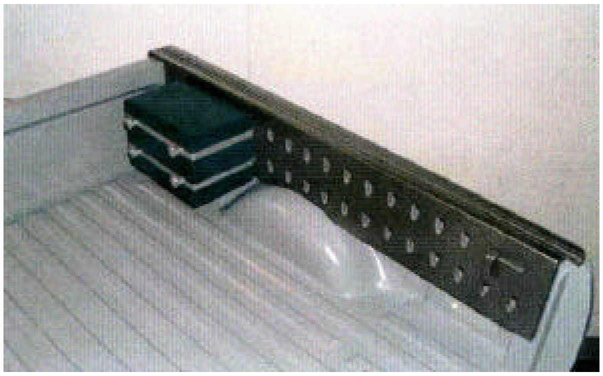

Figure 5: “MasterRack” truck bed storage system.

The “Sidewinder” side worktable for a truck bed (Figure 6) developed by students Rick Bohwman, Dan Darnell, Mark Ehrhardt, Scott Froom, Emily Gustavsen, Josh Guyot. This project was sponsored by Ford Motor Company and was also patented (US Patent 6467417). Most construction pickups have ladder racks and tool chests on the side rails, and a multitude of tools and supplies in the bed. Workspace is thus limited and is often makeshift with saw horses and boards or the use of the tail gate. This product solves the problem by providing a workspace mounted to the side of the truck. Table supports are secured by a bracket attached to the chassis that allows height and tilt adjustments to the workstation while still holding more than 400 pounds. The table folds up against the side of the truck when not in use. The table can also be slid off of its supports and carried to a worksite, where it can be set up on its own legs.

An Interior Writing Surface to create an “office on wheels” within an SUV (Figure 7), developed by students Martin Braun, Zuley Clark, David Del Rosario, Rachel Delphia, Sachin Maheshwari, Ben Turk, Jean Marie Zelt, and also sponsored by Ford. This product is a console-based office in the car integrated into a small SUV. The targeted user is a professional who uses the car as an office, for example an event planner, home therapist, or real estate agent. This console-based system has a writing/laptop surface that pulls out of the top to allow for easy access when needed. The surface swivels and supports sufficient loads to meet the needs of the professional on the go. The console also includes a pocket for files and papers.

Figure 6: “Sidewinder” worktable for a pickup truck.

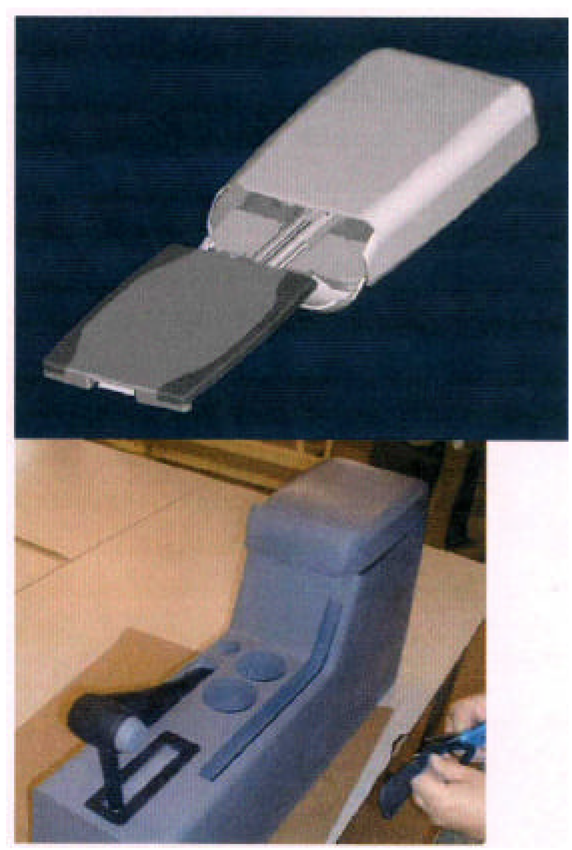

Figure 7: Interior Writing System for an SUV.

An Interior Upkeep System for an SUV center console (Figure 8) developed by students Andrew Birnbaum, JosephGenuardi, Samir Kayande, Esperanza Lo, T. Jonathan Mayer, Lisa Villemure, Erika Wetzel, and supported by Ford Motor Company. This integrated cleaning system is for busy, career-oriented family-focused SUV owners who have little time to clean their vehicle but spend significant time in the car. This system within the center console allow users to vacuum even hard to get to places with a specially designed swivel vac that folds to half its working size and remains charged. A trash bin that is easily emptied is available by opening the lid of the console. Finally, a CD case that allows users to still keep 10 CDs in the console (and can be carried along with them) sits on the front of the console and carries the Ford logo.

Figure 8: Interior Upkeep System for an SUV.

BioMedical Engineering Design

With the conversion of the long-standing BioMedical Engineering (BME) program at Carnegie Mellon into a full department, there was an opportunity to create a unique senior design experience. During the Spring of 2003 the IPD course expanded to serve that role. Added to the teams were two BME students and the theme turned to biomedical product development. Two sections of the course were offered, one sponsored by Respironics to explore new directions for sleep therapy, and the other by start up BodyMedia to explore products and environments for body monitoring.

The first phase was extended to allow the teams an even deeper research period that included physiological and biological research. The same syllabus and methodology was used for the 12 teams to develop complete product solutions. Each project was patentable, and many showed commercial excitement. At the time of this writing the two companies are exploring their patenting options based on commercial feasibility within their business context.

Master's in Product Development

A growing national and international focus on developing consumer and industrial products has created an environment where many engineers and industrial designers seek additional education to enable them to play a more substantial role in product development. As demonstrated with the IPD course, Carnegie Mellon has been a leader in the area of product development, and in particular integrated product development. The close relationship between the Department of Mechanical Engineering and the School of Design has provided a unique environment of collaboration and education for our students. In addition, further participation by the Graduate School of Industrial Administration (GSIA), our business school, has broadened the educational offerings for our students. We have taken advantage of our capabilities and the growing interest in product development to create a new professional masters degree to meet the emerging needs of industry. The goal is to develop engineers and industrial designers into more accomplished practitioners and managers in the product development process.

The degree builds on the IPD course, with the course as the capstone of the one-year experience. The degree is not an MS or MA, but rather a new degree, the Master's in Product Development (MPD). This university degree is jointly offered by the Department of Mechanical Engineering and the School of Design, with support from GSIA. Details of the degree can be found at *www.mpd.cmu.edu* .

The targeted student for this one year program has a BS degree in engineering or a BFA (BA or BS) in industrial design, or related fields with some experience and a strong interest in product development. In the engineering field, mechanical engineers, in particular, often have a background that is particularly well suited to product development. However, a traditional engineering degree provides only the foundation. The student must also gain skills in the design process, manufacturing, industrial and communication design, and business. From the design side, industrial design students may already have a background in product development. However, few designers have a background in Integrated Product Development or any background in engineering. In fact, most ID programs do not focus on the complete product development process; they tend to concentrate on form-giving and aesthetics.

Communication designers also have a background that may be suitable for product development with additional training.

The focus of this degree is the creation of physical, functional devices that meet a user's or stakeholder's value expectation. However, many of the skills and knowledge from this program also apply to the development of services, interfaces, and the general creation of any product that meets a value expectation.

A graduate from this program should have the following skills:

- An understanding of and experience with the product development process, especially through an integrated approach.
- The ability to function and lead the interactions in an integrated team of engineers, designers, marketers, and those in finance.
- An understanding of marketing planning and new product financial justification.
- For engineers, an understanding of industrial and communication design and the ability to communicate with designers. For designers, an understanding of the basic requirements of engineering and the ability to communicate with engineers.
- An understanding of the role of brand in the product development process.
- A working knowledge of historical reference for product development.
- An ability to perform and interpret user research including ergonomics and lifestyle semantics.
- An ability to create manufacturing specifications of a product.
- A working knowledge of material selection for products.
- A firm background in mechanics as applied to product development.
- A basic understanding of electronics.
- An appreciation for environmental and human health impact of products.

Because of the diverse sets of experiences and backgrounds of the targeted students, each student’s skills are reviewed upon entering the program, and the course selection is tuned to ensure that each student develops as many of these skills as possible.

The two semester curriculum includes 4 required courses and 4 electives to meet the needs of each student. The required courses are the capstone IPD course, a course on design history, a course on industrial design fundamentals, and a course on entrepreneurship. If a student already has taken one of these courses an appropriate substitute is allowed.

Carnegie Mellon has a culture and environment able tosupport this type of program. Administrative and teaching cooperation in three colleges and integration of the students within each department is difficult at best at many places. However, the ability for students to take courses from, and be immersed within, top schools of engineering, industrial design, and business is what makes this experience so useful and fulfilling to the students.

Of note, as well, GSIA, the business school, has also begun an IPD track within its MBA program. Mechanical Engineering and the School of Design both support this track, as GSIA supports the MPD degree.

Mechanical Engineering Senior Design: The New Breed of Engineer

As one observes the emerging needs of industry today, and focuses on those companies who are developing the most exciting new products, one realizes that the traditional quantitative and analytical engineer, educated in the current discipline specific focus, is no longer sufficient to meet those needs. Rigorous analytical capability is still required but is no longer enough. Instead, a broader engineer in training and philosophy is essential to fully contribute to the product development process. Certainly a part of that is a broader engineer who is comfortable working across engineering fields, has an appreciation for sciences such as biology and their emerging impact on engineering, and can function in cross disciplinary teams.

At Carnegie Mellon we see the need for a “New Breed of Engineer”, one well trained in (mechanical) engineering fundamentals, but also one with a broader context. Thisengineer not only has exposure to the above issues, but also has the follow characteristics:

- Appreciates aesthetic implications – technology is only one aspect of a successful product solution;
- Creates connection to user/stakeholders – a product created independent of the target user, no matter how well executed, will likely fail in the marketplace;
- Understands brand and connection to form – the product development team *creates* the brand identity for the product, and often company;
- Connects to lifestyle, emotions and culture – products, whether stand alone consumer or components within a larger business-to-business system, create the experience that must fit within the user’s context;
- Demands integration with *equal* discipline contribution – engineers, industrial designers, and marketing and finance all bring equally important roles to the development of a product, and one’s discipline can not lead without full participation of the others; and
- Contributes to soft quality as well as hard quality – quality manufacture programs and cutting edge technology must work in concert with the users’ emotion, the products’ form aesthetics and brand identity, and the ergonomics of use of a product. A well made product that finds no enthusiasm in the market is a failure.

Our mechanical engineering graduates are some of the best at traditional, analytical engineering, but every one is also exposed to, and many embrace, the characteristics laid out for the New Breed of Engineer.

The teachings of IPD and these characteristics are of principle focus within the capstone mechanical engineering senior design class. The IPD process is followed, except to emphasize the engineering content and execution, the first two phases are combined and compressed. Even so, the first third of the course explores the Social, Economic and Technology factors to seek out Product Opportunity Gaps, followed by an intense period of stakeholder identification and primary user research using ethnographic methods. The result is a value proposition, using the Value Opportunity Analysis, and early product definition that speaks to the users' needs, wants and desires. This then provides for a richer and more effective conceptualization process.

Although the emphasis is on mechanical engineering technology, the students are all exposed to soft quality themes. Many of our students have taken advantage of the open engineering curriculum at Carnegie Mellon to minor in industrial design or art, and thus many teams are able to address the aesthetic and emotional content of the product.

To further emphasize the impact that engineers have on individuals and society, the class focuses on a socially relevant theme, for example products to assist the elderly in independent living or recreational devices for children with disabilities. The goal is for our engineers to realize that what they do has a direct effect on society and that they must be aware of the decisions they make and projects they choose to work on. There is no evaluation or prejudice as to what is right or wrong, only that engineers can not be naïve to the implications of their actions.

From our experience in IPD we have come to realize that corporate sponsorship increases the focus, intensity, expectation, and overall quality of the projects. This year is the first that a corporate sponsor has been brought into the senior design course. The industrial participant has a hands on relationship as with the IPD course and the same IP rights. This year Kennametal, a leading machine tool manufacturer, is sponsoring the course. The requirement of a socially relevant theme is met by focusing on *environmentally conscious machining*. Although this paper is being written in the fifth week of the semester, the initial project reports, summarizing the compressed first and second IPD phases, are the most insightful and complete in the history of the course.

Resources and Rewards

The IPD course is a significant investment in resources for a single course. Three faculty support approximately 40 students (and an additional faculty member from marketing is scheduled to join the team in the Spring 2004 term). However, there are multiple rewards from the investment for the students, university, and faculty who teach the course.

Most important, those students interested in product development who elect to take the course have a unique and fulfilling experience. The course has given these students an advantage during interviews for jobs and while participating in product development teams. Many have written to the faculty that they actively use the tools in their employment, and some have even been asked by their employer to lead an effort to teach the methods to their team. One entrepreneurial MBA alumnus has found the niche of buying ailing companies and turning them around before selling them. He has succeeded four times and is now on his fifth company, and has several times communicated to the faculty that IPD was the most important class he took during his MBA studies at Carnegie Mellon.

The university has benefited from the course in several forms. The course has international recognition as a leading effort in Integrated Product Development education. IPD is considered a model within the university of what Carnegie Mellon can and does offer its students, with a philosophy that goes back to 1939 when President Robert Doherty laid out the Carnegie Plan for Professional Education. Other schools are copying aspects of the syllabus in developing their own IPD course. The book also brings recognition to the university and in particular the Department of Mechanical Engineering and the School of Design. The course has provided the launching point for the new Master's in Product Development degree and the IPD track in the MBA program, both of which are likely to bring further recognition to the university.

The course also brings attention to the university through the corporate sponsors. Not only do sponsors benefit from IP rights to the final projects, but they have access to a wealth of research that they typically do not have the time to explore on their own. This is particularly true with the second phase where many companies are deficient with insightful user research. Often, as well, the course explores new strategic directions for the companies, helping to define the space of potential products.

Ironically, although there are three (now four) faculty who teach the course, it requires as much time and at least as much effort as to teach a course alone.

Coordination requires major effort, as well as the ability to work with and manage students across different disciplines. All lectures are taught in an integrated fashion. However, the benefits to the faculty have been great. Visibility within the university and outside is strong. The course has provided windows of opportunity for new research directions. Participation in the course has provided new interactions with industry, and, along with the book, has opened up opportunities for executive and team based training and product development process consulting, further disseminating the IPD teachings. This industrial interaction leads to continued evolution in the faculty's understanding of product development and corporate needs, and these findings then feed into the continued evolution of the IPD course.

Closing Remarks

The Integrated Product Development course provides a unique environment for educating students in the product development process. The course introduces an approach that combines state-of-the-art practice, and is integrated with a constantly evolving educational design methodology that prepares graduates for a career in product development as an engineer, industrial designer or marketer. The course and methodology has led to patented products, a trade book, new design courses, and a new professional master's degree. The IPD course was developed within the Carnegie Mellon culture, rich in professionalism and inter-college collaboration. The course also highlights the emerging changes in engineering practice that require a New Breed of Engineer, integrated into the mechanical engineering curriculum at Carnegie Mellon.