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Articles

PERSPECTIVE: Experiential Education In New Product Design And Business Development

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Abstract

We describe an experiential approach to teaching new product design and business development in a year-long course that combines intensive project work with classroom education. Our course puts together up to six teams of graduate students from management and engineering who work on projects sponsored by individual companies. Student teams work with faculty from multiple disciplines and personnel from the sponsoring companies. The year-long format and involvement with company personnel provide opportunities for students to gain hands-on experience in a real product development project. Time constraints, coupled with students' determination to demonstrate what they can accomplish, stimulate teams to learn how to compress the design and development cycle.

To help students generalize from their own projects to a wider universe of product design and business development phenomena, students participate continuously in constructive critiques of others' projects; and in presentations, case discussions and workshops that help them learn about the product and business development process itself.

This article describes course objectives, syllabus, projects, sponsors, faculty, students and our course administration. In an effort to move towards a "paperless" course, we have put as much of the course material as possible on the World Wide Web; relevant websites are referred to in the article.

At the end of the course each team presents a prototype and a protoplan to the sponsoring company in a final report, which in many cases includes suggestions for the sponsor on how to improve its design and development process. Students' positive evaluations, along with their comments, indicate that they are attaining their educational goals. Course projects have resulted in commercialized products, patents, continuing development projects in sponsoring companies, and placements for students. The course has generated public relations value for the units involved and for the university as a whole.

1. Introduction

New product design and new business development are strategic business activities that can be managed to gain competitive advantage in the marketplace. But management of those activities remains a major challenge [7]. One of the major challenges in managing new product development is the need for integration between engineering knowledge and management skills. This need arises because successful management of new product development requires not only a deep appreciation for technical knowledge but also skills in marketing, and managing projects and individuals with diverse backgrounds. At present few educational programs attempt to prepare individuals with both technical and management expertise. Traditionally engineering schools have educated engineers, while management schools have educated future managers. This separate approach fails to address the need for managing technology in an effective and efficient manner [7].

At the University of Minnesota we have attempted to address this problem with an experiential learning model. During the past seven years we have been educating future product and business development leaders through a course entitled New Product Design and Business Development, a

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graduate level course offered jointly in the Carlson School of Management, the Institute of Technology (the engineering school), and the Department of Biomedical Engineering at the University of Minnesota. The course brings together students, faculty and representatives from client business firms to design and develop new products and business plans. Client firms range from billion-dollar companies to entrepreneurial startups. Teams of five to ten students, half second-year MBAs or MHAs (Master in Healthcare Administration), and half graduate engineers, work together for the entire academic year to develop a product and business plan. By June, each team is expected to deliver a working physical prototype of the product and an extensive business plan which details production, marketing and financial considerations for the product. We typically undertake five to six projects each year.

Our course differs from typical classroom courses in new product/business development in that it includes both didactic instruction and a full-scale project supported by sponsoring companies' dollars and personnel. It differs from typical project-driven courses because of the classroom-based instruction; because students have full exposure both to their own projects and to those of all other teams; because the projects are in every sense real-world projects in which the university-company team acts as an outsourced R&D unit; and because the course runs for an entire academic year. This "experiential learning" activity differs from co-operative programs in which students alternate working for a single company with formal coursework, in that our course integrates both coursework and project activity on- and off-campus, and exposes students to the detailed workings of multiple project teams.

We describe first the objectives and syllabus for the course; then the projects and sponsors; followed, respectively, by sections on students, faculty and course administration. We next describe outcomes and future plans for the course, and conclude with key features and lessons learned.

2. Course objectives

Our primary objective in this course is to enable graduate students to become leaders or key members of multifunctional product and business development teams, or members of startup teams for their own businesses. Contributing to that objective are goals (1) of delivering value to sponsoring companies by developing successful products and businesses (or halting the development of likely losers), and (2) of improving the development process itself by enhancing knowledge of that process.

The course is an elective for MBA students in their second year. It provides an opportunity for experiential learning, that is, learning knowledge and skills in the context of a real-world project, as well as an opportunity to integrate in a live commercial setting knowledge acquired in the first year. The course represents one of several that may be used to fulfill a requirement for graduate students in mechanical engineering, and is an elective for students who have fulfilled or do not need that requirement, but who wish to apply their engineering knowledge in the context of product design and business development.

3. Course syllabus

3.1a. Schedule. The course consists of 30 to 35 whole-class sessions, 35 scheduled team meetings and an uncounted number of informal team sessions, plus two formal presentations to the sponsoring companies, one at the end of each semester. Whole-class sessions have proved to be an efficient format for covering material relevant to all teams. These whole-class sessions use lectures, case discussions, presentations by guest speakers and presentations by individual teams. The scheduled team meetings ensure a time that the entire team can meet with its faculty coaches and company representatives. Teams schedule informal sessions to work on specific tasks.

A timeline for the course appears in Table 1. The schedule for the current academic year may be found at *http://www.npdbd.umn.edu.*

3.1b. Deliverables. Our syllabus includes assignments linked to specified whole-class sessions ("lecture prep"), and tasks to be completed at various times. These latter tasks require delivery of a document ("deliverable") in electronic form, in some instances supplemented with a paper copy; and many require submission of drawings and/or models as prototypes. The "deliverables" specified in our syllabus represent interim versions of material that will appear in the final report. The syllabus is structured so that students will frame drafts of final report material early in the course, and revise that material continuously as they proceed through their development work. This procedure helps assure that teams do not neglect or postpone work on important topics; and encourages simultaneous, rather than linear, thinking about multiple facets of a problem. (Assignments for the current year appear on our website, *http://www.npdbd.umn.edu.*)

At the outset, we provide students an outline of an illustrative Final Report, the text of which is available on our website, *http://www.npdbd.umn.edu.* That outline indicates the topics that should be included in a team's Final Report, and suggests the types of materials to be included as text and appendixes. Because no single outline will fit the broad variety of projects and sponsors we encounter, each faculty member has discretion in advising his team how to modify that illustrative Final Report for that particular project. We remind students throughout the course of the relationship of their interim "deliverables" to this Final Report, and encourage them to modify the outline of this illustrative document to fit their particular project. We also encourage students to draft the protoplan and develop pro-

Table 1
Timeline of the Course

Weeks	Lecture/Workshops	Deliverables
Fall		
1–2	NPD Proc ess overview I&II	Resumes
	Project Management	Choose Team Leader
	Pizza Party/Creativity Workshop	
3–4	Kickoff Meetings at companies	Launch Web Site
	Market Identification	Mission Statement
	Ideation	
5–6	Patent Searching	Project Analysis
		Team Presentations
7–8	Sketching	Marketing Cost analysis
	Market Positioning	Preliminary Patent Search
		Voice of Customer (VOC): Pilot Interviews
9–10	Depth Interviews, Surveys	Product Brochure
	Project Planning Tools	Business Plan Draft
	Focus Groups	
11–12	Cost and Price	Product Specifications
	Team Building	Product Architecture
13–14	Intellectual Property	Concept Rendering
		Pricing Plan
		VOC: 25 Interviews
		Team Presentation
15–16		Project Reviews
		At Companies
Spring		
1–2	Professional Communications	Team Presentations
3–4	Medical Device Design	Final Patent Search
5–6	Medical Device Marketing	Final Product Specifications
	Product Liability	Prototype Presentations
7–8	Design for Manufacturing	Product Pitch
	Pitching Your Product	
9–10	Writing a Patent	Final Product Brochure
		Marketing Plan
		VOC: Reactions to Prototype
13–14	Medical Device Marketing	
13–14		Team Presentations
15–16		Final Project Reviews
		At Companies

totypes “early and often,” even if on a partial basis. Both use of this Final Report as a target and frequent drafting of preliminary versions of the Final Report help keep teams focused on their tasks and desired outcome. Further, we believe that the illustrative final report, along with early and frequent prototyping and protoplanning, helps teams to compress the design and development cycle.

Students often question how they can possibly begin work on a plan to commercialize a product whose design characteristics are by no means clear, and which may require innovative technology. In response, we encourage teams to assume that their efforts to design a product – possibly one employing novel technology – to deliver specified benefits will be successful; and then to develop a business plan for that product. The process of drafting a business plan usually points up areas in which design requirements need to be revised, and helps teams identify price (hence, cost) constraints that they’ll have to meet. Once students catch on to the ideas of quickly roughing out business plans for any design, and using a draft business plan as input to design parameters, the teams become more productive on their projects, and also learn the payoff from parallel development of product design and business strategy. For example, in one instance we asked a team to *assume* that they would succeed in the mission they had set for themselves – to design an endoscope small enough to fit into the root of a tooth – and then to develop a business plan for such an endoscope. The team did so, and learned to develop both the product and the business plan in parallel. As a result, they identified and pursued areas for both technical and market innovation of which the sponsor had not been aware.

3.1c. Specific content. Content of the course is guided by four considerations: (1) what tools students of engineering and administrations, respectively, need to communicate with one another; (2) what additional education in (a) product design and (b) business planning engineers and business

Table 2
List of textbooks used in new product design and business development

Crawford, C. M. & Di Benedetto, C. A. 2000. ***New Products Management.*** Boston: Irwin McGraw-Hill.
Hanks, K, & Belliston, L. 1992. ***Draw! A Visual Approach to Thinking, Learning, and Communicating.*** Menlo Park: Crisp.
Hitchcock, D. 2000. ***Patent Searching Made Easy.*** Berkeley: Nolo.
Krueger, R. A. 1994. ***focus Groups: A Practical Guide for Applied Research.*** London: Sage.
Pahl, G., & Beitz, W. 1999. ***engineering Design: A Systematic Approach.*** London: Springer.
Pressman, D. 2000. ***Patent It Yourself.*** Berkeley: Nolo.
Rosenau, M. D., Griffin A., Castellion, G., & Anschuetz, N. 1996. ***The PDMA Handbook of New Product Development.*** New York: Wiley.
Scholtes, P. R., Joiner, B. L., & Streibel, B. J. 2000. ***The Team Handbook.*** Madison, WI: Oriel.
Siegel, E. S., Ford, B. R., & Bornstein, J. M. 1993. *the Ernst & Young Business Plan Guide.* New York: Wiley.
Urban, G. L., & Hauser, J. R. 1993. ***Design and Marketing of New Products.*** New Jersey: Prentice Hall.

students, respectively, need in order to become proficient in the product design and business development process; (3) what knowledge students from both sides need for proficiency that is not covered in prior engineering or business curricula; and (4) what knowledge about the design and development process per se is appropriate to help students become effective participants in/leaders of design and development teams.

We address the first consideration through whole-class sessions involving individual sketching and team model-building; and in sessions on market identification and customer behavior analysis. A primary goal here is to provide common skills and vocabulary.

To meet the second consideration–additional education–we have exploited a natural area of overlap between management and engineering through a series of sessions on Voice of the Customer [6]. We have teams design interview schedules, conduct interviews and use the results as a basis for design of product and business plan. Because few students will have been exposed to anything but basic knowledge of commercialization plans and pricing for new products, we schedule whole-class sessions on those topics. Similarly, most students regardless of discipline have limited background in developing business plans and "selling" their ideas, so we cover that topic in whole-class sessions.

To address the third consideration, because our course is unique within both engineering and management curricula, we must cover some topics to which neither MScE or MBA/MHA candidates will have been exposed, such as intellectual property protection, patent searches and filings, and product liability, all of which are taught by attorneys practicing in their respective specialties.

To help students learn about the process of new product design and business development – the fourth consideration –we include formal sessions on group processes, to help teams analyze their own behavior and make changes that could improve their activities. In addition, guest speakers make formal presentations on Product Innovation Charters, their experiences with Stage-Gate and other techniques. Faculty coaches encourage teams to use the reference books provided each team (see Table 2) as sources for ideas from documented approaches to apply to their own situations, and to discuss their results from doing so. One result of this procedure is students' recognizing that no single formalized process fits all projects, and that any one project can benefit from borrowing concepts from more than a single formal approach.

Whole-class sessions also include presentations from each of the teams to the rest of the students and faculty. We use these sessions both to provide team members with practice in presenting and defending their ideas, and to help class members generalize about the new product/business development process. For example, when teams present their draft plans for marketing their products, it becomes clear that there is no uniform approach to marketing new products. We then can discuss as a whole class how differences in markets served, novelty of product and resources of the firm itself can influence the structure, content and budget of marketing plans for new products. We use a similar approach in meetings with individual teams, during which we may contrast one team's problems and progress with that of another, helping the students to make distinctions among new product situations, and enabling them to set aside or refine for their own purposes normative statements they have encountered in their reading or from their sponsoring company.

To encourage students to think about a broader range of product and business development phenomena than their own and their classmates' projects, we typically have 10–15 speakers (in addition to course faculty) address the class on various topics. Attendance at these lectures has been uniformly good, because we schedule them in the fall term and early in spring, before end-of-project pressures prevent students from attending to anything but the projects themselves. Further, we schedule guest speakers to address issues that are currently of interest to all teams; for example, we have a guest speaker on focus groups a week or two before most teams will conduct them. All but two or three of our speakers come from the business community; the remainder are faculty from different disciplines within the University. We are fortunate to work in the midst of a large business community that is willing to share world-class expertise with our students, and to have academic colleagues from other units who are willing to share their expertise with us.

We recognized early on that team morale –in this course or in industry – affected motivation, which in turn influenced output. When individual teams become frustrated by technical or procedural delays, or by discovering that particular product design or business development ideas don't pan out, we can intervene as faculty coaches to point out that the team is experiencing a phenomenon normal to product/business development efforts, and that learning to deal with this frustration (one's own or that of others) is an important part of learning how to manage and improve the process. We offer suggestions based on our own experiences to help teams work through particular obstacles, sometimes prodding with constructive criticism, other times offering encouragement and boosting team self-esteem. Because we generally observe a letdown after the presentation to the company at the end of the first semester and the semester break, we schedule sessions on group process at the beginning of the second term to help teams focus on how they function, and how they can improve their work together.

3.1d. Content development. In the first years of the course demands for whole-class sessions far exceeded the hours available, in part because management faculty recognized the need for engineering students to be exposed to a significant portion of an MBA (or MHA) program, and because engineering faculty saw that even highly compressed lectures and readings on design topics for management students would overwhelm the time available.

We struggled with these issues without direction until we were fortunate enough to have join the course faculty a PhD in Adult Education and Organization Development, who had experience developing training courses for industry. With his guidance, we pared down the topics we attempted to cover, and developed for each whole-class session learning objectives, preparation assignments and a statement of how each session contributed to the final report that teams would present, and/or to individual students' learning about new product design and business development. Developing learning objectives for each session had two goals: (1) an internal goal for the faculty to insure coherence and synergy among individual lectures in the course; and (2) a goal to provide students with a clear picture of what would be accomplished in the course, and how individual sessions would contribute to that accomplishment. This process led us to articulate the four considerations (above) that guide selection of materials for whole-class sessions.

As part of this overhaul of our syllabus, we began development of a "book" whose purpose was to provide students with (1) a set of learning objectives, and (2) materials for each session that they could use as supplements during the course and refer to later in their careers. The need for a well-organized set of materials of this sort was pointed out by students who wanted explicit cues to what they were supposed to learn, as well as ready references to materials about particular topics. Over time we have internalized and no longer write out our learning objectives for each session, and our "bookbuilding" activity has lapsed. Nonetheless, our syllabus reflects the precision of topic, assignment and "deliverables" that we've learned.

3.1e. Resources. We provide each team with a set of publications to use as references throughout the course (see Table 2). These books are physically housed in the reserve section of the university's central library.

We encourage teams to make use of the entire spectrum of intellectual resources available at the University. As a course faculty we collectively have a substantial network within the institution, which we tap whenever a team needs additional resources. We follow a similar procedure for resources within the business community.

4. Projects

The course has grown from three projects in its first year to a steady state of five to six projects per year. Of the total of 36 projects with which we've been involved over the past seven years, 18 (half) have been medical products; 11, industrial products; and seven, consumer products. Two projects have involved information technology exclusively, while eight others required software design as a significant portion of the total product. A list of projects, together with their sponsoring companies, appears in Table 3.

In our experience, projects selected carefully by the company in consultation with course faculty have provided the most appropriate educational experiences for students, and greatest chances for successful outcomes from the company's point of view. Often the best project from a company's viewpoint is one for which they have appetite but lack expertise or adequate in-house resources.

Best results for all stakeholders appear to come from projects in which the general area of application is identified, but specific product requirements are left to the team to decide, so that the team has an opportunity to design on the basis of full engineering and business analysis. Ideally the project should have significant market analysis and development challenges, in contrast to minor product line extensions; and significant engineering content, as distinct from clothing, books or paper clips. To take full advantage of faculty strengths and student interests, our projects involve products that come in discrete units, in contrast to those driven by process control issues. Given the expertise in medical devices at the University of Minnesota and the concentration of medical device manufacturers in the Twin Cities area, medical devices provide a natural source of projects for us.

Projects presented by sponsoring companies at the beginning of the class vary in scope and precision of definition. Some projects have called for development of a multicomponent system; others, for one part of a subsystem. Some projects have posed the challenge of identifying a new market for a company's core technology and designing a product to enter that market, while others have focused on development of a specified product-market concept. Projects have included "new to the world" products, and total redesigns of existing products and creation of totally new systems.

Course faculty work with student teams early in the course to limit the scope of projects and to define the

Table 3
Sponsors and Projects

Billion-Dollar Companies	
3 M Company	Fluid Dispensing System; Post-It Flags
Honeywell	Residential air Exchanger
Hormel	Quality Assurance Indicator
Medtronic	Visible Heart CD; Catheter; Heart Analyzer
Sulzer Medica	Joint Replacement; Arthroscopy; Disc Fusion
Toro	Hedge Trimmer
Multi-Million Dollar Companies	
Aetrium	Integrated Circuit Testing Machine
Andersen Windows	Novel Window Product
Augustine Medical	Ptient Temperature Control; Operating Room Equipment
Donaldson	Small Engine Exhaust System
Horton Manufacturing	Clutch and Brake Control System
Irwin Publishing	Interactive Teaching CD
Reel Precision Manufacturing	Appliance Hinge
Scimed	Medical Device
Select Comfort	Individual Temperature Control
Start-Up Companies	
Enhanced Mobility Technologies	Interactive therapeutic Device
EnduraTec	Biomaterials Testing
Lincages	Engineering Software
Introspective	Microcatheter
Iris	Spherical Data Scanner
Machine Magic	Key Duplicating System
MircroMedical	Microendoscope; Optical Endoscope
Molecular Diagnostics	DNA Testing Kit
Rust Engineering	Ice Structure Preservation
Shepherd Medical	Biomechanical Contraceptives
Soil Sensors	Moisture Control Systems
Vivacare	Emergency Medical Data Transmission

Note: 3M, Medtronic, Sulzer, augustine Medical, Horton Manufacturing, MicroMedical have each sponsored multiple projects, which are separated by semicolons in the list above.

challenges precisely. This exercise leads to teams' preparing written "mission statements," which guide the teams' activities through the year. Teams may revise these mission statements as they learn about the market and confront design challenges, and as they provide their sponsoring companies with clearer ideas of problems and potentials. This process mirrors business development in industrial settings. We try to teach students to be sufficiently flexible so that they can change directions without jeopardizing the project mission.

Overall our projects have required students to spend much more intellectual energy at the "fuzzy front end" than projects (in other courses) specified by engineering faculty or cases (or projects) assigned by business faculty. Because prior educational experiences of both engineers and management students consist largely of learning how to address already-defined problems (e.g., design projects, cases), the challenge of project definition and redefinition in a "living laboratory" context expands significantly students' educational experiences.

5. Sponsoring companies and sponsorship agreements

Sponsors have included six multibillion dollar firms; 10 multimillion dollar firms; and 11 start-up firms with sales under $1 million (See Table 3). Three of the largest firms have sponsored projects in multiple years; two of the multimillion dollar firms and one of the smallest firms have also sponsored multiple projects. One of our largest sponsors, Sulzer Medica, is located in Switzerland; we communicate with them primarily by e-mail and videoconference. One of our smallest sponsors is headquartered in Ohio; teleconferences and e-mail supplemented occasional visits to the university by their CEO. Evidence that sponsoring companies take these projects seriously comes not only from their willingness to invest personnel time and dollars, but also from the fact that final project presentations often attract up to 20 senior executives, including CEOs, and larger numbers of managers.

We recruit sponsors from faculty contacts in the business and technical communities. Course faculty have continuing contact with alumni who suggest projects themselves and recommend the course to their colleagues. Companies with whom we have consulting relationships often sponsor projects, though we exercise care to assure that course projects are kept separate from consulting activities, and to comply with the University's conflict-of-interest policies. Over the years students have brought projects to the course as well. This year a student who took the course two years ago brought in a project for a biomedical product on which he and a recent MBA alumna hope to start a business; the pair's business plan won a business plan competition last year and has received initial investor funding.

Each spring as we begin to solicit projects for the following year we keep a running status log of companies contacted, name of contact and likely interest. We update this log continuously as project solicitation proceeds. We have found that some companies are able to commit to sponsorship four or five months before the start of the course; others, not until one to two months before.

Our agreement with sponsoring companies calls for them to provide –in addition to a product design and business development challenge – (1) company personnel to work with the student-faculty team, (2) support for the project at levels comparable to internal projects, and (3) payment of a course fee that partially offsets the extra cost of instruction for this course. (Each of these is described in more detail, below.)

In return, sponsoring companies receive any intellectual property that may be developed in the course of the project, including one or more working prototypes, a detailed engineering report and a comprehensive "protoplan," an early version of a complete business plan. Students are expected to perform at a level that will deliver substantial benefit to the sponsoring company, but no guarantees can be made; our primary mission is to provide appropriate education for the students, and even experienced product/business development teams cannot accurately predict levels of achievement by a particular date nine months hence. If a company needs guaranteed deliverables, a better approach would be to develop the product internally, or to contract with an independent market research or product development firm.

5.1a. Cooperation and support. We ask sponsoring companies to identify at least two individuals, one from the "engineering" side of the house and one from the "business" side, to work with the teams. Many firms do just that (e.g., 3M). Others assign more company personnel to the team (e.g., Horton), with the objective that those individuals will benefit from the learning from the course. While some firms' personnel have only intermittent contact with teams (e.g., MicroMedical), individuals from other firms become full members of the team (e.g., Augustine Medical).

Interaction with the company is substantial. Two or more company representatives from marketing and/or engineering typically attend weekly team meetings held on campus. In many projects students spend considerable time at the company, particularly in the final weeks. Towards the end of the course, as the project is gradually handed off to the company, more and more work is done by company personnel working alongside the students.

We receive the greatest teaching support from companies experienced in creation of new products/businesses, and from seasoned investors in new ventures. Inventors without experience in business offer the greatest challenge to both students and faculty coaches. Notwithstanding our explaining to inventors that market and business analysis may indicate a change in direction –or even aborting the project– inventors often resist team recommendations and attempt to steer the team in a particular direction. Brief descriptions of example projects from the course appear in Table 4.

The design and development team will incur project costs to conduct marketing research, construct prototypes and produce reports. We suggest that the sponsoring company support all expenses associated with these and other activities at the same level as it would if the team were internal. Company resources such as internal prototyping shops should also be available for use by the team when appropriate. Additionally, it is beneficial to send one or two of the student team members to an industry trade show relevant to the project. Each time a major cost is anticipated, the team determines whether that cost is appropriate. Each team is provided with a small discretionary fund for expenses that are course-, but not project-related, and for small purchases that are needed immediately and would take too long to clear company purchasing channels. Companies have spent thousands of dollars fabricating prototypes or supporting professionally moderated focus groups, all part of normal development costs.

Successful product design and business development requires knowledge of prospective customers, competitors, past design efforts, patent position, manufacturing capabilities, financial expectations and other information. We expect sponsoring companies to share with the team whatever information they have. Withholding information under the philosophy that, ". . . the students should learn by figuring that out for themselves," simply delays the whole process and results in a much less productive experience for all concerned. No matter how much information the company may provide, students have to conduct additional marketing research, patent searches, and the like.

5.1b. Sponsorship fee. Approximately 2/3 of the sponsoring firms have paid the full course fee, which currently stands at $25K. Firms with sales less than $1 million (about 1/5 of all sponsors to date) have paid a partial fee, currently $10K. Startups that have not yet advanced to the stage of securing outside funding (about 13%) have had course fees deferred. Over the seven years (including the current year) that the course has operated, our fees have gradually risen. Total course fees collected over the seven years that the course has been offered approach $600K; our average income per project over that period is about $16.3K.

5.1c. Formal agreement with sponsors. We discovered in the early years of the course that attempting to separate intellectual property creation between the company and the university proved an all but intractable problem, and that assigning all the intellectual property to the sponsor offered an attractive inducement to participate in the course. Sponsors maintain confidentiality of proprietary information

Table 4
Summary descripotions of illustrative projects

The **3M Post-It © Flag** group approacheds use with a challenge to find innovative products and uses for Flags which could increase sales, possibly by opening new markets. The team of students, faculty and 3M representatives generated some 200 concept ideas at the level of index card sketches, built about 40 prototypes and narrowed selections to five ideas realized in refined prototypes. In the process, voice of the customer information was gathered through dozens of one-on-one interviews and four professionally-moderated focus groups. Sales forecasts encouraged 3M to go forward with final development and full commercialization of a design combining elements of the final prototypes.
A team working with **Augustine Medical,** a medium-size medical device company specializing in producs that control patients' temperatures during surgery, sought new markes for the company's core technology. The team identified an appropriate market, and built and field-tested several prototypes. Augustine Medical officials stated that working with the team saved then at least a year and a half in the development cycle.
Sulzer Medica, a Swiss company that is the leading European producer of joint implants, asked a team to develop a new product to facilitate hip surgery. Having a sponsor several thousand miles away highlighted the avantages and limitations of e-mail, fax, phone and videoconferencing communication meda, all of which were used. Because the product was to be introduced first in Europe, getting voice of the customer data from othopedic surgeons proved difficult. Nonetheless, the team took some risks to develop a working prototype that Sulzer will carry forward to full manufacture and commerciallization. the team also prepaed a detailed business plan for product introduction both in Europe and in the United States.
Medtronic sponsored a project that resulted in production of a CD-ROM, the Visible Heart Viewer. The CD was distributed in PACE magazine and at the North American Society for Pacing and Electrophysiology. Through intensive brainstorming sessins, the team defined its mission statement and analyzed the target audience. A content subgroup obtained new images, developed supporting text and laid out animations to be developed. A multi-functional marketing team focused on developing a comprehensive launch strategy, obtaining both voice of the customer information and internal support. By the end of the academic year, the team presented its finished prototype, a project analysis and a handoff plan, which outlined final development activities. More than 60 Medtronic executives and managers attended the final presentation. At the end of the class, three student members of the team were hired to expedite completion of the CD.
Machine Magic brought to the course a novel key duplicating machine, onb which the compamy's principal–an independent investor–had already spent several thousand dollars with a design engineering firm. the investor knew little about demand for this type of product or how to position it in the market, but was attracted to the key duplication market because he believed it to be very large and because he had experienced frustration in obtaining duplicaes of particular keys. The student team began work alongside the engineering firm. After a class lecture on focus groups, the team convinced the investor to fund one. They argued that the $3K cost would provide as much value as the tens of thousands already invested in the machinery itself. The team organized a focus group with local hardware store owners; artists' renderings of the machine and a videotype of the prototype in operation conveyed the concept. The focus group identified several aspects of the machine and duplicting process that the machine could not handle; focus group participants essentially said, "We wouldn't use it." This information, coupled with the team's report, convinced the investor to wind the project down. While disappointed at the outcome, the investor praised the team for its professional approach and thanked them for saving him future development investments that would have come to naught.
Rust Engineering provided one of our more challenging projects, which involved the development of a device for preserving ince structures and ice sculptures. Team members came from five different countries; engineering students from India, Russia and Tunisia had to participate in voice of the customer research. The resulting education helped bring the group together with a common understanding of the marketing, cultural and engineering challenges before them. the team began with a very "fuzzy" problem, but ended with a working prototype and a plan to commercialize the product.

through all students and faculty signing confidentiality agreements for *all* projects.

This procedure facilitates team interaction, and enables the faculty and students to generalize what is being learned from each project. We have found sharing information to be one of the best methods for learning about and improving the product development process, and each company has the benefit of many more students and faculty thinking about its project.

The text of our formal agreement with sponsoring companies appears on our website, http://www.npdbd.umn.edu. This agreement among students, faculty and sponsoring companies obligates signers to prevent disclosure of confidential information that is revealed to them by the companies. Confidential information may take the form of product concepts in existence at the company, design drawings, reports; information about customers, suppliers, resellers, competitors. We take care that any such information with which students or faculty come into contact is marked "Confidential," and every effort is made to limit the transfer of information to only what is required for the team to succeed on the project.

Some implications of the *confidentiality* clauses of the agreement include the following:

1. Students and faculty cannot disclose confidential information to friends, family, spouses or faculty not involved in the course. In short, students are prevented from revealing the information to anyone who has not signed the agreement.
2. The agreement is between the student and the company, not between the university and the company. In case of litigation, the University of Minnesota's legal office will not be able to represent students.
3. The agreement has a five-year time limit.
4. Students must maintain confidentiality up to the time limit, even though they may work for a competitor after graduation. Students may not discuss details of their projects in job interviews, though they can –and do – give potential employers adequate descriptions of their activities during the course and the skills they have learned.
5. Faculty and students may publish results from the project, provided that any submission for publication or presentation is first screened by the company to ensure that it contains no confidential information.

These confidentiality provisions have made sponsors comfortable with revealing cost, manufacturing and market data–

in short, any information to which a company insider would have access. We discuss with prospective sponsors, in advance of signing, the need for full disclosure and access for the student teams. Companies reluctant to divulge information that might be central to the team's work are advised either to set aside their reservations or not to participate in the course.

The *intellectual property* portion of the agreement covers what happens to any patentable ideas that are developed as a result of working on the project. The agreement requires that students and faculty assign to the sponsoring company their patent rights as named inventors. Because the design teams are large, it is likely that patentable ideas will result from the contributions of more than one team member. The Patent Office has a strict definition of who appears as named inventors on a patent, and it is those named inventors who will be assigning the patent over to the company. Some implications of the intellectual property clauses of the agreement include the following:

1. A student or faculty member may be a named inventor on a patent even if patent ownership is assigned to the sponsoring company.
2. Because rights are assigned to the company, students are not allowed to make, use or sell any product they invent; only the company may do so.
3. The company pays all fees and expenses associated with patent filing. These costs typically range from $10K to $20K.
4. Ideas, concepts or methodologies developed by the team may have potential for significant increases in sales and/or cost savings by the sponsoring company. The company is free to pursue those ideas without returning monetary rewards to student inventors or to the university.

The confidentiality and intellectual property agreement enables the university to participate in real projects with companies. Settling on a form for the agreement required substantial negotiations between lawyers for the companies and those for the university. Universities have no hold over student work done for courses, but it is unusual for a university to allow a contract where faculty assign their rights to a company, since faculty are employees of the university. Nevertheless, all parties agreed that this procedure was essential to enable a substantial learning experience for the students.

6. Students

Enrollment typically consists of 30–40 graduate students, about half of whom come from engineering disciplines and half from management. Engineering students include first- and second-year students in mechanical, industrial, electrical and biomedical engineering who are enrolled in Master of Science in Engineering (MScE) programs; over the years we have also enrolled three doctoral students in engineering. Management students are second-year MBA and MHA (Masters in Health Care Administration) students in the Carlson School; their concentrations have been in marketing, strategy, operations and management science, information and decision sciences.

More than 85% of our students attend the University full time. They represent a cross-section of our master's degree classes in management and in engineering. With respect to gender, age, prior academic performance, ethnic background and country of origin, the students in our course do not differ significantly from the MBA, MHA or MScE populations, respectively.

The course is an elective; it fulfills a requirement for a design course for engineers, but engineering students may choose other courses to meet that requirement. The course is not required of management students.

Students who enroll in the course make a more substantial investment of their time and effort than their colleagues who simply take two single-semester courses. Our students must commit to a two-semester sequence. Although the course workload is heavier than a typical graduate elective, students receive the same eight credits as they would for two single-semester electives.

6.1a. Team composition. At the beginning of the course students rank projects in order of their preference. The faculty intervenes in this choice process only insofar as necessary to make team sizes roughly equal across groups, and to match students' particular backgrounds (e.g., marketing, electrical engineering) with requirements of the projects. To date, more than 80% of students have received their first choice; the remainder, their second choice. No student has withdrawn from the course because of disappointment over project assignment.

The combination in task groups of students whose educational and (often) cultural backgrounds are quite diverse may generate conflicting viewpoints on team procedures and project priorities. Occasionally these conflicts can threaten to stall a team. Faculty coaches are sensitive to such conflicts, and suggest mechanisms for resolving them. These mechanisms range from simply pointing out that conflict exists and indicating that the team should resolve it, to serving as arbitrators who render decisions so that work on the project does not become paralyzed. Should conflicts arise between the team and the company, faculty coaches typically take the roles of "honest brokers" to effect amicable compromises to move the project forward.

7. Faculty

Each team has an interdisciplinary faculty coaching staff, typically one member from the Carlson School and one from engineering or health sciences. One of the coaches typically takes a lead role.

Faculty for the course come from marketing, operations, information and decision sciences and entrepreneurial studies within the Carlson School; from mechanical and electrical engineering from the Institute of Technology and the Department of Biomedical Engineering; from anesthesiology in the Health Sciences unit of the University of Minnesota; from independent professionals in the product/business development community; and from practicing attorneys. (Current faculty appear on our website, *http://www.npdbd.umn.edu.*) Additional coaching comes from executives and technical personnel from the sponsoring companies. Coaches provide instruction in business creation, product design and development; and have overall responsibility for seeing that the teams set appropriate, realistic goals and proceed towards them on a timely schedule.

The composition of this faculty team has varied over the years. One member of our founding team has retired, another left the university and others have been drawn away for other assignments. As faculty members have left the teaching team others have volunteered to replace them. This turnover has enriched the team: we have all learned from teaching with specialists in adult education, thermodynamics and industrial engineering, respectively, who participated in the course for two or three years and were then called to other responsibilities. This turnover has also forced us to codify our curriculum and procedures, to make the course structure strong enough to withstand faculty turnover without upheaval or change in direction.

Each faculty member has his own style of working with a team. Some of us behave like senior members of the team; others play more of a "coaching" role.

8. Course administration

The course meets Tuesday and Thursday mornings from 7:30 to 9 a.m. Whole-class sessions occur every Tuesday and some Thursdays; formal team meetings take place Thursday mornings unless teams make other arrangements. To make early morning classes more palatable, teams rotate responsibility for serving continental breakfast at every whole-class session.

8.1a. Faculty assignments. Faculty assign themselves to particular projects according to their interests and expertise. We attempt to have one engineering or health science faculty member and one management faculty member working with each team. Because for some years we have had only one senior marketing professor in the course faculty, and because fairly extensive market analysis and planning was essential for almost all teams, the senior marketing person met periodically with each team, rather than working continuously with only one or two teams. In addition, when a team requires expertise of a course faculty member other than those assigned to the team, we see to it that such expertise is made available.

Throughout the year course faculty meet approximately every three weeks to attend to administrative matters, to work through ideas for improving the course, to discuss progress of the teams, and to plan any intervention that may be appropriate related to business or design problems confronted on a particular project, or related to team morale.

Each spring a self-designated subset of the course faculty takes responsibility for drafting a schedule for the coming academic year. Other subsets take primary responsibility for recruiting projects, speakers and students, respectively.

8.1b. Communication. The course is managed almost wholly electronically, and is nearly "paperless." Faculty and students use e-mail extensively for communication. Each team has its own e-mail address. As a faculty, we can send mail to one student, one team, all teams, all faculty and to everyone involved with the course. Each team uses e-mail to communicate among members, including company representatives. Each team's e-mails are password-protected. The course syllabus and all assignments are posted on the course web page, *http://www.npdbd.umn.edu*, which contains links to all materials related to the course, including brochures, confidentiality agreements, and the like. We update the website continuously to provide information on schedule changes, clarification of assignments, critiques of presentations (we typically share our critiques with the whole class when the whole class has heard the presentation) and student questions.

Grading combines the faculty's overall evaluation of the progress of the team as a whole, the evaluation by the faculty coach of individual team members, and team members' anonymous evaluations of one another. As a faculty, we consider where the team started, how far they've moved toward accomplishing the goals that they set (and the faculty approved) and what obstacles they've had to overcome to do so. In a typical year all but one team will fall into the A or A- range; the "laggard" will usually receive a B+. Within the teams there appears to be significant peer pressure for everyone to "pull his own weight." Perhaps one or two students each year are judged by their teammates to be "slacking off." We ask each student to evaluate his peers by dividing 1,000 points among them, and commenting on their contributions and shortcomings. Students' evaluations and comments are typically consistent with, but somewhat more critical than, those of the faculty. During our first four years, we included two or three quizzes on reading material, but have dropped those, as they accounted for an unmeasurably small amount of variance in grades, and diverted students' energies from their projects. We believe that students will generalize more effectively from exposure to and discussion of their classmates' projects than they will from readings per se.

Funds collected from sponsoring companies are used first to defray direct expenses of the course, which include (1) purchase of time from an information systems specialist to serve as webmaster for the course, (2) purchase of time from the Administrator of the Center for Entrepreneurial Studies and her staff to serve as "course administrator" (this position is a combination of budget director, secretary and research assistant), (3) purchase of course materials – books, reprints and photocopied materials – (4) expenses associated with faculty meetings, and (5) a "petty cash" fund of $1K for each team.

Once course expenses have been met, remaining funds (about half of the total collected from sponsors) are divided equally among (1) the course, (2) the Carlson School dean's office and (3) the Department of Mechanical Engineering within the university's Institute of Technology. Careful management of funds has led university administrators to allow course faculty full control over course revenues.

9. Outcomes of the course

The course has produced Final Reports on each project, education for students, knowledge of the development process, new products/businesses, as well as some unforeseen benefits.

9.1a. Reports. At the end of the course, each team delivers to its sponsoring company and to the entire course faculty a report on its activities. This report includes a product prototype, a "protoplan" (early version of a business plan, which details marketing and manufacturing activities, proforma financial statements; and includes a plan for "handing off" the project from the team to the company, and for the activities to be undertaken between the end of the course and commercialization of the product), and a description of the processes the team followed to achieve its results. Many teams include in this report a set of suggestions for modification of the sponsoring company's own product design and business development procedures. We know that three companies, who have together sponsored six projects, have adopted many of those suggestions.

The "handoff" provisions are intended to make the transfer from the team – essentially an outsourced R&D function –to the company's internal R&D activity as smooth as possible. This transfer typically goes smoothly because company representatives have worked with – or as integral members of –the teams throughout the year. The transfer is all but seamless for projects in which several company personnel have been closely involved throughout the year. In those situations, which represent almost all of our projects, participation of company personnel (1) avoids the "not invented here" problem of products developed externally, (2) minimizes need for transfer of knowledge to company personnel which could delay or derail a project, and (3) provides built-in "champions" for the project. To facilitate smooth transition, faculty coaches and company personnel help teams "look ahead," as they approach the end of the year, to identify the future path the project will follow to achieve success. Coaches then help teams build bridges from where the project stands at the end of the academic year to the path it will take thereafter. Three companies have hired team members as interns to facilitate transfer, and companies have contacted faculty coaches with transfer questions after the course has ended.

9.1b. Students. With respect to our primary mission of preparing students for key positions in product design and business development teams, evidence is more difficult to gather. Five of our students have been hired into development positions in the companies that sponsored their projects. At least two more are working to start their own businesses. What information we can obtain from graduates who've been involved in the course suggests that a large percentage have accepted positions in design/development.

We do know that the course functions effectively as a cross-functional teaching/learning vehicle. As a faculty, we are rewarded when we see a business student sketching ideas in a brainstorming session or making a part on the lathe in the Mechanical Engineering student shop, or to see an engineering student conduct a customer interview or run revenue forecasts on a financial spreadsheet. We do not expect engineers to become expert marketers, nor management students to become engineers, but are encouraged when we see them learning from one another and learning to work together.

At the beginning of the course we often have to encourage strongly some engineering students to speak up in meetings, class sessions and presentations (management students are required to make presentations in almost all their classes, and are typically fluent as presentors). We often require engineering students to present business topics in class, and business students to make technical presentations. One method we've found effective is to have engineers who are reluctant to speak respond to technical questions; their responses are typically direct and clear, and the experience of responding leads them to feel at ease in formal presentations. By the end of the course, most management students are comfortable making technical presentations, and most engineers are at ease with business material.

Students tell us through the anonymous evaluations required by the University that they find the course very worthwhile, despite the workload and despite their experiencing the frustrations that are part of every new product/business development process. These evaluations enable students to evaluate the course, instructors and materials. Compared with departmental evaluations, this course and its instructors typically fall into the top quartile, and in many instances the top decile; materials, in the top third.

9.1c. Process. We believe that the requirement to produce a prototype and protoplan within nine months teaches students how to compress the design and development cycle. In our second year one team needed samples of customers' equipment on which to try various versions of the product they were designing. They asked the company, whose routine procedures for such requests would've taken weeks –weeks that the team simply could not afford. After a course

Table 5
Project outcomes by size of sponsoring company

	Discontinued	On hold	Development continuing (pre-patent)	Patents applied/issued	Products on market	Total
Billion-dollar companies	1	1	0	4	3	9
Multi-million dollar firms	5	3	3	1	0	12
Start-ups	2	1	4	2	1	10
Total	8	5	7	7	4	31

faculty member made a few phone calls, the team had what they needed within three days. Part of their final report recommended changes in many of the sponsoring company's procedures that could shrink the development cycle substantially. On another project, after the sponsoring company executives heard the team's final presentation, the president declared that the team had accomplished in less than nine month's time what their own R&D staff would take 20 to 24 months to accomplish. Other techniques that appear to help shrink cycle time include continuous revision and extension of Gantt charts used to schedule group activity, frequent prototyping and drafting of protoplans, and continuous focus on shaping the Final Report.

9.1d. New products/businesses. We have outcome information on the 31 projects completed in past years. Sponsoring companies continued development on 18 of those projects, discontinued eight and kept five under evaluation. Outcomes are displayed graphically in Table 5.

Among the 18 projects on which companies continued development after our course teams completed their work, eight are in development preparatory to filing for patent protection, patents have been applied for in five cases, one patent has issued, and four products have reached the market.

Of the eight projects discontinued after transfer to the sponsoring companies, three were aborted because of the student teams' recommendations, two fell by the wayside because their internal "product champions" changed employers, two were discontinued because sponsoring companies needed resources for other projects, and one was dropped because the sponsoring company's customer altered its requirements. One sponsor that accepted the team's decision to abort told us that the team's work had saved the company ". . . well into six figures of (subsequent) development costs, and into millions of dollars if the product had been taken to market and failed. Those funds not spent are available for other projects or for the company's bottom line."

The five projects remaining under evaluation include two that are likely to become active R&D projects within their companies, while our best information suggests that the other three will likely lapse.

There appears to be some relation between sponsoring firm size and project outcomes. Seven of nine projects sponsored by the largest companies have undergone further development, as have seven of the ten from the startup firms. In contrast, only four of 12 projects sponsored by multimillion dollar firms have proceeded to development. Those medium-size firms account for five of eight discontinued projects, and three of the five projects currently on hold. We observe that the infrastructure in these multimillion dollar firms is not as well-developed as that in multibillion dollar firms to integrate outsourced R&D projects. Yet those midsize firms have grown beyond the stage where the firm could focus all its attention on a single product.

Medical, industrial and consumer products are found in approximately the same proportions in all outcome groups as they are in our population of projects as a whole. Initial scope and definition of project appear not to affect the type of outcome.

We consider the 18 projects that the companies continued to develop after the course and the three that were aborted based on our teams' recommendations to be clear evidence of success in delivering value to the sponsor. The discontinuance of five projects because of changes in personnel, priorities and customers' requirements; and the "on hold" status of five others projects provides no clear evidence for us of the success –or lack of it –in delivering value to sponsoring companies. We conclude that the course yields a "success rate" of at least 21 of 30 projects. This level of success dramatically exceeds that of university technology transfer activities, in which only about one project in ten transfers successfully from universities to industry [3]. We are aware of no benchmark evidence on success rates of outsourced R&D projects to which our course experience might be compared.

9.1e. Unforeseen outcomes. We have found four unexpected outcomes of the course. One is its "public relations" value. Our deans and department heads in management and engineering have found the course to be an excellent "talking point" with members of university administration and with members of the broader academic community. We were invited to make a presentation on the course to the AACSB deans [2], and before engineering societies [5]. A second unexpected benefit goes to students, who report that, when they bring up this course in their job interviews, the course dominates the rest of the conversation. Interviewers welcome the opportunity to have a dialogue with students about a real-life design and development experience that has constituted a major part of their graduate education. The third benefit, which we did not foresee at the beginning of the course, is its utility as a "living laboratory" to study the process of product/business design and development. Members of the course faculty, working with other faculty in both management and engineering, examined e-mail and meeting transcripts between marketing and engineering members of one of our project teams, and drew conclusions on how the quantity of that communication affected project outcome [4]. Fourth, revenues from the course have supported the building of infrastructure that supports the design program at the University, as well as the Center for Entrepreneurial Studies.

10. Future development

For the future, we aspire to have on the web (1) all materials (syllabus, assignments, readings, sources used by teams in prior years) related to the course; (2) nonconfidential project descriptions; (3) a database including former students (who could be contacted by prospective students about course-related issues), business and professional people willing to serve as part of an "ask the experts" network; and [4] links to websites related to product design and business development, including additional materials relevant to product design and business development (a sort of electronic reference library). The first three objectives could likely be met with modest investment and continuing expense.

A major challenge remaining before us is to evaluate the course against our objectives, both to ascertain the extent to which we are achieving them and to revise them as appropriate. To date our principal measures of success (or lack of it) have been the outcomes of the projects and the course-end evaluations of students. One method we are considering is asking students to articulate their objectives at the beginning of the course, and then at the end asking students to assess the extent to which they've met their objectives.

Refinement of whole-class sessions remains a continuing challenge, because of the pressure to include more material. We plan to address this and related challenges by reactivating our "book" development activity, specifying learning objectives, assignments and materials for each whole-class session.

Review of our past projects suggests that we should adopt a more systematic approach to sponsor and project selection, to select the types of sponsors and projects that provide the best learning experiences. We would also like to develop a means of "tracking" our students after graduation, as the University's career and alumni offices lack reliable means of doing so at this time.

We have been asked to make the course available electronically, and could do so with many of the whole-class sessions, now that we have refined and documented them. Whole-class sessions requiring a discussion format pose a greater challenge. It remains to be seen whether we could provide faculty coaching to enrollees from multiple companies or to individuals within a single company in a distance-learning format. Members of the course faculty have provided consulting services on product design and business development to individual firms, but none of us has attempted to deliver anything like the entire course.

11. Conclusion

We have identified a combination of several features that we believe makes this course unique. We have learned – the hard way – some lessons that may be useful for others. Finally, we consider the course to be a successful experience for all its stakeholders.

Key Features of this course include (1) a self-directed faculty work group, driven equally by management faculty and engineering faculty, (2) interaction with the industrial community on real projects on a "quid pro quo" basis that delivers value both to the community and to the university, (3) students' learning the development process as a whole for a variety of projects about which they have detailed knowledge, (4) a full-year schedule and (5) fully integrated multifunctional teams comprised of students, faculty and company personnel. In the year we began this course (1994–95) only 31 of 1000 North American business schools offered interdisciplinary courses in product design, and none of those ran for a full year [1].

11.1a. Lessons learned. Our experience with this course suggests several lessons for those who may be interested in offering such a course. First, engineering and management must lead the program equally. Ours is not a program out of the engineering school with a business component added, nor a management school program with some engineering, but is led equally by faculty from both schools. Students benefit from learning the whole development process, not just the management or engineering component. Both students and faculty learn from their new colleagues who are nominally in different areas, but who find common ground in new product design and business development.

Second, creation of appropriate agreements on confidentiality and intellectual property takes time and can consume tremendous amounts of time from faculty, university attorneys and company attorneys, and may not always come to closure. To avoid long negotiations and to encourage companies to participate fully, we use the same agreements for all companies and teams, and assign all intellectual property rights to sponsoring companies.

Third, the formal academic component of the course should center on learning a product development process. We use whole-class sessions and readings to expose students to a total development process, from need identification through product commercialization. The combination of didactic instruction and observation of other teams' projects helps students to generalize beyond their own

Table 6
Keys to success

Multidisciplinary student teams
Multidisciplinary faculty teams
Cross-disciplinary teaching:
Management faculty to engineering students
Engineering faculty to management students
Student exposure to all projects for comparison/contrast
Intellectual property rights belong to sponsor
Development driven by faculty, then endorsed by administration

projects to a larger universe of product design and business development phenomena.

Tables six and seven list, respectively, what we consider Keys to Success and Pitfalls to Avoid.

11.1b. Conclusion. Although we lack ideal measures to compare results of the course with objectives, we believe that overall the course has successfully met its goals of educating students to become lead members of product design and business development teams, delivering value to sponsoring companies and increasing our knowledge of the design and development process itself.

Table 7
Pitfalls to avoid

Projects lacking meaningful components in either business or design
Projects involving inventor-dominated startups
Students reluctant to commit to full effort for full year
Overly formal administrative arrangements until course has proved success
Dominance by one school or department

This course has demonstrated that it is possible to teach new product design and business development in a fully multidisciplinary manner with sponsors and students from across the world. The course has also shown that student-faculty-company teams can deliver value to sponsors on real projects while integrating that activity with learning about the product design and business development process. Although the course requires significant investment of faculty, student and company time, this "experiential learning" carries substantial payoffs for students, faculty, sponsoring companies and the University.

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