Product Design and Innovation:
Architectural Pedagogy as a Template for an Interdisciplinary Degree Program

FRANCES BRONET
RON EGLASH
GARY GABRIELE
DAVID HESS
LARRY KAGAN
Rensselaer Polytechnic Institute

BACKGROUND

The pace of technological change is unprecedented and the impacts of technological innovation are often profound. Concurrently, there is a growing recognition that significant challenges await us if the nation is to compete successfully in a highly aggressive global economy, while also seeking to share social well being and restore the natural environment upon which all life—and technology—depends. While uncertainty and insecurity clearly exist, so do opportunities for innovative and creative thinking; traditional disciplinary boundaries are more permeable, and new connections can be forged. The complex, multidisciplinary challenges of the twenty-first century demand leaders able to integrate diverse perspectives into creative design solutions.

Encouraging future engineers to "contemplate their work in the larger context," NSF Acting Deputy Director Joseph Bordogna [1] enlists philosopher José Ortega y Gasset to support his call for a greater emphasis on integration. Ortega writes, "The need to create sound syntheses and systemization of knowledge...will call out a kind of scientific genius which hitherto has existed only as an aberration: the genius for integration. Of necessity this means specialization, as all creative effort does, but this time the [person] will be specializing in the construction of the whole". With this as his inspiration, Bordogna asserts:

> *Design becomes the leverage point of determining a product's impact on our lives. In this sense, when we educate [for] the incorporation of technology we must instill not only technical expertise but also lead them to examine and question the goals and value-system of the society they are being prepared to build. And, we must also help them recognize that their skills as constructors, technologists and engineers allow them to alter dramatically the present and future direction of that society.*

To achieve these goals engineering design education must provide concrete experience in integrating first-rate technical competence with a thorough understanding of the social and cultural context of technologies and the design processes that shape them. The School of Architecture and the School of Humanities and Social Science (H +SS) saw this as a call to action for a proposal that could inform the general engineering community around us. This multidisciplinary approach to building science and engineering design education demands that the relevant knowledge base be expanded to include facility and expertise not currently being required of engineering students. What is often taken for granted by architectural educators, the collision of the formal with the social and technical through design, is a radical shift for engineering pedagogy.

Over the past eight years professors from the Schools of Engineering, Architecture, and H&SS have been working together to develop an inter-school, multidisciplinary design pedagogy. According to a survey that we conducted of industrial and product design programs around the country[2], similar programs fall into two categories: one stresses technical or engineering expertise (housed in an engineering school), and the second stresses aesthetic or arts expertise (housed in an arts and/or architecture school). Since there is little, if any, overlap, they fail to integrate the insights and expertise of each other. Moreover, neither specifically incorporates into the curriculum an expertise in how products shape social and cultural relationships and how these relationships shape products. The challenge is to provide models and experience in integrating all three kinds of expertise as equal components of design education: the technical, the social/cultural, and the aesthetic.

Industrial Design (ID) is concerned with a broader spectrum of design activity, spanning everything from graphics and package design to exhibit and environmental design. Typical Industrial Design training entails a broad art education that does not delve into any one subject most interested in the skin of products but not the actual inside workings.

The primary concern of engineering design is the application of analysis to achieve some function with the optimal use of resources (materials, money, energy). Most engineering design problems are not concerned with developing the initial needs for a product, nor are they typically concerned with the interdependence with society. The technical challenges of making a product function safely and efficiently—as if the product could be disconnected from the social/cultural context in which it will come to life (e.g., crash tests of air bags with an average male body)—are typically of most concern to an engineering designer.

The innovative product designer is able to observe the world from a perspective informed by both understanding technology and "seeing" (or "reading") the mutual shaping of technology and society. The strong technical education allows the product designer to understand the "inner workings" of technological products or systems, as well as to imagine how the elements of these inner workings—entirely new elements or "technological enablers"—might be put to work in previously unrecognized ways. The strong education in the social sciences helps understand ways of life deeply enough either to anticipate a future need in those lives or to escape being trapped by everyday inertia.

Rensselaer's strengths in its Schools of Engineering, Architecture and the Department of Science and Technologies Studies (STS) in H&SS, serve as the foundation upon which to base a totally new approach to product design education. STS includes faculty from six disciplines—anthropology, history, philosophy, political science, psychology, and sociology—all of whom work on understanding how science and technology shape society and how in turn society shapes science and technology.

Our inter-school program in Product Design and Innovation (PDI) integrates these basic ingredients of design education: a sense of creativity and visualization; sensitive perceptual and communication skills; hands-on modeling and drawing skills; an understanding of the human body and its ergonomics; a design sense, including an understanding of problem formulation, idea generation, and solution itertion; the ability to work well on teams; technical skills, including machining, rapid prototyping to computer aided design (CAD); an understanding of basic engineering science and manufacturing, with the art of functional analysis; an understanding of the basic disciplines in science and technology studies, featuring the art of reading a culture (ethnographic methodology); an understanding of how a product is/will be situated in our lives, or rather, the art of reading a user; basic market and human factors analysis skills; an ability to work at all scales of a product's context and life history; and presentation skills to convey all of these ingredients at once.

The design experiences in the program are intended to cultivate in students the ability to function effectively in new situations and unfamiliar environments, to collaborate with a diverse constituency to formulate and analyze problems of varying complexity, and to work individually or in teams to produce innovative design solutions that reflect this "genius for integration." Even for the architects, the joining of a rigorous pursuit of STS and deep engagement with technology pushes the limits of our discipline.

THE BASICS OF PDI

The institutional and administrative infrastructure for the PDI program are two dual-degree programs- one jointly offered by the Schools of Engineering and of Humanities and Social Sciences (H + SS) and the other by the School of Architecture and H + SS. Students will satisfy the requirements for the Bachelor of Science in both Engineering Science/Engineering or Building Science and STS.

The core of PDI is the design studio that students take every semester, giving them a hands-on opportunity to bring together the major curricula. The studio acts as the melting pot and arena for interdisciplinary contamination by the students of engineering, architecture and humanities and social sciences.

THE FIRST DESIGN STUDIOS

PDI 1 is based on the premise that disciplined, creative design is learned through the act of doing and making in the studio experience. PDI design studios seek to develop active, dynamic drivers of innovation, and strive to uncover, and get rid of, overt and tacit barriers to creativity within each student. The central concerns of this semester are to open up ways of being in the world - through sensory awareness, through experimentation and physical engagement with artifact, client, site and program and through working methods for suggestive and precise communication. These studies are meant to encourage curiosity and risk while maintaining exhaustive rigor and investigation. The development of reflective judgment is a significant aspect of this course. At the same time, the first design studio (PDI 1) begins the process of building a toolkit—primarily on the exploratory and aesthetic side—that the student will use throughout the entire program.

1. Keeping a design notebook
2. Seeing and visual exploration
3. Values and objectives
4. Drawing and spatial constructs
5. Creativity exercises: wire modeling exercises
6. Negotiation – reaching for consensus
7. Problem identification and definition
8. Design by scenario
9. Short design projects
10. Course capstone project

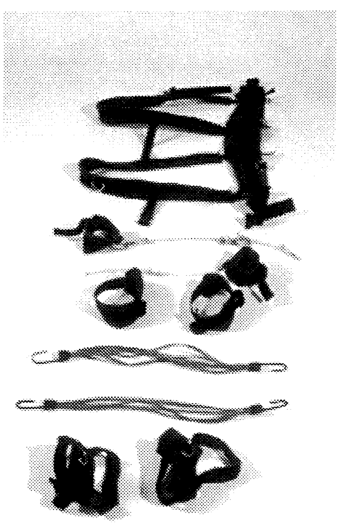
Figure 1. Topics in PDI Design Studio I.

There are ongoing seminars and assignments in freehand drawing and computing parallel to the main design studies that are linked to the main design studies in varying degrees and at various times. They are designed to give students multiple modes of understanding and delving into design processes. We emphasize challenging preconceived assumptions and encourage processes that set up opportunities for their defamiliarization. In developing the pedagogical framework for this new curriculum, many issues and concepts that we, as architects, take for granted had to be put on the table again.

While practical creativity is the primary emphasis of PDI 1, a concern for the social context of design is introduced in each assignment's review process. For example, in the first iteration of PDI 1 the students were broken up into four teams and challenged to design something to improve the space of their own studio. No explicit reference was made to the social relations or tacit assumptions of the students and faculty. (One team, for example, had designed a new kind of table, but for exactly the number of people in their own group, as if this number were sacred, not to be questioned).

A good example of how we want the students to explore design issues is the wire model exercise. Take some wire and try to model the motion of some part of your body, say, a hand reaching to open a door by turning the door's knob. Because of the inherent complexity of ergonomics, to understand the human body requires at the same time to defamiliarize the human body, to become, as much as possible, aware of it at all times, especially for those aspects of body which have long ago disappeared from consciousness.

The semester continued with the students working with a local camping gear manufacturer – Tough Traveler (TT)- to explore new uses for TT's existing technologies and to develop their product line. The students produced drawings and conceptual models, from which the seamstresses and structural formworkers generated working prototypes.



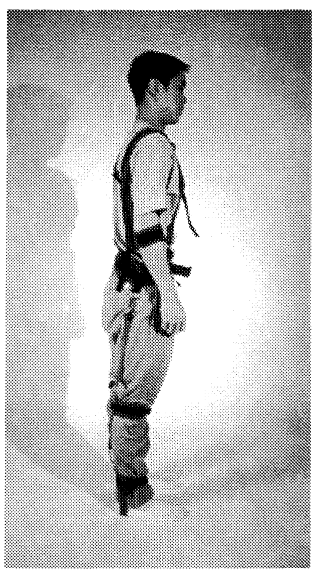


Figure 2. Components of the Passive Exerciser. Figure 3. The Passive Exerciser in situ.

The Passive Exerciser uses existing bungee cords and straps to bind parts of the body. The straps are embedded with a chip rendering the straps "smart". These chips can be removed, sent to a physiotherapist to be analyzed and appropriate exercises appended to this "passive" exercising can be supplemented for a complete physiological workout.

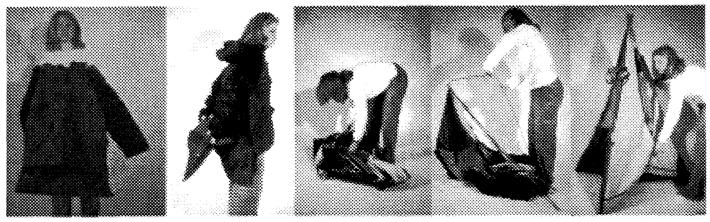


Figure 4. "Jacket into Tent" project.

The next iteration of the studio began by developing an imagined topological construction that addressed very specific, but open-ended constraints where we were looking carefully at the relationship between form, construction, fabrication and renewable resources.

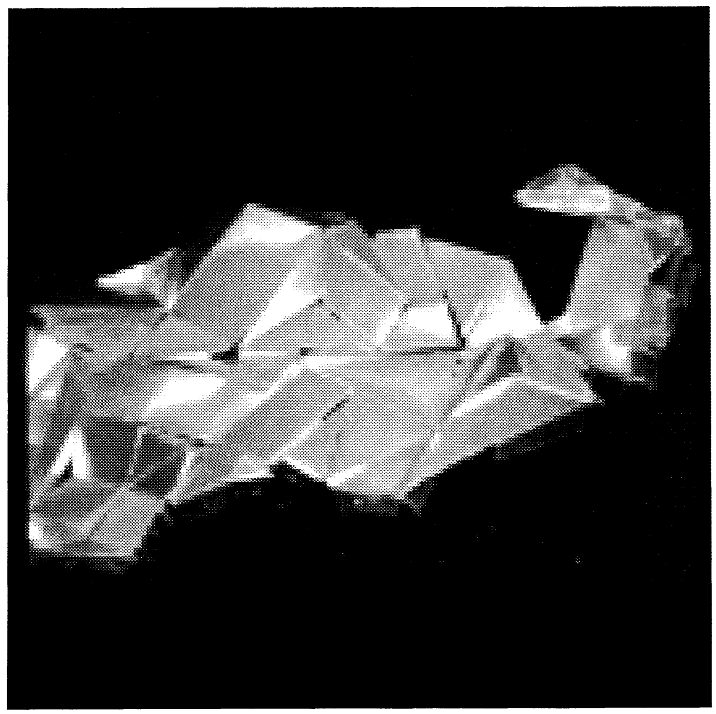


Figure 5. Topological exploration.

In the second half of the semester we developed prototypes for local farmers' market structures. The purpose was to develop an expandable/collapsible/portable system of display, shelter, attachment, layout, etc. for the vendors' goods and could be secured to the site.

After a two-part research phase including the examination of the existing Troy Waterfront Farmers' Market and documenting existing expandable displays, tents, connections, advertising, baskets/

carrying devices, layouts etc. as precedents, the students generated full scale working prototypes for an actual day in the working market. In this way they were able to address many aspects of their manufacturability as well as their usability and spatial consequences.

Figure 6. The Booja transportable shelving unit.

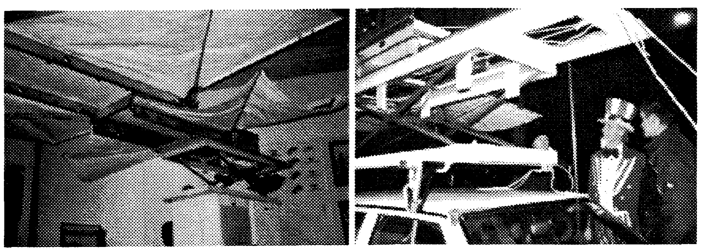


Figure 7. The "Wing-It"-an expandable tent system attached to the car.

The new possibilities inherent in the interplay of the social and the technical received a more explicit focus in PDI 2. PDI 2 was led by Edward Tenner's, "How the Chair Conquered the World" [3]. How many of us in the USA have any awareness of what it means to be in a culture that does not typically have/use chairs? What happens when chairs are introduced, and gradually adopted throughout the culture? Tenner tells us, "In Japan, where many households have maintained both tatami and Western rooms, younger people are finding it increasingly difficult to maintain traditional ground-level seating positions." It also established an even larger "generation gap" as the elders occupied the floor, and the youngers the space above.

The major design project of PDI 2 became the design of a chair to be manufactured from cardboard (again, an obvious project for architects vis a vis Frank Gehry, in his study of materials and ergonomics through an investigation of layered corrugated cardboard). The students were presented with the Tenner article as well as other related articles. To bring out all the social and cultural aspects of this design experience, the students were presented with the basics of doing ethnographic research, particularly conducting interviews. Along with this social study of sitting, the students progressed through a series of (perhaps typical architectural) design explorations aimed at understanding how cardboard could be used as a building material. The intensity of the social study of sitting as well as the manufacturing and production of chairs challenged fundamental perceptions that could open up the material questions of "What was the effect of laminating it, of peeling it apart to form a new material, of wetting and forming it, or of weaving? How could it be joined to make new kinds of joints?" What difference does the technical make to the social?

The third PDI studio focused on the intersection between ethnographic techniques of data gathering and information technology (IT) design. Ethnographic methodology includes participant observation, explorations of the social dimensions of technology, participatory design, and other anthropological perspectives that illuminate both the design process and the potential social impact of the finished product. IT includes both hardware and software, and ranges from new forms of communication (internet, intranet, infrared, etc) to new aspects of the human-machine interface (detection of body movement, sound, light, heat, etc). By training students to think about the synthesis between these two themes - ethnography and IT - they are able to explore mutual collaborations between product design and the knowledge of lived experience.

This semester's projects were based on design of educational toys. The field site that allowed students to learn ethnographic skills was at an elementary school with significant numbers of low-income children, which allows for consideration of wider social issues such as ethnic identity and economic class. Design students 0conducted four phases of ethnographic experience:

1) Participant Observation: actively participated with students in the classroom and playground. They were directed to record field notes that included learning challenges, emotional changes, spatial patterns, and other behaviors, and then follow up with an interview with the teachers.

2) Design probes: required the creation of a design which would produce some response in students that illuminated the aspects of learning and play that would (hopefully) be manifested in their final design. Here the value of the ethnographic technique became clear, since most of their predictions and expectations were wildly off, and many new directions were inspired. By the time prototypes were produced, a keyboard device had turned into a floor mat; a series of weighted balls became a video game, and a video game had turned into a "sensor glove" that turned light patterns into sound.

3) User feedback: working prototypes were brought back to the school for a final round of observation and refinement. Feedback from teachers on various aspects of the designs, from safety concerns to special learning needs, were also invaluable in the final assessment.

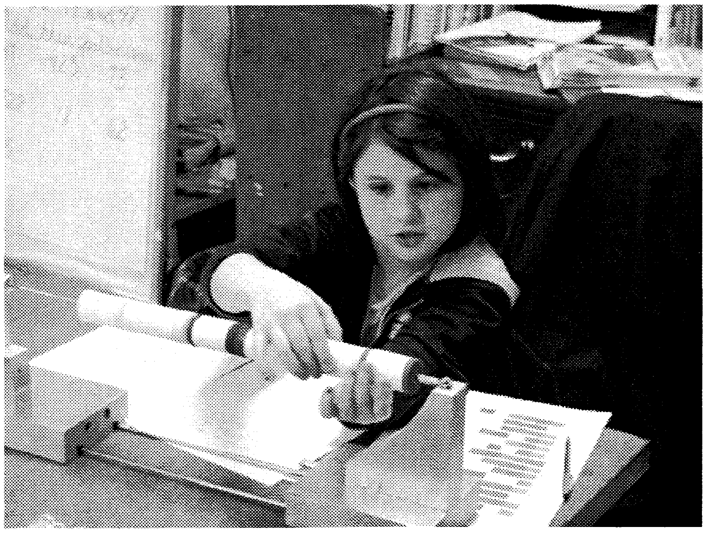


Figure 8: The Sentence Stick – an example of IT. automatic writing and toy: navigating grammar through color.

PDI 4 is an existing core engineering studio that works across all engineering disciplines. PDI 5

is an industrial design studio devoted to exploring the relationship of abstract ideas and values, particularly esthetic, to industrial design and its presentation. The students take "General Manufacturing Processes" along with this studio and creating a compelling coupling of the abstract and the produced.

The ethnographic approach envisaged for PDI is distinctly different from what is traditionally referred to as market research. Responding to this, our sixth studio addresses a specific goal of the program, which is to educate designers with a strong sense of advanced technology and the tools for employing new technologies into design. As new technologies emerge, new, unanticipated products often emerge as well. This design studio focuses on developing new product ideas that utilize emerging technologies that are being developed on campus. Students investigate the range of research efforts currently under way at RPI from nano-technology interventions, to polymer development, to optical simulation devices, select technologies that hold particular interest for them, match them to a particular societal need, and then develop a new product idea through a series of prototypes.

Acknowledging that the program needs many real connections to industry, for good student placement, for realistic up-to-date and cutting edge manufacturing sensibility, pairs of industry person-theory person will be running particular studios (e.g. medical equipment designer and sociologist of medicine on a neonatal instrumentation). The interpolation between these radically different realms, and also towards material embodiment without relying on formal esthetic descriptors (i.e. most product designers) brings us to PDI 7 and 8 that are centered around the Multidisciplinary Design Lab. The students bring their STS and engineering backgrounds to bear on industry sponsored design projects. They work as members of a multidisciplinary design team comprising different engineering and non-engineering disciplines in the solution of a design problem posed by an industry sponsor. Students pull from their backgrounds in engineering and STS. It is in the demand to fulfill the sponsor's expectations and look at previously unconsidered conditions of social, political, cultural and economic frameworks that make this capstone significantly different from normative engineering curriculum industry-run projects. Numerous meetings, presentations and reports are required to document student findings. Topics include robotics, injection molding, computer numerically controlled, machines, metal-processing systems, nondestructive testing, and industrial safety. Both industry sponsors and theoretical analysts critique the prototypes. This provides a forum for corporate and academic interaction.

THE REAL CHALLENGE

Every product tells a story. Our students need to learn how to 'read' products, including their technical, social/cultural, and aesthetic dimensions. To illustrate what this means for the challenge ahead, reconsider the wire model exercise.

Suppose that someone is trying to model the motion of a hand reaching out to turn a door's knob. Crucial will be raising to consciousness what it is to twist the arm, wrist, hand, and knob. Imagine a student reaching out time and time again, slowly and painstakingly trying to figure out how to work the wire to express what he or she is feeling from inside out.

But suppose we step back from this level of the twist. Can all of us perform the twist, for example? One striking innovation in our lifetimes is barrier-free design. What can we 'read' from a culture that has only knobs that need twisting on its doors, and then gradually begins to replace knobs with, for example, levers to open doors by pressing with one's elbow? What *is* involved in the breakthrough that ushered in barrier-free design? Notice that here we are asking about a hole in a culture, where a breakthrough can take place. (The ability to 'read' such a hole is the other side of the coin of the ability to 'read' an existing product.) How do we create a design studio in which students ask and understand such questions?

One thing is surely to foster an understanding of a person's disability as *between* that person and the world rather than 'in' that person. If we rearrange the world in a suitable way (replace knobs with levers), the disability disappears. But a suitable rearrangement of ourselves may equally well remove a disability: just imagine stationing at every door a person whose job it is to open and close the door for those who cannot twist its knob! And who has trouble twisting a knob? Sometimes this too is due, at least in part, to how we arrange ourselves. Imagine a person carrying a child in one arm and groceries in the other. But most importantly, notice that to illuminate the relations between us and the world several viewpoints are necessary. Even in the relations between the human body and a door knob or lever we will already need the whole variety of perspectives in PDI. What part of the human body will we use to get through doors, and how does it work/move? If we choose a lever, for example, how much pressure should the lever require in order to move, and what sort of mechanism will work? Where on the door is it, and what kind of door is best? Then again, perhaps we should not have a door at all, or alternatively, a door-person to open and close it. The sociology of a door-opener/closer is actually famous in STS circles, as Bruno Latour (1995) has written a revealing piece about the social and cultural trade-offs between a person and a mechanism for opening/closing doors: we learn how to 'read' products such as knobs by treating them as 'actors' who play a role in our lives.

DIFFICULTIES

For engineers and other technologists we may need to begin in a way where we can see technology as a kind of social institution. For the arts-based designers we need to work in a way to have the technology embedded in the social from the very beginning. It is as difficult for our arts-oriented students to address this reciprocity between technology and culture or social institutions as it is for the engineers. Neither constituency has yet been involved in setting up alternative social contexts as initial conditions in their lives and it is very difficult for them to conceive of the technical penetrating every aspect of their "creative" designs. This was as complex for the faculty as the students. The engineering faculty, although intrigued by the breadth of architectural or industrial design proposals, sees our work as abstract and not resolved enough with respect to the fabrication or the implementation. The architects see the engineers as moving too quickly to analysis and preconceived solutions in order to get a fix on the completion of the project.

A recurring problem that our experience has taught us is that successful multidisciplinary experiences for the students require a faculty that are themselves multidisciplinary and understand the associated issues. Unfortunately, these qualities are not always cultivated in a research university where accomplishments and recognition in one's own discipline is what is often most prized. We faced this issue in defining the PDI program, which attempts to truly bridge the gap between the humanities, architecture and engineering to create a new kind of design education for our students. The challenge of the core group of faculty who could see the value of a stronger connection between the disciplines became, how to convince the other faculty?

We developed a charrette based on the "Deep Dive' design exercises made popular at the firm IDEO to involve faculty in a multidisciplinary experience aimed at educating them on the benefits of this type of approach to design education. When you lock 8 faculty from diverse backgrounds in a room for a week and ask them to design something, as architects know, something incredible happens. In this case, the faculty designed a product for a 90 year old senior housing resident who called her 40 year old nephew on a regular basis to help her get stuff off the top shelf in her kitchen. At the start, social scientists brought to our attention that asking for specific help was more socially acceptable than nagging for a visit. Engineers looked at ease of access and adaptability and architects at how this fit into contemporary kitchens and whether the room itself should be reevaluated. By the third day, the boundaries and areas of insight were not so clear and the groups became informed teams.

We are developing an advisory board that links industry, government, international firms and academies. As Natalie Jeremijenko has noted, "a recent talk at MIT/STS demonstrated to me that there aren't that many Science Studies types who think that there can be a material practice that results from/is informed by STS nor are there many looking at how engineers develop design intuition. It would take another paper to evaluate how the formation and critical review of this fledgling curriculum is affecting the restructuring of the architectural school. Suffice it to say that the criterion of a 1:30 faculty:student ratio in PDI and 3 disparately disciplined faculty at the helm is just the beginning of a cathartic look at design education. We are hoping that this paper will generate feedback that guides it even more.

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