Product Design and Innovation:
A New Curriculum Combining the Humanities and Engineering

Gary A. Gabriele, Larry Kagan, Frances Bronet, David Hess, Ron Eglash,

Rensselaer Polytechnic Institute
Troy, NY 12180

ABSTRACT

Successful competition in the global economy is increasingly dependent on a stream of new products and services that will open up new business possibilities. At the same time it is increasingly evident that new products and services must be regarded not only as commodities in a marketplace, but also as social actors which can constrain or enable the quality of our life. In recognition of these two perspectives, Product Design and Innovation (PDI) is a new undergraduate dual degree program at Rensselaer that seeks to educate students for careers in new product development. PDI is a dual major program satisfying the requirements for the Bachelor of Science programs in engineering and Science, Technology and Society (STS). PDI prepares students to become innovative designers who can integrate contemporary technologies with changing social contexts for a new generation of advanced product designs.

This paper will describe the PDI program, its goals, how it was formulated, and review experiences we have had in offering the first three years of this innovative program. We will provide the curriculum templates and discuss how the design studio sequence fits together.

BACKGROUND

Like it or not, we live in interesting times. The pace of technological change is unprecedented and the impacts of technological innovation are often profound. At the same time, there is a growing recognition that significant challenges await us in the years ahead if the nation is to compete successfully in a highly competitive global economy, while also seeking to share social well-being and restore the natural environment upon which all life and technology depends. These overlapping goals have prompted a widespread effort to re-think our approach to life and work in an increasingly technological world. Throughout higher education, the need to understand this rapidly changing environment is felt at all levels. 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 trained to understand problems from all relevant perspectives and to integrate these perspectives into creative design solutions.

To achieve these goals, we believe, 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. This multidisciplinary approach to engineering design education demands that the relevant knowledge

base be expanded to include facility and expertise not currently being required of engineering students.

Over the past eight years, professors from the Schools of Engineering, Architecture, and Humanities and Social Sciences (H&SS) have been working together to develop an inter-school, multidisciplinary design pedagogy. Based on our work to date, which included several co-taught design courses and studios, we have realized that a truly unique opportunity existed at Rensselaer to create an undergraduate product design program that (i) makes concrete progress towards realizing the disciplinary synthesis called for in these challenging times and (ii) can serve as a model for other design programs around the world.

Rensselaer's traditional strengths in its Schools of Engineering and Architecture, when combined with its strength in 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. Supported in part by NSF, STS has also been working on its own focus on design as a natural complement to the traditional focus on design in engineering and architecture.

Our inter-school program in **Product Design and Innovation (PDI)** integrates these basic ingredients of design education, which we will elaborate on below:

1. a sense of creativity and visualization;
2. sensitive perceptual and communication skills;
3. hands-on modeling and drawing skills;
4. a design sense, so to speak, including an understanding of problem formulation, idea generation, and solution iteration;
5. the ability to work well on teams with a variety of different people;
6. technical skills, from using machine tools and rapid prototyping to computer aided design (CAD);
7. an understanding of engineering science and manufacturing;
8. an understanding of the basic disciplines in science and technology studies, featuring the art of reading a culture (ethnographic methodology);
9. an understanding, specifically, of how a product is/will be situated in our lives, or rather, the art of reading a user;
10. an ability to work at all scales of a product's context and life history; and
11. the presentation skills to convey all of these ingredients at once.

The design experiences in the program 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.

The PDI program was begun with the incoming class of the Fall 98 semester and we have taught the first 6 design studios of the sequence. This paper describes the curriculum design for PDI and our experiences teaching some of these first studios.

THE BASICS OF PDI

The institutional and administrative infrastructure for the PDI program is a dual-degree program jointly offered by the School of Engineering and the School of Humanities and Social Sciences. Students satisfy the requirements for the Bachelor of Science in either engineering and STS, or architecture and STS. For the purposes of this paper, we will describe only the engineering option. The students have a choice of either completing a mechanical engineering degree or an engineering science degree. (The PDI curriculum template is available at http://www.rpi.edu/dept/sts/pdi/index.html.)

The core of PDI is *the design studio that students take every semester*, giving them a hands-on opportunity to bring together the two major curricula. The engineering science curriculum includes courses in engineering mechanics and electronics, energy, materials, and manufacturing. The STS curriculum covers the social and cultural dimensions of product development and innovation, including case studies of successes and failures. Through the design studios, students will have the opportunity to translate into practical terms the diverse skills acquired in these two curricula.

The design studios will also challenge students to integrate and balance these two domains of learning with PDI's third domain, the aesthetic, including the relevant elements of arts and architecture design. This challenge changes from year to year because students will enter the PDI design studios with an increasing background from previous studios as well as from engineering and STS courses. In this light, the two first-year design studios face a challenge more to establish the basic atmosphere of PDI than to proceed with the 'messy work' of integration.

THE DESIGN STUDIO SEQUENCE

The eight PDI design studios can be divided into two halves. The first half consists of 3 new design studios and the required second year engineering design course, *Introduction to Engineering Design.* The second half begins with PDI V, an introduction to industrial design, and ends with a year long multidisciplinary capstone design experience. The specific PDI studios are discussed below.

PDI 1

The central concerns of this semester were to open up ways of being in the world - through sensory awareness, through experimentation and physical engagement with artifact, site and program and through working methods for suggestive and precise communication. These studies are meant to encourage curiosity and risk while maintaining a concern for exhaustive rigor and investigation. The development of reflective judgment is a significant aspect of this course. Students are asked to reflect on the consequences of doing something in alternative ways, and determine who and what is affected by these design decisions.

Goals of the studio:

- To introduce the concept of Design: Learning by doing through hands-on exercises, synthesis, analysis; engaging the creative process though active learning, discovery, and reflection.
- To understand how design and creativity inform daily living.

- To be aware of the larger context - the social, cultural and political realms in which we design and build.
- To understand the inter/relationships among disciplines that inform design.
- To learn the complexities of design through participatory student-faculty course development and collaboration.
- To reinterpret the condition of technology.
- To develop the ability to reflect critically on your own work and to evaluate consequences.

We considered it important to develop the practice of simultaneously working-through the relationships among societal considerations and the possible physical designs. For this studio, we worked on projects for which our culture's habituated physical design responses are unsuited. This will call taken-for-granted assumptions into question.

The design project acts as a vehicle to pull together a diverse number of philosophical issues, technical concerns, and basic theoretical knowledge. By using a number of modes of inquiry as well as faculty from various disciplines, we can ask students to consider many things simultaneously and juggle many ways of investigation at the same time.

The first studio had two main projects, as well as a series of continuing exercises in computing, drawing and technology. We began the semester 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.

In the second half of the semester we developed prototypes for farmers' market structures. The purpose of this project was to develop an expandable/collapsible/portable system of display, shelter, attachment, layout, etc. that could display, carry, or protect the farmer's produce, fliers, etc. and could be secured to the site (walls, ground, cars, bodies, etc.)

The teams of students were responsible to specifically identify the materials, weight and mechanisms of their system as well as the interaction of the body with the system. The students looked at the collision of two systems of movement; that of the human body in relation to the artifact, and that of the body of the artifact in relation to its mechanisms of operation. Often, in industrial design, the object is seen as ending at its physical limits, and not to where the body that engages it extends. (Think of how we perceive the automobile ending at the tailpipe; certainly environmentalists don't believe this!)

We started with a two-part research phase that began with the examination of the existing Troy Waterfront Farmers' Market. This included interviewing the farmers and other occupants, site analysis, and documentation as well as looking at the existing expandable displays, tents, connections, advertising, baskets/carrying devices, layouts etc. as precedents.

For their final installation, 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.

Over the course of the semester the students developed ways of understanding design in both an abstract as well as lived approach to engaging the environment.

The students kept notebooks of exploratory design sketches, notes/sketches on board critiques and public reviews, observations/drawings from the weekly exercises - (self-reflective journal keeping). Along with the drawings, three-dimensional model studies, design studies and presentation work done for the course was included in the portfolio in the form of photographs.

Figure 1: Portable, foldable fruit stand for Farmers Market

PDI 2:

PDI 2, the second in a series of design studios in the Product Design and Innovation Program, provides the student an opportunity to continue development of their design skills and their ability to visualize and synthesize innovative design solutions.

The course builds on the design exercises and experiences in PDI 1. A major difference in this studio is that more of the design work is done individually rather than in teams; the focus is on the development of individual basic design skills required for creative design work. These design skills fall into two categories: (1) skills for design expression (e.g., drawing, sketching, CAD, and modeling), and (2) skills in design development (e.g., problem exploration and formulation, ethnographic methods, iteration of ideas, methods for creative thinking, and conversion of ideas into realizable designs). Of course, (1) and (2) are not entirely independent of each other (e.g., drawing or modeling may well become a way of developing a design). In addition, students are exposed to the basics of design presentation and the development of design portfolios.

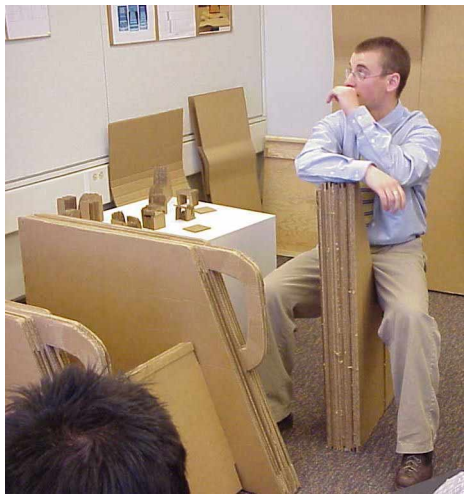
In our search for a suitable project for **PDI 2** we ran across an article by Edward Tenner, "How the Chair Conquered the World" [1]. How many of us in the USA have any awareness of what it means to be in a culture that does not typically have/use chairs? What happens when chairs are introduced, and gradually adopted throughout the culture? Tenner tells us, for example, "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." Chairs are 'hard' as design projects, of course, just think as well of all that we need to understand about the human body and the forces and tensions of supporting it in order to design a chair.

The major design project of **PDI 2** became the design of a chair to be manufactured from cardboard. The students were presented in the first class with the Tenner article as well as other related articles. In order 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. All of this beginning work, led them to a deeper understanding of the chair as an artifact of our culture. They began to look at sitting and chairs in a whole new light. They studied people sitting in different situations both in our culture and in others through various articles and photographs.

Along with this social study of sitting, the students progressed through a series of design explorations aimed at understanding how cardboard could be used as a building material. What was the effect of laminating it, of pealing 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? They discovered that they could make strong yet very lightweight structures using various methods. An example of one of the final projects, a multipurpose chair for a dorm, is shown in Figure 2.

Basic Chair

Side panels raised for work surface



Seat back separates into temporary seating for guests

Figure 2: Multipurpose cardboard chair for dorm room

In the second offering of the course, we decided that more emphasis was needed on design iteration. Too often, students settle on one design quickly and fail to iterate it to explore other possibilities. Again, we stayed with the design theme of cardboard furniture but brought them through three different design exercises aimed at getting them to look at dorm furniture in many different ways. Ethnographic methods were introduced and students were asked to observe their dorm room life to determine how it could be improved through a re-design of the furniture. A sample of a set of stackable storage containers is shown in Figure 3.

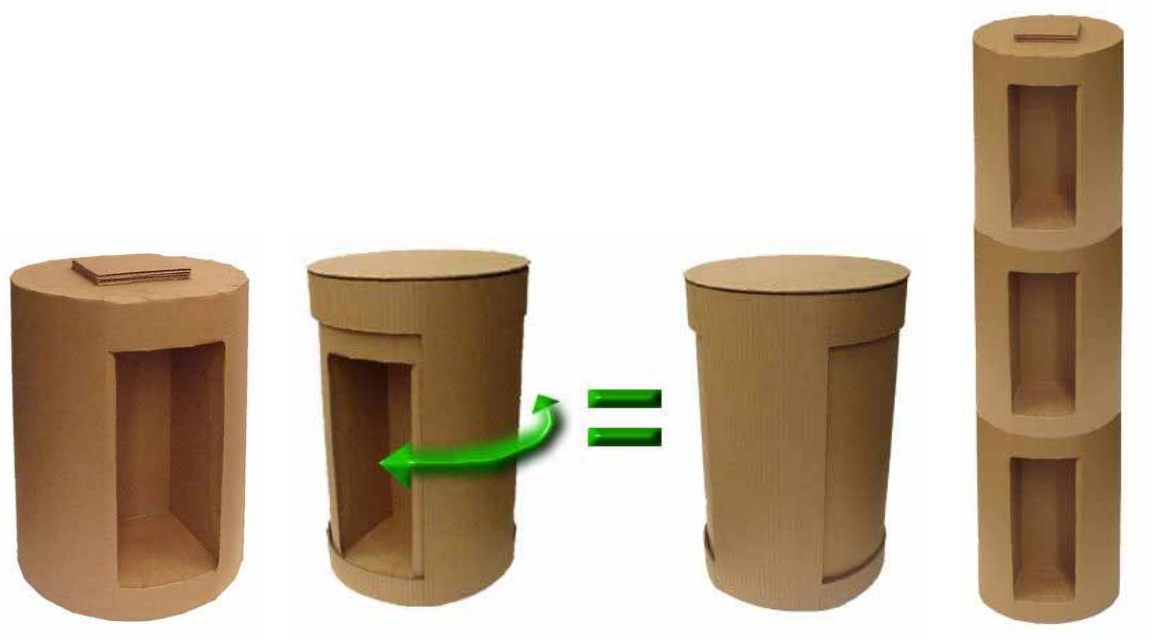


Figure 3: Stackable storage containers, also can be used for temporary seating.

While the second offering was much more successful at getting students to iterate their designs, and we were much more satisfied with the design work, we saw two important areas for improvement. First, all the students seemed to be designing furniture for himself or herself rather than for someone else. We felt that this situation avoids one of the most important lessons to learn in design, how to design for someone else. The second important feature we felt was missing that not being able to experience if their design actually satisfied the need. In almost all design courses, students finish their projects at the end of the semester and rarely get to see them actually used. It was felt that this, the opportunity to see the impact of their work, misses a real learning opportunity. Does it solve the problem? Does it have the intended impact? Is it used as expected? Are there any unexpected results?

The third offering of the course, to be given in the Spring 01 semester will attempt to deal with both of these observed shortcomings. We will require students to design for someone else, and we will ask them to complete their designs early enough that they will be able to observe its use and report on the results.

PDI 3

The third PDI studio is focused on the intersection between ethnographic techniques of data gathering and information technology (IT) design. Ethnographic methodology goes far beyond

"user feedback." It 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.

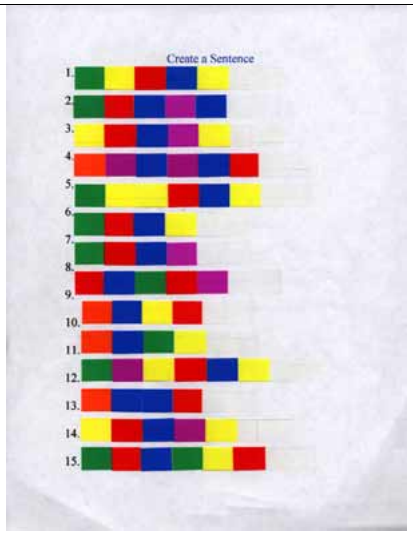
This semester's projects were based on design of educational toys. The field site that allowed students to learn ethnographic skills was at an elementary school with significant numbers of low-income children, which allows for consideration of wider social issues such as ethnic identity and economic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

1) Participant Observation: here they 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 concerning these observations.

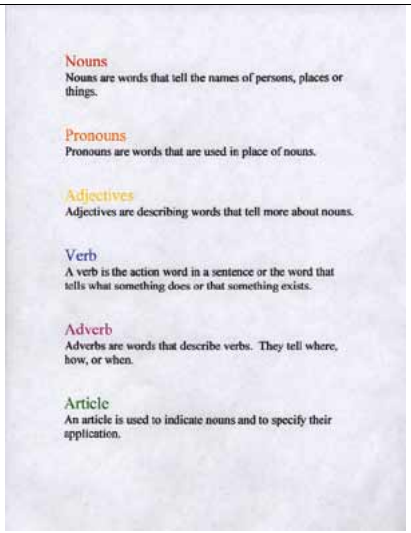
2) Design probes: this assignment required the creation of a design which would produce some response in students that illuminated the aspects of learning and play that would (hopefully) be manifested in their final design. Here the value of the ethnographic technique became clear, since most of their 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: These 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.

An example of one of the student projects, called the "Sentence Stick", is shown in Figure 4.



Color codes for creating a sentence



What the codes represent

Steps of the game

1) Chose the number of the sentence that you would like to create.
2) Read the definition of the grammar block each time you place one on the stick.
3) Place the word blocks on the stick one at a time, according to the color scheme picked.
4) Starting at the beginning, spin each block in order to line up a sentence that sounds correct.

A satisfied "user".

Figure 4: The Sentence Stick

PDI 5

This studio was devoted to exploring the relationship of abstract ideas and values, particularly aesthetic, as well as real world forces, to industrial design and its presentation. We tried to discover if there are rules for designing and what they are. If there aren't, we will explore why not. To do so, we visited the designs and writings of our predecessors – in particular designers and designs of the 20th Century. We looked at contemporary products with an eye to understanding their similarities and differences and the forces that shaped them. We deconstructed and reconstructed the formal design of products to better understand their organization and the decision making process that led to their design. Using our design understandings and skills we then designed a product developed from a need/market analysis, to concept; from preliminary design studies, sketches, and models, to final design, presentation, and three-dimensional appearance prototypes within real world constraints.

The Course Objectives were:

- To become aware of the elements and concepts of design.
- To become exposed to the factors which affect form.

- To become aware to the history of Industrial Design.
- To become exposed to the vocabulary used to discuss form and to develop the skills to verbally explain ones own formal ideas and raisons d'être.
- To develop skills necessary to describe form two-dimensionally and three-dimensionally.
- To experience the process of designing from beginning to end by determining a need in the market, designing a product to fill that need, and presenting the finished product in two and three dimensions.

The work in this course was divided between design/studio work, and reading/discussions. The readings address a number of issues, from form and function [2,3] to the influence of technology and design on society [4]. The design/studio work was divided among three problems.

- Deconstruction Exercise. Each student selected a small, hand-held, non-mechanical product to be analyzed. The object was analyzed and described (technically, verbally, visually) with an emphasis on why it looks the way it does.
- This was a short sketch project. Using the same restrictions on the object as for Problem 1 (and using the same object), add one feature to the object. A final presentation in drawings and other visuals is expected.
- Design Problem 3: This is the major project of the course. Identify and design an accessory for computer use. The product should aid and complement the using of a computer, be it desktop or notebook. It should not be part of the computer function itself – e.g. not a new pointing device or new keyboard. The product should make use of an existing mechanism or technology, adapted if necessary for this application. It should not be dependent on a totally new mechanism or technological invention. The product should be limited in size to something that can fit on a desk. The project will have two phases. The first will be one of writing the design brief based on perceived need and/or market. The second will be the design of the product based on a design brief. The presentation of the product will include an appearance prototype (if a working prototype is not feasible).

An important part of the final project was that each of the design briefs created by the students was randomly assigned to other students in the class to develop into a design proposal. Hence, each student served as both customer and designer. Some of the final designs are shown in Figure 5

Figure 5: Student projects for PDI V, Introduction to Industrial Design

PDI VI

The sixth PDI studio will be offered for the first time during the Spring ’01 semester. This studio will address 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 will focus on developing new product ideas that utilize emerging technologies that are being developed on campus. Students will investigate the range of research efforts currently under way at RPI, 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.

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, suppose that, someone is trying to model the motion of a hand reaching out to turn a door’s knob. Crucial to this effort will be raising to consciousness what it is to twist the arm, wrist, hand, and knob. We can imagine a student reaching out time and time again, slowly and painstakingly trying to figure out how to express what he or she is feeling from inside out, as the very body initiating the twisting.

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 that one can use 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, so to speak, 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 come to 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, most likely a woman in our culture, carrying a child in one arm and groceries in the other.

But most importantly, notice that to illuminate the relations between the world and us several viewpoints are necessary. Even in the relations between the human body and a doorknob 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 (easily enough for a person carrying a child in one arm and groceries in the other), 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.

However we resolve this dilemma, it is the kind of dilemma we face for every design studio, though we will not remain at the level of doorknobs, of course. We are, indeed, asking for NSF support to meet this challenge: how to arrange the projects in PDI studios, one semester after another, so that the complexity and character of the projects changes to allow students slowly and surely to practice designing in a way that will allow them to integrate and balance technical, social/cultural, and aesthetic expertise—all the basic ingredients of design education we listed at the end of **part b** above—as well as to reach the end of the studios ready to design in all the significant areas calling out for new ideas? We like to think of this as nurturing *a design culture*.

CONCLUSIONS

Our experiences in teaching the first five semesters have taught us a lot about how to teach these design studios. The students have produced some very innovative work and their assessment of the classes has been very positive. We are also gaining a clearer picture of what we want to accomplish in each of the following design studios.

ACKNOWLEDGEMENTS

Work on the first and second design studios was supported by a grant from the NCIAA. Work on studios III, V, and VI was supported by a grant from the NSF Division of Undergraduate

Education (DUE-9950931). A Strategic Initiatives Grant from Rensselaer supported initial development of the curriculum template. Support from each is gratefully acknowledged.

BIBLIOGRAPY:

1. Tenner, Edward. 1997. “How the Chair Conquered the World,” **Wilson Quarterly**, Spring: 64-70.

2. Thompson, D. W., 1961, **On growth and form**, Edited by John Tyler, Cambridge University Press.

3. Alexander, C., 1964, **Notes on the synthesis of form**, Harvard University Press.

4. Mumford, L., 1934, **Technics and civilization,** Harcourt, Brace and Company.

5. Latour, Bruno. 1995. “Mixing Humans and Nonhumans Together: The Sociology of a Door-Closer,” in Susan Leigh Star, ed., **Ecologies of Knowledge**, State University of New York Press: 257-277.

GARY A. GABRIELE is Vice Provost for Administration and Dean of Undergraduate Education at Rensselaer. Dr. Gabriele is also a Professor of Mechanical Engineering and a co-founder of the Product Design and Innovation curriculum.. He continues to perform research in design methods, and to teach at the undergraduate and graduate level. His design course has won national recognition for innovation from the American Society of Mechanical Engineers.

LARRY KAGAN, Professor of Art and Associate Dean of H&SS for Undergraduate Programs, is a sculptor who has combined a strong record of producing and exhibiting innovative steel-and-shadow sculpture with thirty years of teaching and administration. A Chair of the Arts Department a successful Integrated Electronic Arts education program was developed. He was also one of the founders of the Product Design and Innovation program.

FRANCES BRONET, associate professor of architecture, has been developing and publishing work on multidisciplinary design curricula between architecture, engineering, science and technology studies, dance and electronic arts for the past 10 years. She has presented and published extensively on integrated early design studies programs. She is currently Vice-President/President-Elect of the Association of Collegiate Schools of Architecture in North America.

DAVID HESS is professor of anthropology and chair of the Department of Science and Technology Studies. He is the author of ten books in anthropology and STS, most of which focus on cultural aspects of science and technology. He is the recipient of the Diana Forsythe Prize of the American Anthropological Association for his collection of published writings in the anthropology of science, technology, and medicine.

RON EGLASH is an assistant professor Science and Technology Studies. He received a Fulbright fellowship for his studies of fractal patterns in the material culture of west and central Africa, and the resulting book, African Fractals: Modern Computing and Indigenous Design was recently published by Rutgers University Press, Ron holds a BS in Cybernetics, a MS in Systems Engineering, and a doctorate from in the UCSC History of Consciousness program.