Integrating User Experience Research into Industrial Design Education: The Interaction Design Program at Purdue

Zhenyu Cheryl Qian, Steve Visser, and Yingjie Victor Chen
School of Visual and Performing Arts, Purdue University

ABSTRACT

The new generation of innovative technologies, such as ubiquitous computing, personal informatics, tangible interaction, and internet-based systems, blurs the boundaries between objects and services. Purdue University's interaction design program is its latest addition to the Industrial Design area within the Department of Art and Design. The goal of this program is to arm students with the necessary knowledge and tools to prepare them for the integration of physical interaction and digital interaction. This paper focuses on introducing several education approaches to fit user experience research into the context of industrial design, which has led to several new interaction design courses. We also discuss the experiences we have gained from teaching these courses, along with potential improvements we envision. Differing from traditional human-computer interaction courses in the computer science, we try to weave real-world projects into the courses, study related cognitive and social systems to inform knowledge, employ research methodologies to evaluate and improve the design, and adopt innovative technologies to better accommodate human experience.

Introduction

With today's increasing computing power, miniaturized chips, and the advent of the internet, the meaning of traditional product design has been altered. Traditional industrial design focuses on how people interact with things, designing for a product's form factor and considering ergonomics and psychonomics. Computing and networked technologies introduce a new dimension of interactivity beyond the product's physical form. Some computing technology may be invisible (Norman 1998), but aware of it or not, we are surrounded by products with complex digital interaction and control logic. For example, modern versions of traditional products such as toasters and shavers now commonly have digital interfaces. Household appliances have been equipped with multi-level digital control panels. Mobile phones have been extended to include an alarm, a MP3/MP4 player, a camera, GPS, and even a computer. Today, more and more industrial designers are being asked to design products and systems that incorporate interactive components. For example, some Korean product designers explored the possibilities of gesture recognition technology while designing a gesture-based TV remote control (Kim et al. 2004). In order to design a tangible toy, a group of European designers manipulated electronics placement, insightfully analyzed child behavior, and conducted tests to search for a better solution (Johansson 2009). Blevis et al. (2007) stated that “interaction design, as a necessity, has been embedded with luxury and sustainability as a contemporary product design critical framework.” Since the level of complexity increases exponentially as a product gains more digital intelligence, a new kind of developmental expertise is needed.

Due to the incredible increase in both product and system complexity that the use of advanced technology enables, it is more important than ever for industrial designers to engage directly with interaction design, a design discipline focused on the design of the interaction between products, systems, and humans (Malouf 2010). What should an industrial designer create in the information and digital age? How should industrial designers innovate for the new breed of products? From an educational perspective, how can we improve on industrial design education to establish a new generation of designers better prepared for their future careers? As has been recommended and supported by our industrial partner, the Whirlpool Corporation, the Interaction Design (IXD) program was established at Purdue in 2010. IXD is a graduate program where students and faculty aim to explore interaction design approaches and possibilities in the context of industrial design. During the program's development, we encountered problems and also learned from our explorations. This paper gives a glimpse of the journey we have taken and plan to pursue.
Unique Problem Set
Computing and networked products introduce a new dimension of interactivity beyond the product’s physical form. IXD not only refers to complex human interactions, but also encompasses enhanced usability and user experience issues. For a designer, being able to merely design interaction is a good skill, but being able to control, amplify, and support the human-product interaction is even more desirable. The field of interaction design is in its early infancy and has only been around for the past decade or so. Most related theories and methodologies are comparatively young or under construction. Therefore, how to teach industrial design students about interaction design and user experience becomes the big challenge. There are three major problems: in essence, gaps which repeatedly arise between design and cognitive science, design and evaluation research methods, and design and information technology. Design is essentially a creative process to plan something that does not exist. On the other hand, cognitive science, research methodologies, and information technology are all focused on what does exist. We must recognize and bridge the gaps.

Gap between design and cognitive science
The role ergonomics plays in improving productivity and quality has been well recognized in the domain of industrial design. However, another important aspect among human factors, cognition, has not been widely introduced into design education. Cognition refers to the mental processes involved in gaining knowledge and comprehension, including thinking, knowing, remembering, judging, and problem solving. These are higher-level functions of the brain and encompass language, imagination, perception, and planning—mental faculties which are essentially interdependent. Attention guides both perception and memory; language and reasoning are similarly closely connected. All of these are closely related to the interface and interaction design of products. There are many models and theories of cognition to describe different ways by which thinking takes place. Some established models, illustrated with engaging examples, are quite ready for integration into design education. For example, Donald Norman makes the distinction between experiential cognition and reflective cognition in describing human thinking processes (Norman 1993). Benyon et al. (2005) use the information-processing paradigm to illustrate the functions of brain. Sohn et al. (2009) identified four attributes of unconscious human behaviors (reaction, adaptation, conformity, and signal) to inspire eco-friendly interaction design. Contemporary product designers have to deal with the related cognitive issues so that they are not only able to predict how users will hold the products, but also perceive how users will communicate with the products. Unfortunately, cognition is usually still a missing piece in design education.

Gap between design and evaluation methods
Usability is a quality that many products possess, but many more lack. What makes something usable is the absence of frustration in the actual use of that object. To be usable, a product or service should be useful, efficient, effective, satisfying, learnable, and accessible (Rubin 2008). Designing useful products is definitely the goal for every industrial and interaction designer, but how to ensure product usability is a challenge. Traditionally, systematic evaluation methods have not been a focus of the design domain. Nowadays, designers should learn how to conduct evaluation studies from scientists or researchers in other domains. In the domain of user-centered interaction design (UCD), researchers emphasize three basic principles: early focus on users and their tasks, evaluation of product usage, and iterated design. A common lesson learned the hard way in the UCD industry is that it costs 100 times more to make a change in the next release of a product than it would cost to make that change at the beginning of the project development cycle (Nielsen 2000). As a result, techniques (such as ethnographic research, participatory design, focus group research, etc.) for building in usability in human computer interaction are preferable for industrial design as well.

Gap between design and information technology
Traditional products are mainly physical in nature and design constraints are governed by the principles of physics, mechanics, and human factors. Today, many products are equipped with microcomputers with a high computing capability and increasing processing speed. Products become hybrid in nature with both hardware and software components. Furthermore, with the advent of the internet, products can be networked and digital information stored in products can be transferred, shared, analyzed, and represented. However, there is a gap between traditional design training and information technology. First, designers are not programmers; they haven't been trained to understand programming. The training of programming is a systematic process, distinctly different from design education. Second, even if the designers purportedly understand the coding process, a number of researchers will argue that this fact might still raise issues. “If the designer implements his own design, he is beholden to two different goals: clean code and great user experience. The two goals contradict each other and in many cases he may make premature decisions and compromise” (Mathis 2009). Many industrial design students are very curious about the fascinating effects some simple codes can produce. Whenever they can see some new technologies from research, they are excited to track the information down. But such students are often not ambitious enough to consider integrating the new technology into their current design plans directly. These students design buttons, but then can’t get engaged in a critical discussion of the buttons’ particular functions. For the project itself, separating the interface design and interaction design is a problematic approach.

Interaction Design Education for Industrial Design
Although gaps between traditional industrial design education and contemporary user-centered interaction design do exist, we believe these gaps are not insurmountable. These two areas can come together, and we have gained a lot of support and collaboration inside Purdue University.
Under the same department of Art and Design, we have sibling programs such as VCD (visual communication design) and ETB (electronic and time based arts). After discussing curricula and syllabi with faculty from both of these programs, we have found that they could contribute fascinating interaction design-related courses, such as “Robots and Culture,” “Electronic Media Studio,” and “Advanced Website Authoring.”

Purdue is famous for its prestigious engineering schools. Our industrial design students have abundant opportunities to collaborate with engineering students on various projects. For example, the US Department of Energy Solar Decathlon is an international competition held every two years at the National Mall in Washington, DC that challenges twenty collegiate teams to design and build solar-powered homes. For the 2011 competition, Purdue’s team of solar decathletes was first initiated by students from the college of technology. It then expanded to comprise a multidisciplinary group of students from the entire campus. Our students are currently participating in the interactive control device design and website design.

We frequently invite professors and experts from other majors to give talks based upon their expertise. For example, our students are working on designing home-based healthcare monitoring devices sponsored by GE healthcare. The four diseases upon which we focus are: cerebral palsy, Parkinson’s, multiple sclerosis, and arthritis. In order to help students learn more about the contexts of these diseases, we have invited professors from the Department of Health and Kinesiology and the Department of Speech Language and Hearing Sciences to talk about human motor control issues and their research on how to support patients with those diseases. Insights and advice from these field professionals make the product elegant not only in form, but also in function and operation.

Currently, it is typical to have Human-computer Interaction (HCI) programs in the computing schools. Building up an interaction design program in the context of industrial design is somewhat unique. In order to gain experience and insights from our institutional peers, we found a few interaction design programs offered by design schools, such as Carnegie Mellon University (n.d.), the University of Washington (2010), School of Visual Arts (2010), Philadelphia University (2010), Simon Fraser University from Canada (2010), Copenhagen Institute of Interaction Design from Denmark (n.d.), and Umeå Institute of Design from Sweden (2010). We have established communications with design schools and visited a number of them. Through such communications, we realized that there were a lot of common issues and challenges for these pioneer interaction design programs. Having the common interests in the domain, we are able to share experience and gain support from differing perspectives.

Planned Curriculum

The MFA (Master of Fine Arts) program in the Department of Art and Design at Purdue University takes three years (six semesters). The curriculum plan for the interaction design program was based on the original industrial design program. The six primary area courses are organized by four new interaction design courses and two industrial design courses. In order to encourage students to explore more related concepts from the field, we also require them to select two VCD or ETB courses as electives. In total, a student must take 60 credits and complete a graduate internship during the summer to earn the degree. Here is an example of an MFA student’s study plan:

1st year Fall Semester:
- Introduction to Interaction Design (3 credits)
- MFA program orientation (0 credits)
- Theory in Art Seminar (3 credits)
- Problems in Industrial Design I (3 credits)

1st year Spring Semester:
- Cognition for Interaction Design (3 credits)
- Design History I (3 credits)
- Advanced Web Authoring (3 credits)
- Elective course (3 credits)

Summer: Graduate Internship

2nd year Fall Semester:
- Problems in Industrial Design II (3 credits)
- Design History II (3 credits)
- Elective course (3 credits)

2nd year Spring Semester:
- Information Visualization Design (3 credits)
The interaction design MFA program in Purdue is still in its infancy. We started to offer interaction design courses from the spring 2010 semester, and recruited the first group of interaction design majors in the fall 2010 semester. Prior to writing this paper, we have taught two interaction design courses, and are currently teaching another two.

Interaction Design Process
This course aims to lay the foundation for advanced courses in interaction design. Students were working in a prototypical interaction design context and were guided through the major steps of interaction design, resulting in a simple artifact prototype throughout the course. The main course focus was to help students learn how to design and tailor interfaces and interactions to best support human abilities and desires. Students were asked to choose design topics based on their own interests. A series of lectures were delivered to the class parallel to the design process on basic interaction design principles, some key cognitive theories and design methods, and several simple evaluation methods. These lectures were designed to match different stages of the students’ design work. For example, in week seven, students learned design principles and how to conduct hierarchical task analysis (HTA) while they were reviewing and reporting on existing products. In week twelve, they submitted paper prototypes of their proposed interaction design after being presented a series of lectures on requirement analysis, conceptual design, and prototyping methods. They documented their design process in the project reports (existing product review, literature review, HTA chart, requirement analysis outcomes, different stages of prototypes, peer review results). At the end of week sixteen, all of the students submitted their final reports and digital presentation files.

We enjoyed the work they submitted and were very pleased with their progress in both knowledge and skills. Two students teamed with senior students from mechanical engineering to design and build a chalk printer that prints advertisements on the campus walkways (Figure 1). They created a design with improved ergonomics and an improved interface, and even made it a little nicer looking than the original engineering prototype.
Based on the frequent problems encountered with projectors in the classroom, one student redesigned both the physical and digital control interface of a remote control. As shown in Figure 2, he started by comparing different commercial remote control products, identifying the implicit problems and user requirements through case studies, tested with duct tape prototypes, integrated current movement recognition technology, and finalized the design with detailed illustrations. The final design integrated both the remote controller hardware design and the on-screen menu design for a classroom-based projector.

Figure 2. Redesign of Classroom-Based Project Remote

Another student was very interested in improving the control of a treadmill. He was frustrated with the control panel of the treadmills with which he had to interact daily in the fitness room. Through informal interviews in the field, he refined the task analysis into a diagram and identified the problems he wanted to solve. He decided to design the interface in a way that “simulates nature.” He used paper prototypes to negotiate the navigation with subjects he recruited from the fitness room and finalized it with a digital version.

Figure 3. Redesign of Treadmill Control Interface

We were proud of the work that our students created; on the other side, our students enjoyed creating as well. At the end of semester, all the students rated this course as a 5 out of 5 in their course evaluations (seven students were enrolled in this course evaluated it through the Purdue course evaluation system). In the course feedback, one student wrote of the course: “This has been my favorite class of the year. It has been incredibly informative and eye opening. I am able to identify and quantify problems in a whole new way which has greatly affected my evaluations of designs I considered to be amazing. Now, I can now see objects like the XXX (omitted brand) vacuums are beautiful industrial design but have poor interaction design…”

Industrial Design Presentation

This is a course for senior industrial design students during their final semester. During the past three and half years, they have created a body of excellent design works (many were award-winning). Well-designed portfolios are more than essential for job hunting or com-
peting for graduate education opportunities (Liu 2007). Learning how to organize the same into an information-rich, engaging, and an interactive presentation was the course goal. Traditionally, students presented their work to potential employers with printed portfolios. Design projects were represented via static images, storyboards, and text captions. This class helps students present their products as virtually alive and operable.

We delivered lectures on graphic design and information design in Monday classes, and tutorials of the software Adobe Flash CS4 and ActionScripts in Wednesday classes. Students started by making simple animations of objects sliding, and finished the course able to manipulate and manage comprehensive nested animation structures. As instructors, we worked with them shoulder to shoulder. Apart from debugging their files and searching for solutions, we provided an interface to package their videos and digital portfolios as a whole. An online version of the project can be found at URL: www.interactiondesign.us/courses/2010_AD406/2010_Senior_iPortfolio/

![Figure 4. Interactive representations of product design selected from six different student portfolios.](image)

From the interactive information design perspective, students were encouraged to review different digital portfolios (some provided by us, others found by them online) and to brainstorm the best approach to organize and present their works. The first level of interactivity design questions how the students can optimize the navigation across their projects. Then, with a certain capability to use the software, students comfortably began to explore the possibilities to represent the uniqueness or functionalities of one product design with interactive techniques. This is the second level of interactivity design (see examples in Figure 4). To help these design students grasp basic programming skills, we created many examples. Some examples are simple abstract demos that show the code and the interaction effect created by the code. Some examples show how to integrate simple operations into a more complex interactive model. Following these examples, students quickly grasped the foundations of programming, were able to twist and enrich the example code, created their own codes, and integrated their designs into beautiful interactive projects.

We presented the whole project with a touch screen in the senior student show and received very positive feedback from the audience. The presentation was much more intuitive and complete in order to cover the shape, function, operation, and flow. One of our students even found a job in interaction design with the help of her digital portfolio.

**Current Course: Introduction to Interaction Design**

![Figure 5. Screenshots of a GenerativeComponents model simulating the building façade responding to the sun movement.](image)

Apart from attending lectures, students have opportunities to explore an innovative parametric design application—Bentley’s GenerativeComponents—to sketch design concepts. At the time of writing this paper, students only have used this software for three weeks.
However, some of them were able to create a parametric model simulating a responsive building façade, in which each of the cells adjusts its openness according to its direction and angle toward the moving sun. In Figure 5, there are five screenshots of this GenerativeComponents model, while the moving sun is conceptually represented by the moving sphere above the building model. In this software, designers can drive the variables freely and generate an infinite number of model variants.

After being introduced to the parametric modeling software, students will work on a web authoring project. They will compete to design the official website of Purdue's Solar Decathlon project with Adobe Dreamweaver. We purposely selected two distinctively different software packages to teach (parametric modeling in an expertise domain and website authoring is a widely used conventional skill). The reason for such a choice is to demonstrate the variety and potential of the interaction design domain.

**Current Course: Interaction Design Evaluation**

Compared with the survey-style interaction design introductory course, this course is systematically constructed around the topic of evaluation. It aims to build a foundation for design evaluation research. This foundation will be used to analyze recent evaluations of design frameworks, concepts, prototypes, and systems which use mixed quantitative and qualitative methods of inquiry. Our lectures introduce a range of evaluation approaches, including informal usability studies (heuristic evaluation and cognitive walkthrough), lab experiments, field studies, and analytically-based evaluations. Students explore techniques for feedback including usability tests, observation, interviews, heuristic reviews, and discursive evaluations. Then the underlying concepts of evaluation, including scientific experimentation, ethnography, phenomenology, and aesthetics, are discussed.

![Figure 6. Photos of usability testing of a blood pressure monitor.](image)

To implement these evaluation techniques, students design and conduct appropriate evaluation studies for a range of design projects. In the fourth and fifth weeks, students are using an “observational usability study” to evaluate four commercial home-based healthcare monitors. Shown in Figure 6, a team records a problematic process of using a blood pressure monitor. Their goal is to understand the advantages and disadvantages of these commercial products’ interaction design. From the beginning of the sixth week, they will collaborate with another group of students in an industrial design course to design home-based healthcare monitors to support patients with one of four different diseases/conditions (cerebral palsy, Parkinson’s, multiple sclerosis, or arthritis). The insights interaction design students gain from the evaluations of commercial products will help them to review their group's conceptual designs from the interactive perspective. Furthermore, they will be responsible for designing the interface and interaction of these healthcare monitors. Understanding patient user groups and supporting their limited mobility are goals for these students to achieve in the iterative process of design and evaluation.

**Conclusion**

In 2001, at one of the prominent industrial design events, IDSA “DesignAbout: Interactive Edges,” it was actively summarized: “[w]e can no longer think about products as isolated objects that are designed, produced, and inserted into people's lives, nor can we think about products consisting of hardware design and software design. Hardware and software need to become one, and products need to be thought of as part of a bigger system of object and space.” Nearly a decade has passed since this declaration; young designers are now expected to be able to have these integrated skills.

Purdue’s Interaction Design MFA program was initiated by an urgent need for such skills from the industry (first funded by Whirlpool). We are facing the unique problem sets with three distinctive gaps (between design and cognitive science, design and evaluation methods, and design and information technology). We took a user-centered research perspective to start the program. It took computing science a long time to realize that the human side is more important than the computer side of the industry itself. Only in recent decades has the domain of computer-human interaction been re-titled as human-computer interaction. Industrial design naturally considers human needs. Therefore, in order to teach interaction design’s theories and technologies in a user experience-centered approach, we integrate cognitive theories with design principles, enhance the lectures with real-life design examples, and encourage user testing throughout the design process. The response from our students has been very good.

However, we are facing some challenges at this beginning stage. First, we must prepare suitable design tasks for all of the courses. In the first Interaction Design Process course, the enrolled students selected their own interested design projects. The types of final design
outcomes (digital models, physical prototypes, and working prototypes) varied significantly. It was hard to advise, improve, and evaluate. Now we are trying to build up long-term relationships with industry partners to engage in more expansive and realistic projects. Arranging some suitable design tasks and inspiring our students to then solve real-life problems are our goals. Second, we delivered theory-based lectures and instructed practice-based workshops every week in these courses. However, we sometimes found that the design principles introduced in the lectures had not been adopted directly into our students’ design practices. It seems that the content of lectures and workshops should be woven more closely together to enhance the education quality. Third, there is an important issue not just for the students, but also for the varied faculty and researchers. Traditionally, industrial designers show their works in design competitions and exhibitions; HCI (human-computer interaction) researchers publish their works in papers. We are still searching for the most efficient medium to exhibit, publish, and promote interaction design works to an academic and industrial audience. It is too early to discuss the lessons we have learned from the program development. But the one thing we are very sure about is that it is an exciting, rewarding, and challenging journey, one which should be continued as an on-going and developmental process.

References


Malouf, D. 2010. Interaction design and ID: You’re already doing it...don’t you want to know what it’s all about? http://www.core77.com/reactor/02.08_ixd.asp (accessed Sept 15, 2010).


