Educational Framework for Interactive Product Prototyping

Nam, Tek-Jin

Korea Advanced Institute of Science and Technology, Department of Industrial Design
tjnam@kaist.ac.kr

Abstract: When the design profession started, design targets were mainly static hardware centered products. Due to the development of network and digital technologies, new products with dynamic and software-hardware hybrid interactive characteristics have become one of the main design targets. To accomplish the new projects, designers are required to learn new methods, tools and theories in addition to the traditional design expertise of visual language. One of the most important tools for the change is effective and rapid prototyping. There have been few researches on educational framework for interactive product or system prototyping to date. This paper presents a new model of educational contents and methods for interactive digital product prototyping, and it's application in a design curricula. The new course contents, integrated with related topics such as physical computing and tangible user interface, include microprocessor programming, digital analogue input and output, multimedia authoring and programming language, sensors, communication with other external devices, computer vision, and movement control using motors. The final project of the course was accomplished by integrating all the exercises. Our educational experience showed that design students with little engineering background could learn various interactive digital technologies and its' implementation method in one semester course. At the end of the course, most of the students were able to construct prototypes that illustrate interactive digital product concepts. It was found that training for logical and analytical thinking is necessary in design education. The paper highlights the emerging contents in design education to cope with the new design paradigm. It also suggests an alterative to reflect the new requirements focused on interactive product or system design projects. The tools and methods suggested can also be beneficial to students, educators, and designers working in digital industries.

Keywords: Prototyping, Interaction Design, Design Education, Prototyping, Interactive Product and system, Human Computer Interaction

---

This work was supported by the Korea Research Foundation Grant funded by the Korean Government(MOEHRD). (KRF-2005-041-G00050)

♦ Received : Mar. 31. 2006 ; Accepted : May. 05. 2006

1. Introduction

In the traditional manufacturing industry, the main role of designers was to create aesthetic forms of mass produced products. The new networked society has changed the design paradigm. Designers now add humane value to new technologies and create application concepts to enhance the quality of human life. The design targets of the manufacturing industry were mainly hardware goods with static characteristics. The design targets of the network information society became hardware-software compound, dynamic and interactive artifacts or services. Emerging technologies such as ubiquitous or wearable computing accelerate the emergence of many products, systems or services that are digitally converged and interactive. This change attracts the attention of many designers to interactive digital design projects.

One the most important design tools for innovative product development of interactive digital products is rapid and effective prototyping[1]. It allows designers to iteratively explore, develop and evaluate new concepts. Prototyping is also a means of communication between participants in the design process. For hardware centric products, sketching or foam mockups have been used for this purpose. For interactive digital products, additional aspects such as contents, user interface and integration of hardware and software as well have to be explored in the conceptual phase of the design process.

In the university level design education, prototyping education has not been well executed in spite of the perceived value. One of the reasons is the lack of temporal and methodological resources. To educate product designers who manage all aspects of product development, it is required to deliver the contents of ergonomics, manufacturing technologies, mechanical engineering and business in the design curriculum as well as visual formative languages. Design in the network information society requires more specialties such as human computer interaction, cognitive psychology, computer programming, electronics and so on. The available time is much too short to introduce all these areas within the typical four year design education program. Another problem is the lack of motivation by design education institutes which should consider the industry's needs. Although the role of designers is considered differently, many people still believe that the core contribution of design is to create aesthetic visuals. The difficulty of prototyping education also comes from the low acceptability of technology subjects by design students who tend to have intuitive and artistic propensity. It is difficult for them to accept engineering knowledge without considerable efforts and training. There are also little studies on the methods, tools and facilities required for a successful prototyping education.

To address these issues, this study investigates an educational framework of contents and methods for interactive product prototyping in the design curriculum. The aim is to effectively deliver the knowledge on digital prototyping related technologies in the university design curriculum. The study shows the case study of 'Interaction Design' course at the department of Industrial Design, KAIST, Korea, to examine the acceptability of the new contents and the methods and to identify the issues to be addressed for design education.

2. Interaction Design for Prototyping Education

There are some requirements to include prototyping education in the design curriculum. Considering the limited resources in design education, prototyping education should not conflict with the existing education contents such as aesthetic visual languages. The prototyping education may have to be covered in one or two compressed courses. However, the technological knowledge gained by the students should be at the level where they can explore the ideas and implement the concepts into concrete applications. It should also be considered that typical design students with artistic propensity may have low acceptability of engineering and technology. Moreover, the scope of the contents and the methods to deliver the technical contents should be taken into account.

Interactivity is defined as a cyclic conversation of listening (Input), thinking (Processing) and speaking (Outputting) between two actors [2]. A central concern of interaction design is to develop interactive products that are easy to learn, effective to use and provide enjoyable user experience[3]. It is necessary to teach students to flexibly think about the three parts of interactivity. The goal of the interaction design course at KAIST is to introduce the theories and the methods of interaction design and to help them gain prototyping skills of interactive products. The course was developed in response to a situation where the number of student projects in the final year rapidly grew in the area of interactive products, and such projects require rapid and effective prototyping skills on user interface, contents and hardware-software integration.

2.1 Contents for Prototyping Education

The skills to implement physical computing[4] and tangible user interface[5] were referenced and were used to optimize prototyping education for interactive digital product design. The contents were developed to reflect the three parts of interaction, listening (input), thinking (processing) and speaking (output), as a whole. In terms of the listening part, sensors, computer vision, digital or analogue input were considered. For the thinking part, training for logical thinking, algorithm development, and computer programming were taken into account. The contents for the speaking part include digital analogue output, motor control for physical movement, multimedia authoring and presentation. For prototyping of standalone interactive products, microprocessors and related programming environments were also included. Basics of electronics were introduced at the beginning.

2.2 Education Method

The course was developed as a semester-long (16 weeks) module. For the first seven weeks, basic practices on electronics, multimedia authoring, and script based programming were introduced. The step by step exercises on microcontroller programming, digital input and output, motor control and so on, were followed by the main project that required the application of the exercises. Demo movie clips were presented during the class to introduce the new technology contents. Students were also encouraged to use short movie clips for submitting and sharing the assignments results that are the applications of the exercises introduced during the class. Examples of early exercises include blinking LEDs that uses a PIC microprocessor and multimedia contents that change at the PC side according to the values received from external sensors. Students also learnt how to control different motors, such as DC motors, servo motors and stepper motors. After the basic exercises using PIC microprocessors, MIDAS[6], a prototyping system developed for designers with non technical background, was introduced.

MIDAS is a tool developed by Collaboration and Interaction Design Research Group at KAIST for implementing interactive tangible media. It stands for Media Interaction Design Authoring System. MIDAS provides easier ways to manage electric input and output of external devices and to support augmented reality with vision processing functionalities. MIDAS consists of a PC interface boards and an ActiveX control in the MS Windows environment. It is targeted to be used within Macromedia Director© or Flash©. Director or Flash users control external input and output hardware by the LINGO script, an embedded programming language of Director, or ActionScript for Flash. MIDAS also supports the 3D Augmented Reality feature by overlaying 3D virtual objects on marker images of a live video from a camera. This feature is based on the popular Mixed-Reality library, ARToolKit [7]. Designers can easily use these features by creating a sprite object and control the functions attached to the sprite.

For two weeks, computer vision and augmented reality were introduced. In the remaining 5 weeks, students individually developed new concepts of interactive products and integrated the skills they acquired from the exercises. Additional individual technical research was also conducted according to the project concepts. Table 1 shows the project schedule and the study contents by weeks.

Table 1. The Structure of the Interaction Design Course

Week	Topics	Demo and Assignment	Final Project
1	Electronic Basics,	LED blinking	
2	Microprocessor Basics, Digital Input Output	Application Digital Input & Output	
3	Analogue Input with Transducers (Sensors), Director Lingo Basics, Communication between	Director Movie controlled by Sensors	

	Microprocessor and computer		
4	Digital Output Control using Relay and Transistor, Analogue Output Control (e.g. DC motor speed).	LED dimming and DC motor Control	
5	Movement control Basics	DC motor direction control, Solenoid	Main Project Brief Announcement
6	Movement control	Servo Motors	
7	Movement control	Stepper Motors	
8	Mid term break		
9	Application of Computer Vision	Video Tracking and Manipulation	
10	Application of Computer Vision	MIDAS-Augmented Reality features	
11	Digital and Analogue Input and Output Control with MIDAS	Digital Analogue Input and Output	
12	Main Project Proposal Presentation		
13	Tutorials and Technology Research		
14	Tutorials		
15	Tutorials		
16	Final Presentation of the Main Projects		

2.3 Education Tools and Facilities

PIC Rom Writers and a PIC basic programming environment were used for microcontroller programming. Macromedia Director was used for multimedia authoring. MIDAS allowed simple control of external devices connected to the computer via USB. The interface boards, K8000®, K8055®[8] or Phidgets®[9], and MIDAS software allowed simple prototyping by skipping PIC basic programming and serial communication between the microprocessor and the computer. Various Sensors and motors could be connected with the PIC Microprocessors and the interface boards. TrackThemColors Pro®[10] and 3D augmented reality feature of MIDAS were used for computer vision applications. The process of searching appropriate components such as sensors and motors was an important learning process. The students visited electronics shops to understand what transducers and actuators are available and which ones are appropriate for their projects. Basic electronics tools and facilities are illustrated in Figure 1 and Figure 2.

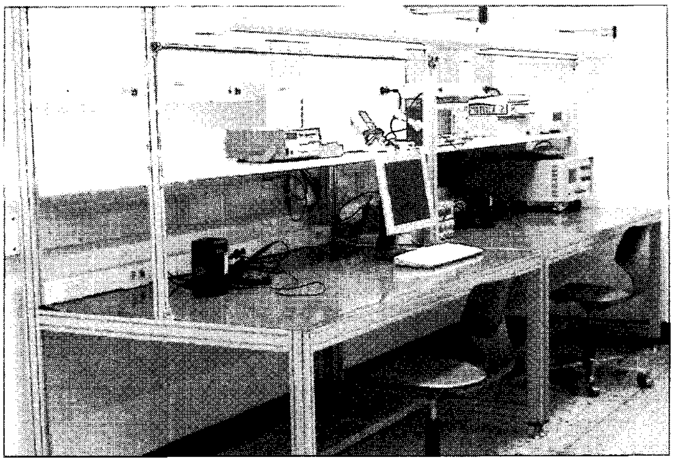

Figure 1. Electronics Workshop

Figure 2. Tools for Prototyping (PIC ROM writer, Power Supply, Tester and Solder from left)

3. Results and Lessons

3.1 Main Project Results

In the final phase of the course, the main project was assigned to integrate the skills from the exercises. The brief was 'to design interactive products to support people in their everyday and working lives'. The scope of the project was made internationally broad to cover most of the interactive digital product design projects. In the brief, students were required to consider the utility of interactive digital products for human life, to take user and task centric design methods and to produce a working functional prototype. Additional considerations were to include experimental and fun aspects and aesthetics. The work was accomplished as an individual project. The followings are the examples of the main project results.

3.1.1 Interactive Frog – Interactive Agent for PC interface management.

The design concept was to develop an interactive physical agent that allows PC users to manage the computer more easily and friendly. The result product, named Interactive Frog, is placed on top of a computer monitor and shows the status of the computer hardware and software with behavioral expressions [Figure 3]. It supplies appropriate feedback with the movement of arms and lights attached to the arms. For example, when a computer virus invades the computer, it poses the gesture of alert. When the computer virus is cleared, the posture returns back to normal. When a user plays music, Interactive Frog dances along. If the computer is turned on for too long or is over heated, it shows tiredness by the posture and the lights. To prototype the concept, motors and LEDs were controlled in a Director movie showing the simulation of the different status of the computer. Although the simulation did not fully connected to the computer's operating system, it was sufficient to show the abstract concept in a concrete tangible prototype form with which anyone can understand the purpose and the result of the design.

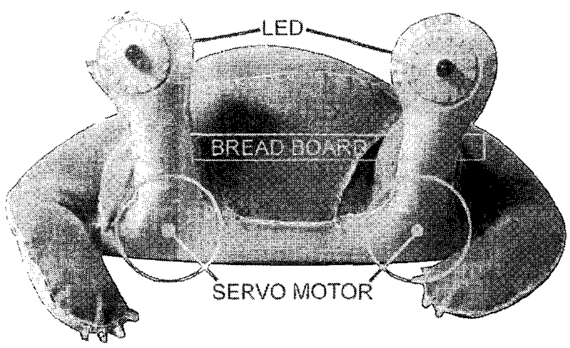

Figure 3. Interactive Frog, an interactive physical agent for PC interface management (by Jinkyung Kim)

3.1.2 Portable and Wearable Drum

The concept of this design project was to develop a portable interactive drum that allows users to exercise without a full drum set that requires large space and volume. It consists of portable drum sticks and wearable bands that recognize the movement of the user's arms and legs [Figure 4]. The prototype was implemented with PIC microprocessors, flex and vibration sensors, and a Director simulation. The unit worn in the right leg sends an electric signal to the computer by activating the vibration sensor. The band worn in the right elbow triggers the switch when the user straightens the elbow by using the flex wires inside. For the right hand movement which plays different sound, a flex sensor was used to recognize the angle of the arm. All the signals from the sensors were captured by the PIC microprocessor and subsequently translated to the Director movie simulating the interactive drum play. Table 1 shows the Lingo Script (Frame Script) used to create appropriate sound according to the user's drum gestures.

Table 1. Part of Lingo Script (Frame Script) used to create appropriate sound according to the user's drum gestures.

```
global theXtra, a, b, c, d, e, foot, f1, f2, lef,l1, l2, counter

on exitFrame

// send character to the serial port using a SeralXtra object named theXtra
   theXtra.writeString("1")

// wait until characters are received from the serial port.
   repeat while theXtra.CharsAvailable()=0
      nothing
   end repeat

// read the string and assign the value to the variable 'temp'
   temp=theXtra.readString()
   temp=value(temp)

// calculate the current state (variable a, foot, and lef) of arms and feet using the 'temp'
// value received from external sensors.
   lef=temp-temp/10*10
   l2=l1
   l1=lef
   foot= (temp-temp/100*100-lef)/10
   f2=f1
   f1=foot
   temp=temp/100
   e=d
   d=c
   c=b
   b=a
   a=temp
   put a, foot, lef

// examine if the received values are within the specified range.
// According to the conditions, create the sound of crash, hihat, basedrum and snare.
   if 290<temp and temp<310 then
      if a<e then
         crash
      end if
   else if 400<temp and temp<650 then
      if a>b and b<c then
         hihat
      end if
   end if

   if f1=1 and f2=0 then
      basedrum
   end if
   if l1=1 and l2=0 then
      snare
   end if

   go the frame
end
```

Figure 4. Portable and Wearable Drum (by Yoon-Young Choi) Right images show the wearable devices to capture the movement of arms and legs.

3.2 Feedback from the Students

The students were asked to report the feedback of the learning process in the course by writing a project diary. Among 31 students in the class, 30 students successfully produced functional or semi-functional prototypes of new interactive digital product or system concepts, although they had no prior experience on interactive product prototyping. Most of the students showed satisfaction on their achievements in the exercises and the final project.

They reported that although the technical contents introduced in the course were not familiar and considered to be difficult in the beginning, the experience was valuable and seemed helpful in designing new interactive digital products. The listening and speaking parts of interactivity, such as dealing with sensors, controlling motors and so on, were considered simple in the later phase of the course. Instead, the need of programming and logical thinking was recognized as more difficult for the implementation of compound interaction features of new products.

Although the technical contents of engineering, electronics and computer science were introduced for the first time in the curriculum, students recognized the needs of these prototyping technologies. This helped the learning process more efficient. They reported that as hardware model making skills are essential for traditional industrial design domain, technical prototyping skills are important in design education for the interactive digital products. They were also able to understand the technical terms used by other engineers. For example, knowledge of microcontroller programming, communication between devices and programming helped communication with electronic engineers and computer scientists. Understanding of technical requirements in design was also improved.

One of the most interesting applications of the prototyping skills was in exploring and simulating systems or user scenarios. For example, in the 'location based information system for the blind' project that developed a guiding stick, a location awareness environment and an information service were suggested as a system solution to the problem. To simulate the system, a miniature and video tracking was used to show the situation of human movement on the street. Multimedia information was used in parallel with the miniature system. This allowed the student to explore new interactivity and responses to specific situations and environments. Consequently, the skills helped to design more complex systems and improve synthetic thinking. Through this training, it was found that designers can make greater contributions in systematically related design problems or ubiquitous computing environments.

On the other hand, students had difficulties debugging their programs or electronic hardware construction. The students with intuitive and artistic propensity tended to solve the problems as a whole while the debugging required an analytic and logical approach. The starting point of debugging is to distinguish the problems and examine where the problems occurred to solve them one by one. This explains the need for training on logical and analytical thinking for interactive digital product design.

It was found that the speed and the quantity of education contents needed refinement. A total of 10 small exercises and a final project were accomplished throughout the semester. The student feedback showed that there were too many exercises. Group work in these exercises can reduce the efforts required and enhance the learning effect. It was also found that the acceptance of prototyping technology is slightly different according to gender. Some male students showed competency in programming and electronic circuit construction, while some female students expressed difficulties in hardware construction. They were frustrated when the final prototypes were not working or incomplete although they spent more time than some talented male students. This problem can be addressed by applying different level of exercises according to the students' acceptability or propensity.

The teaching contents on engineering knowledge didn't leave much time for exercises on thinking and visual language. Another aspect to be addressed is that the knowledge on engineering or prototyping becomes a constraint for concept development. Students often reduced the scope of the concept or changed the concept direction while considering the implementation issues. This is also shown in traditional industrial design projects where students develop formative concepts of simple construction with consideration to the difficulties in modeling. The prototyping skill should not constrain the concept development and the freedom of expression. The students should be able to compromise that technical implementation with the flexibility in design thinking.

4. Conclusions

Rapid and intuitive modeling with sketching or design mockups has been an important tool in the traditional industrial design process. With the growing importance of interactive digital products as the main design targets of designers in the network information society, the educational demand also leans towards prototyping interaction products. This paper presented a new model of education contents and methods for interactive digital product prototyping, and an application of the model in a design curriculum. The new course contents, integrated with related topics such as physical computing and tangible user interface, included microprocessor programming, digital analogue input and output, multimedia authoring and programming language, sensor, communication with other external devices, movement control using motors and computer vision. The final project was accomplished through an integration of all the exercises by individual students.

The experience and execution of the course development showed that design students with little technical background can learn various interactive digital technologies and its' implementation method in one semester course. At the end of the course, most of the students were able to construct a prototype that illustrates interactive digital product concepts. However, the need for training on logical and analytical thinking was identified. Prototyping education can contribute to concept exploration, evaluation, and communication with other professionals in the design process. This should be valuable for designers, who are involved in new kinds of projects, such as applications on mobile technology, wearable, ubiquitous computing and augmented reality and other new interactive digital technologies.

The contents suggested in this paper is based on the case applied to a design curriculum of an engineering based design university, the department of Industrial Design ,KAIST, Korea. This can be customized for many art based design universities. It is necessary to improve the tools, such as MIDAS, by reflecting the needs of design educators and students with more intuitive and visual propensity. The systematic framework of educational facilities, tools and methods should be further investigated to maximize the efficiency. Prototyping can also be addressed by working with other engineering specialists or by educating more designers who know various prototyping technologies. Further comparative studies should be conducted to guide the educational model for the design discipline.

References

[1] Kelley, T., Littman, J. & Peters, T. (2001). *The Art of Innovation : Lessons in Creativity from IDEO, America's Leading Design Firm*, Currency

[2] Crawford, C. (2003) *The Art of Interactive Design*, No Starch Press

[3] Preece, J., Rogers, Y. & Sharp, H. (2002). *Interaction Design: beyond human-computer interaction*, Wiley

[4] O'Sullivan, D. & Igoe, T. (2004). *Physical Computing*, Thomson Couse Technology

[5] Ullmer, H. & Ishii, H. (2000). Emerging Frameworks for Tangible User Interfaces, *IBM systems Journal* 39(3-4): 915-931

[6] Yim, J. & Nam, T. (2004). Developing Tangible Interaction and Augmented Reality in Director,

Extended Abstracts of ACM Computer-Human Interaction (CHI) '04, ACM Press

[7] Kato, H., Billinghurst, M., Poupyrev, I, Imamoto, K. & Tachibana, K. (2000). Virtual Object Manipulation on a Table-Top AR Environment. In *Proceedings of International Symposium on Augmented Reality 2000*

[8] Velleman (2005) http://www.velleman.be

[9] Phidgets (2005) http://www.phidgetsusa.com

[10] Smoothware (2005) http://www.smoothware.com