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Enhancing human–computer interaction design education: teaching affordance design for emerging mobile devices

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Abstract The evolution of human–computer interaction design (HCID) over the last 20 years suggests that there is a growing need for educational scholars to consider new and more applicable theoretical models of interactive product design. The authors suggest that such paradigms would call for an approach that would equip HCID students with a better understanding of the social context of technology design and development. An intrinsic part of the proposed pedagogical model is the concept of affordance or that which implicitly suggests to the user a particular kind of functionality of the product. According to cognitive theory, people approach multi-functional mobile devices by building mental models of their functions, starting with physical appearance. A case study of an HCID teaching strategy, based upon the primacy of affordance, highlights how students can be taught a range of knowledge domains for product design to support creative problem-solving and critical thinking skills.

Keywords Human–computer interaction · Design · Social context · Affordance · Multimedia mobile device

Introduction

Human–computer interaction design (HCID)[1] education is no longer a peripheral area of study for information technology, computer science, engineering, or industrial design

[1] Although there are varying definitions of human–computer interaction (HCI), HCI and human–computer interaction design (HCID) are a combined phrase that includes the traditional field of HCI and interaction design (ID). The latter is a further development of the first that places more emphasis on human interaction

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scholars. Rather, the market-driven acceleration of emerging technologies increasingly demands that professionals understand multiple knowledge domains and master various skill-sets in the context of a human-centered design process (Beyer and Hoszbalatt 1998). McCrickard et al. (2004) refer to HCI as a scientific and engineering discipline working in a creative dimension. Consequently, they pose the questions: Where should the focus of HCI be? How can HCI graduate programs produce interaction design professionals with vision, knowledge, and skill, in spite of a multitude of opposing views on HCI education (Sears and Williams 1997)?

One possible approach is institutional in nature. Program directors and faculty could devise novel approaches to curriculum design that are effective in delivering a multidisciplinary blend of theory and best practice. In this way, students will acquire the knowledge and skills they need to be effective design practitioners and researchers with a broad theoretical grounding (Owen 1998). At the same time, however, HCID education should pay attention to more than institutional arrangements. It should have a clear theoretical perspective that takes into account how users pursue their goals in a social and material world (Hollan et al. 2000).[2]

As Hollan et al., Hutchins, and Kirsh argue, "we need a new theoretical basis and an integrated framework for research … in which the focus task is no longer confined to the desktop but reaches into a complex, networked world of information and computer-mediated interactions" (p. 19). Their proposal sets the stage for educational research that aims to achieve three goals: (1) integrating the dynamics of socio-behavioral contexts into learning processes, (2) bringing into the classroom interaction design principles that are directed by a human-centered approach to usability, and (3) applying these principles and practices within technological contexts as they emerge.[3]

With such an approach, faculty will be faced with the challenge of understanding the evolving nature of a far more complex problem space and students will inevitably grasp the concept that everything in today's science and technology research is in a state of flux, i.e., "the theory driving the research is changing, many new concepts are emerging, the domains and type of users being studied are diversifying, many of the ways of doing design are new and much of what is being designed is significantly different" (Barnard et al. 2000, p. 11).[4]

Footnote 1 continued
and user interfaces, focusing primarily on design as a key factor that impacts user behavior, cognitive style, and the overall human–computer experience. As a branch of informatics, we define HCID to include all of the above definitions, with an added concern for the study, design, development, and implementation of humanly usable and socially acceptable information technologies.

[2] Participatory design emerged in Scandinavia in the early 1970s, becoming an approach that involves users as equal partners in the design process, i.e., designing the product in cooperation with the design team. Several models of how to carry out this technique have been developed since its inception (Muller et al. 1991).

[3] Pluralistic walkthroughs: Another form of cognitive walkthrough that integrates user participation into the process of assessment of prototype design. As with cognitive walkthroughs, pluralistic walkthroughs simulate a user's interaction process at each step of executing a task. Driven by the scenario, the user and design team check to see if task goals are being fulfilled, while noting memory, cognitive overload, and overall ease of use (Muller et al. 1998).

[4] Raskin states, that to be humane, is to truly be "responsive to human needs and considerate of human frailties" (p. 7). HCID must grasp the relationship between context, cognition, and technology. Hence, a greater concern for humane technologies is argued from the position that an underpinning of epistemology should form the base of human–computer interaction design methodology for system design. This is because current software design still remains traditional, with outdated research models that do not give adequate attention to social context, human limitations, and the enhancement of human creativity and processes of learning.

In summary, this paper details a teaching methodology that emphasizes the integration of applied with theoretical design research. Starting from the affordance paradigm, proposed by Norman (1988, 1999), it extends into the new territory by tasking the students to think first and foremost in terms of the functional implications and signals sent by a device's physical appearance. As such, the use of affordances should invoke questions that probe correlations between technology design and its impact on the users understanding of control and implementation of function.

Ultimately, our goal is to discuss and present for debate, in-case study format, the theoretical grounding of our approach, the pedagogical strategies we have used to implement, and the teaching outcomes the strategy produced. The case study outlined can be used for further pedagogical research and testing of novel methods to integrate HCI teaching with theoretical approaches.

Teaching affordances

Teaching the idea of affordance relies on recent developments in HCID. Oshlyansky et al. (2004) argue that when an object has an affordance, it refers to what we have already learned regarding its particular use or how it works in a particular way, i.e., in the way we use switches, dials, knobs, and buttons. They suggest that affordances become even more complex when we abstract them, that is to say, when used in PC user interfaces or smaller consumer products such as mobile phones or PDAs. This can be illustrated by considering the abstraction of an interface button that has only two states, ON and OFF. Switching it in either direction is a simple action, but this abstraction doesn't fully describe what goes on the first time a user attempts to use it. For example, when designing the graphic objects for a user interface, is it sufficient merely to model what the user *thinks* he/she is doing in terms of his/her control of the system? In other words, do users really think they are actually turning the switch or button On or Off when clicking or scrolling? More importantly, do the controls themselves communicate, through shape, positioning and conventional representation their intended function and use?

We also drew upon the work of Sanders (1997), who argued that affordances should be considered physical characteristics of the environment, while the implicit, and often real, intentions and feelings of the user should be left outside the concept. Gaver (1991) concurs when he suggests that affordances imply that the "physical attributes of the thing to be acted upon are compatible with those of the actor, that information about those attributes is available in a form compatible with a perceptual system, and (implicitly) that these attributes and the action they make possible are relevant to a culture and a perceiver" (p. 81). He goes on to say that common examples of affordances refer to perceptible "perceived affordances", in which there is perceptual information available for an existing affordance (Gaver).

As a summation of these views, we consider affordance to be a key conceptual concern in HCID education, because of its heightened relevance for designing the next generation of multipurpose communication devices. As third generation wireless technologies become more prevalent, the complexity of multi-purpose/plurifocal devices will necessitate a specific concern for affordances that are capable of bridging the gap between the device's functional capabilities and human mental models (Agre 2001; Dourish 2001). As Goldstein et al. (2003) suggest, the practical integration of multimedia functionality within a mobile device is a relatively recent concept. However, the complexity of use is accelerating as mobile device designers continue to integrate interface and physical control functionality on all sides of the device.

Studies suggest that users approach mobile device system mapping with a multiplicity of cognitive models derived from prior experiences with cameras, camcorders, personal digital assistants (PDAs), and personal computers (PCs) (Bay and Ziefle 2003; Ji et al. 2006; Oulasvirta et al. 2005; Zhang and Adipat 2005; Zhang et al. 2004). Hence, we hold that HCID students should acquire a basic understanding of how users' prior experience with media devices may conflict with new cognitive models associated with handheld devices, e.g., cell phone, PDA, etc. On the other hand, we emphasize that all such devices should be consistent, with a repertoire of gestures that feel natural. They should minimize cognitive friction and should communicate their states and capabilities to the user as intuitively as possible.

In pursuit of this new pedagogical model, the authors developed a 10-week HCI project that challenged graduate students to rethink all their basic assumptions, learned or perceived as being "common sense." The project proposed designing a multi-functional mobile device. Of particular interest was the complex nature of physical affordances that the design of hand-held devices demands. Based on Gibson's (1977) earlier groundbreaking theory, that holds that affordances bring together the actors intentions and their action, we explained to our students that a properly designed affordance should implicitly convey to the user, information (attributes) that designate the capacity and a particular kind of use of a technology. In particular, the students were tasked to start the design process not from abstract functionality models, but from delineating how the way the device presents itself physically. The emphasis was on a deeper understanding of "user requirements", where the needs were not conceived in terms of abstract tasks, but very practical interactions with a physical object whose form and controls are to be designed in a manner that affords the user a clear and immediate understanding of what the device can do and how can it be creatively utilized by users.

The project we assigned, which was theoretically informed by affordance theory (Norman 1988), addressed the interplay between specific external physical affordances and internal cognitive models and this interplay's role in facilitating or hindering the use of multi-purpose plurifocal devices (Matei et al. 2005). Project specifications required students to consider the problem space in light of a new device design that could provide multimedia content generation, transfer, and visualization.

Students were assigned tasks that directed them to explore various user cognitive models of physical affordances in the context of a multimedia mobile device. Students were directed to apply design innovation by first outlining the device's problem space. Then, they were instructed to identify and describe its potential mobile affordances and related features. Two and three-dimensional prototypes were designed and tested for usability. Students designed user scenarios and an array of context-based data was collected. In what follows we present examples of project outcomes together with an analysis of the learning process.

A theoretical overture for technology design education

Since the early 1990s, unprecedented attention has been given to software engineering that changed the focus of product development from computing algorithms to "experiential" and user design (Winograd 1997). Companies adopted system design protocols directed by a broader understanding of the need to address "use and user needs through a process of intelligent and conscious design" (Kapor 1996, p. 4). Shneiderman (2002) names this period of time the “second transformation of computing.” The shift from “machine-centered automation to user-centered services and tools” enabled users to be more creative (pp. 12–13). Being confronted with the new reality of product design, technologists slowly adapted to a more user-centered model.

Our model attempts to propose to educators and practitioners a perspective for HCI education that embraces a broader knowledge domain. In addition, it can better account for the social context and human perception (Nardi 1996), and it de-emphasizes system engineering. Science and technology students are thus encouraged to approach interactive systems design as a problem space that is less confined to traditional conceptual boundaries (Barnard et al. 2000). Our model, in compliance with Winograd’s (1997) suggestions, approaches software development as a process in which the designer creates “spaces for human communication” (p. 8).

The cornerstone of our pedagogical model for HCI is the attempt to understand the sifting, forming, and refining of design knowledge through multiple and evolving processes of product conceptualization. These processes primarily investigate relationships between interactive experience and user context, i.e., the physical, social, cultural, and historical setting of the technology. Within this more diverse disciplinary view, our students learned to design and manage knowledge that in turn better informed their experience of the creative process of system design. In our pedagogical model students learn to design “sophisticated knowledge structures that reinforce their capability of accessing, exchanging, capturing and generating knowledge in product design activities” (Lim and Sato 2001, p. 33).

Although many HCI programs throughout the U.S. have made considerable progress in developing multidisciplinary curricula, their invested interest and commitment to design that is adapted to the requirements of social science and psychological advance in perception research has been limited. For example, there is currently a wealth of course content on computing, interface design, and diverse usability techniques, but a lack of problem-solving courses that take have integrated view of HCID (Faiola 2007). In our model, the application of a social scientific/psychological approach to design offers a novel pedagogical framework for organizing, planning, and managing design events (Faiola 2006). Our perspective takes into account the complexity of knowledge domains and their holistic integration in the design of interactive technologies.

It is paramount to ground technology design education in a social scientific theory that focuses on holistic approaches and on the experiential facet of human–computer interaction. As Buchanan (2004) argued, in the “evolution of the design field, design education has sought a harmony among the different kinds of knowledge needed to make effective and valuable products, … [including] the fine arts, engineering, and the social science in the activity of design thinking” (p. 34). In like manner, if HCID students can acquire an education that facilitates their understanding of technology in its social context, and if this understanding sharpens their skills related to operational application (best practice) of design procedures, we can significantly enhance the quality of the educational process.

The authors hold that the broader inclusion of context-based approaches can provide students with significant knowledge about the social and organizational phenomena that inform human-centered processes. Similarly, HCID educators must acquire problem-solving skills so that they can visualize the behavioral contexts and problems that occur when humans engage in the dynamic action of technology interaction.

HCID problem-solving for mobile technologies

The authors' application of HCID integrates theory, design concepts, and class exercises. Students spend considerable time analyzing a problem space associated to a particular technology, e.g., mobile devices. It is critical to the assignment that there is an emphasis on designing from a human-centered perspective. Students are required to explore and conceive of a formal conceptual model of a particular technology—in this case, a mobile device. Norman (1999) strongly suggests several times that the most important component of a successful design is an appropriate conceptual model and a sustained effort to ensure overall consistency.

Once a conceptual model is devised, interface and interaction design options are formulated. All the while, class lectures and workshops reiterate the importance of focusing on user goals and social contexts, including user experiences and needs relative to the required system tasks (Löwgren and Stolterman 2005). Finally, students apply a series of usability techniques and tests to static and dynamic prototypes, whereby they validate their original conceptual model or related design elements and interactions.

The problem space

In our basic learning scenario, students are gradually introduced to understanding the impact that design and usability have on a user's experience. Meanwhile, they are encouraged to imagine use scenarios and devices that are growing in complexity and multiplicity of function.

For example, they are encouraged to think about the complexities involved in designing smaller and smaller devices that incorporate more and more functions. The controls and interfaces of such devices have become either more crowded or have been buried in sprawling hierarchical user interfaces (Vivrou and Kabbasi 2002). As a result, such novel technologies may be limited by the sociocultural maps and personalized cognitive models that users and designers have in mind regarding mobile device capabilities and their corresponding physical affordances (Gibson 1977; Hartson 2003; Norman 1988).

An example of such a scenario, which spawned a series of learning activities, involved a cell phone that serves as a PDA and multimedia repository (henceforth referred as a PDA multimedia phone—PMP). Devices of this kind are rapidly becoming one of the main access points to, and a storage repository for, personal media, such as music, photos, and video, including person-to-person voice communication with plurifocal capabilities (Monk et al. 2004). These functions may be further enhanced by the transfer of media content to a fixed interface display, such as a personal computer, television, or music system. The emergence of such multimedia-enabled mobile devices creates a number of physical and conceptual design challenges. First, problems can arise when a PMP serves as a gateway between various types of information and media content in addition to different types of platforms. Second, the process of "unveiling" the functional potential of a multimedia device relies heavily on developing new design solutions, which suggest that the features of the device are not just for a cell phone or PDA, but also serve as a vehicle for content capture, storage, and transfer between various platforms.

Because of the ubiquitous nature of portable devices, designers have focused their efforts on creating affordances that utilize what users know about interfaces and social connectivity in the context of current personal computing experiences (Agre 2001; Klopfer et al. 2004). However, in an early study on interface design and affordances of multimedia mobile devices, Goldstein et al. (2003) argue that the efficacy of such devices decreases dramatically with their functional complexity. Regarding the use of information appliances tailored to accomplish a single task, they state that the “porting of the stationary computer metaphor to a mobile multipurpose device may prove ineffective if it is in conflict with previously acquired efficient source metaphors” (p. 373). They add that to omit “well known affordances under the assumption that the intelligent user is capable of accomplishing the task efficiently, anyhow, is a bold assumption” (p. 373).

This brings us to the special problem of attempting to extend the uni-functional affordances of a mobile device, such as a standard cell phone, to a more complex multifunctional device. In this scenario, how does one design a multi-purpose device with affordances that are visible and immediately graspable to a user who intuitively associates the device with a traditional cell phone? Traditional devices that allow the user to take pictures and videos and make group voice calls and device-to-device media transfers rely on screen interfaces that borrow heavily from the feel and iconic vocabulary of the personal computing and PDA environments. This puts the user of such a device in a situation, as described by Goldstein et al. (2003), where manipulating a camera phone through an on-screen interface is in latent conflict with the familiar operation and the mental model of clicking a shutter button and holding the camera with both hands. Goldstein et al. suggest that, although on-screen controls seem to be more efficient from a usability perspective, they can in fact make devices more confusing and difficult to use.

Designing mobile device affordances: adapting to limited interface real estate

In an attempt to elucidate the pedagogical problem outlined above (i.e., how to integrate HCI design with a user-centric, social scientific perspective), we assigned to our students the task of reconsidering the process of designing a highly mobile multifunctional cell phone. From the onset, our instructions directed them toward a problem space that would be defined not in terms of functionality and capability, but rather in terms of tactile controls and those human experiences that would identify, define, and require such functionalities and capabilities. The devices designed by the students, which were supposed to facilitate several multimedia tasks (e.g., sending live video and videoconferencing, picture taking, and phone conferencing), had to be designed around the overarching principle that “form indicates function.” And conversely, that controls are not to be designed after the device is created, i.e., after the physical attributes have become communicative and mnemonic signposts.

Thus physical affordances, as opposed to menu based interface controls (with or without physical input devices, such as a stylus) were assigned in designing a multimedia plurifocal communication device. The students were advised to think in generous terms about using physical affordances (Goldstein et al. 2003). The specific terms of the assignment were as follows:

> Your final project assignment is to create a physical (3D) prototype for a mobile communication device that should meet a number of device requirements consisting of both physical and digital affordances. The device must speak to the user with a suggestive language that unifies form and function into a single statement, i.e., its physical affordances. By virtue of these physical affordances, the object should explain its own functions as much as possible, without requiring much from the user in terms of training or reading a manual. You should ask the following question for each feature or system requirements that you design an affordance for: What is it about this particular device affordance that will cause people to want to handle it and use it in a specific way?

We also directed the students to Weiser's concept of ubiquitous computing (1993), and to his emphasis on the idea that the marriage between mobility and multimedia should be marked by a dramatic shift from the desktop paradigm and its ancillary metaphors to devices and interfaces that are already well known, including cameras, Walkmens, etc. As Weiser points out, such devices and the conventions associated with them are easier to incorporate into the natural flow of human behaviors and actions. Abowd and Mynatt (2000) also concur when they argue that, although users desire natural interfaces that facilitate a richer variety of communication capabilities, it is the goal of these natural interfaces to "support common forms of human expression and leverage more of our implicit actions in the world" (p. 42).

All these requirements are in tune with emerging research agendas that emphasize the physical or "embodied" aspects of technology design and use (Dourish 2001). The idea of the "embodied" nature of technology addresses its existence and interaction in the physical world in specific contexts and with specific expectations for immediate and facile manipulation. Users prefer tangible controls and rely on intuitive use, primed by context and the task at hand. From this perspective, Dourish holds that the future belongs to small information appliances that maximize, not minimize, external affordances. This assertion includes adaptive interfaces that rely directly on the physical appearance of the objects. More specifically, picking up a mobile device with both hands and holding it lengthwise makes it ready for taking a picture, while grasping it with one hand and bringing it to the ear triggers the cell phone functionality. Norman (1999) concurs when he notes that our reliance on "abstract representations and actions is a mistake" and that "people would be better served if we would return to control through physical objects, to real knobs, sliders, buttons, to simpler, more concrete objects and actions" (p. 40).

Case studies: applying HCID to student learning

The students first acquired the adequate theoretical knowledge of designing a new generation of portable multimedia-based computing devices (Oulasvirta and Saariluoma 2004). They learned about basic information processing issues, such as the human mind has restricted working memory, i.e., cannot handle more than four or five items at a time, and that external mnemonic aids are critical to support cognition and to avoid human error. Equally important, students learned that features in complex systems should be made as visible as possible to reduce information overload, while functionality and feedback should be clearly visible in the interface. As Raskin (2000) suggests, features should be "detectable," i.e., the user should be able to notice the features that he or she needs from the multitude of functionalities available at any particular time. Emphasizing some features at the expense of others, might make certain features unavailable for unsophisticated users.

At the same time, an excess of visibility makes the device "gadget-ridden and feature-laden," which can intimidate even experienced users" (Norman 1988). The latter vulnerability can be particularly acute in the context of multipurpose devices, which combine the functionality and versatility of many individual technologies, each involving its own complexities. For example, a multipurpose device that captures, enriches, and transfers moving and still pictures would combine features from current digital video and photo cameras, PDAs, and desktop computers. Collectively, these devices can include more than 25 physical affordance points.

For example, a typical digital camera has seven contact points located in two areas of the device (back and top), a camcorder approximately eight contact points located in three areas (top side, bottom side, and back), a PDA six contact points, located in two areas (the display and the bottom panel), and the PC four major contact points, in three areas (keyboard, display, and mouse). This collection of physical affordances would need to be simulated in a plurifocal mobile device and, significantly, squeezed into its far smaller physical confines. Confronted by this challenge, HCID students learned how to make the device usable through well-designed and tested solutions and the corresponding physical affordances.

Building on those theories previously outlined, the authors argue that student designers should work toward achieving a natural or intuitive human–technology interaction based on physical affordances. As Overbeeke and Wensveen (2003) state, “the world appears to us as inherently meaningful because we perceive action possibilities, i.e., affordances” (p. 93). This suggests that the meaning we directly gather from the world is not inferred through reasoning. Therefore, student designers should arrive at a workable solution of interaction design that strengthens the relationship between people’s actions and functional meaning provided through the technology.

The project specifications

Motivation to succeed in the design enterprise began when students were provided a problem accompanied by a particular scenario in the form of a design brief that stimulated their thinking to “discover a viable solution to satisfy a human and/or environmental need” (Howard-Jones 2002, p. 222). In the view of Howard-Jones, “effective teaching encourages students to implement a process that has interactive aspects” (p. 222). For this reason, we designed our class project to promote student learning via an affordance-driven design process that could achieve clearly defined outcomes. This was accomplished by first emphasising the importance of affordance theory and best practice as core to design. Next, we provided different problem solving strategies whereby students could arrive at a well-informed design. For example, students were directed to create multiple paper prototypes, beginning with quick thumbnail sketches for concept generation, which eventually evolved into more refined drawings, clay prototypes, and finally interactive prototypes.

In this way, design students could observe their own creativity and the flow of ideas, which were especially beneficial during the early stages of designing (Denton and Williams 1996; Howard-Jones 2002). More significantly, the students were assigned to design the device in three-dimensional space from the earliest stages of their conceptual mapping of the problem, making it necessary for the students to provide quite early in the design process a conceptual and intellectual model that could be visualized as a graspable object.

Barak and Goffer (2002) state that problem solving should be considered an integral component of technology education. Moreover, they argue that there is a “strong bond between creativity and innovation—in problem-solving and new product development and teamwork” (p. 244). Hence, students who have limited experience in creative thinking realize that their team-mates are also learning through asking similar questions in a kind of team-think process. Here, individual investment in collective creativity processes serves as an “ongoing stimulus that intensifies teamwork in the realm of thinking and problem solving” (p. 244), a process that is well-documented in the professional sphere.

To reiterate, the class project focused on affordance design where teams of three or four students were grouped together based on their various skill-sets, genders, and cultural backgrounds. The class was presented with the general problem space related to the design of a mobile device that integrated a cell phone with conferencing options, three mega pixel digital camera, digital video camera with mpeg compression, and video phone conferencing options. Users of the device would have the ability to understand the device's functionality through its physical affordances, rather than interface menus or commands. Also, the audience for the device would be primarily composed of "early adopters" of technology.

First, student teams secured research data about potential markets, users, and the social and cultural context surrounding the identified problem space. Next, teams designed innovative conceptual models that reflected their solution to the physical affordance problem. Core to the learning process, students applied affordance theory and design knowledge obtained throughout the semester. In each case, design and project strategizing remained integral to the process of knowledge building, design, prototyping, and documentation (Owen 1998).

Students were required to submit a detailed report on their methods of problem-solving, conceptualization, product usability, and user experience. In total, issues investigated included: (1) the prospective technologies needed, (2) users and the overall target audience, (3) usability goals and user experience expectations, (4) the design problem space and solution, (5) features/specifications and functionality, and (6) product scenarios.

Deliverables consisted of paper and three-dimensional prototypes. A number of paper prototypes were developed by each team member based on the preliminary product specifications, including the problem space, cognitive model description, and a call to design the appropriate affordances. Team members then agreed on one particular design, from which a clay prototype and dynamic prototype were made. In addition to the actual product, a final report was prepared that included documentation of cognitive walk-throughs, usability testing, data collection, and analysis.

The development of the final HCID prototype and report reflected the team's comprehension of and solution to the assigned problem space. Also, the final project report reflected the students' understanding and application of HCID theory presented throughout the semester (Preece et al. 2002).

The designs were evaluated throughout the semester. There were two milestone presentations, the first a week after the assignment was handed in, and the second at the end of the semester, after the projects were turned in. The presentations followed a precise protocol, which included mandatory questions the students had to answer. These referred to: device intended functionality, design strategies, and manner in which the device emphasizes physical affordances. The answers had to be delivered in the form of physical (paper and clay) prototypes, posters, written reports, and in class presentations. Each project activity had to follow a specific format and had to attain specific goals. Presentations were recorded on tape. Alongside the two physical models of the device, the group written reports and the video recordings constitute the evidentiary basis of our interpretation. The discussion and conclusion sections are derived from interpretations of these documents, which can be obtained from the authors upon request. The evaluations and conclusions below summarize the general consensus about each device, based on all three types of feedback. They are also a summative assessment of the main impact of our pedagogical methodology on learning HCI design methodologies.

The project solution

Of the three design teams that worked on this class project, the FlexFon design was clearly the most successful in applying the HCID perspective. In addition, its conceptual evolution over the course of the semester most clearly indicated how a teaching paradigm that emphasizes a social, cultural, and affordance-based approach leads to truly innovative solutions. After briefly reviewing the specification of the leading product design, we will discuss how our method impacted the design process and how the team that came the closest to our pedagogical vision implemented our proposed methodological and theoretical vision.

The FlexFon represented a more structured, thoughtful attempt to meet the challenges of the exercise, but it seemed burdened by an excessive number of features and required static usage. The device, roughly the size of a standard cell phone, allowed users to change its shape for many of the proposed functions. Each shape that the unit took corresponds to a function that the device is capable of. While this device's primary function is to serve as a cell phone, the other four pre-established functions are not only representative of a phone, but also suggest a standard still camera and a video camera. The cognitive model that applies to the FlexFon's intended purpose is an integration of the user's experiences of using a camera, a camcorder, a cell phone, an office teleconference, possibly an iPod or other audio player, as well as various PC-based file transfer and media functions. Working from the proposed project problem space and related device requirements, the FlexFon team organized the cognitive model around a range of activities (see Table 1).

Table 1 Outlines the key features of the FlexFon, as well as the design of two additional products presented here

<table>
<tr><th></th><th colspan="4">FlexFon Functionality / Features</th></tr>
<tr><th>Feature Area</th><th>Cell Phone</th><th>Camera/ Camcorder</th><th>Media Player</th><th>System Manager</th></tr>
<tr><td>Requirements</td><td>□ Dial a Phone Number
□ Make a call from the Address Book
□ Conference another user into an existing call
□ Select Vibrate, Silent, Normal Modes
□ Communicate with Audio & Video
□ Select Ring Tone/Ringer Volume
□ Answer/Hang Up</td><td>□ Select an Operating Mode
□ Select destination
□ Start/Stop taking a picture/video
□ Determine flash/lighting mode
□ Zoom
□ On-The-Air Indication</td><td>□ Select an Operating Mode
□ Select a Source
□ Start/Pause/Stop/Rewind/Skip to Next Track
□ Adjust Volume</td><td>□ Search for Sources
□ Create Path for Outputs
□ Review/Preview Files
□ Delete Files
□ Copy/Move a file to/from a Remote Device
□ Edit Address Book Entries
□ Program hot keys & voice commands</td></tr>
<tr><td>Addition Features</td><td colspan="2">□ External Display
□ Multi-rotation display for different modes
□ SD Memory Card Slot
□ Bluetooth technology
□ Web browsing capability
□ Speakerphone
□ Downloadable Ringtones</td><td colspan="2">□ Text Messaging
□ Color Screen
□ Voice Activated Dialing
□ Changeable Faceplates
□ MP3 Player
□ Store contacts/addresses
□ Instant messaging</td></tr>
<tr><td>Specifications</td><td colspan="2">Physical Characteristics
□ Weight: 4.7 oz
□ Flip Style
□ Silver faceplate/color (interchangeable)
□ 3.8 x 2.02 x 1.21 inches
Battery:
□ Lithium ion battery
□ 220 minutes talk time
□ 340 hours standby time</td><td colspan="2">Display:
□ 2” internal & external LCD displays
□ 176 x 220 pixels
□ 16-bit color depth (64K colors)
□ TFT display
Included Bluetooth USB dongle for file/video transfer to PC/Laptop
□ Transfer rate up to 1Mbps
Included expansion base(s): Charging cradle
□ Installed Memory: 32 MB – unlimited SD card support
□ Audio input type: Microphone
□ Audio output type: External Speaker/Headset</td></tr>
</table>

FlexFon team members focused much of their conceptual modelling on the device's flexibility with the intent of allowing it to perform as a camera, cell phone, and recording device. Hence, the key feature of the device was its freedom of movement or "flexibility", as illustrated by their paper and clay prototypes. Based on the "flex-enabled" or "action" of the device, the team referred to it as an "action" device. Clay prototypes were developed by each team member based on the paper prototypes. The team reviewed the prototypes and selected the one that best matched with the "natural flow of human gestures and actions" (see Fig. 1). A dynamic or interactive prototype was also created using Flash that included the functionality of the device in the various media modes (see Figs. 2, 3). Each mode showed screen content to demonstrate the software and screen functionality. Most multi-function capabilities were available through the use of specific buttons on the device, as the specifications outlined according to the principle of maximizing physical affordances.

User feedback was solicited throughout the design life-cycle by means of cognitive walkthroughs, questionnaires, and interviews. The product studies used helped to gather user data on both the clay prototypes and interactive prototypes. Four tasks were used to guide the cognitive walkthrough study with potential users. Five users performed the tasks with the preliminary clay prototypes. The walkthrough included the following tasks: (1) dialing a phone number, (2) taking a picture, (3) starting a video conference, and (4) capturing video. Significant variation in task times was seen, due primarily to the clumsiness of the clay prototypes. Mean task scores were recorded to better inform the development of the interactive prototypes. A final cognitive walkthrough was performed using the dynamic prototypes with a group of eight participants from the software and usability industry. Feedback was consolidated and included in the product report.

At first, the features of the FlexFon device seemed to meet the assignment goal: an emphasis on physical affordances and on mobile usage. The two usability studies this team conducted seemed to indicate that the users like some of its features. However, a few issues surfaced during these studies and re-emerged during the final presentation. The central concern revolved around the physical bending and hinging functionality required to allow the users to activate each media mode of operation. The device needed a lot of

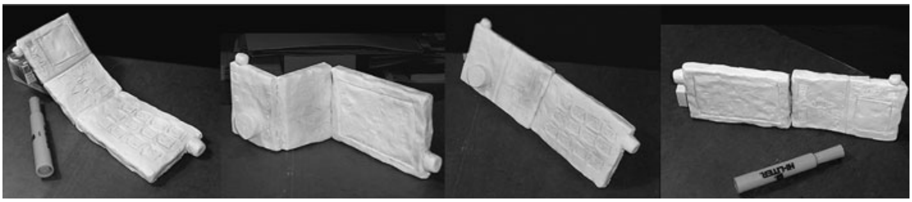

Fig. 1 Photograph of four views of the final clay prototype from the FlexFon design team

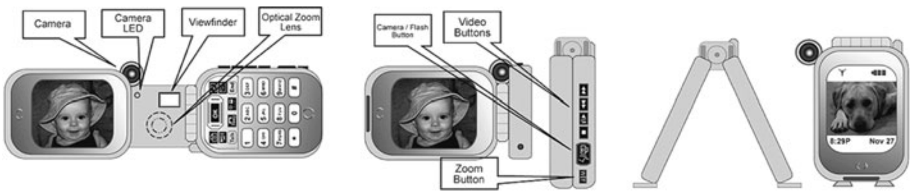

Fig. 2 Illustration of dynamic prototypes used in user testing

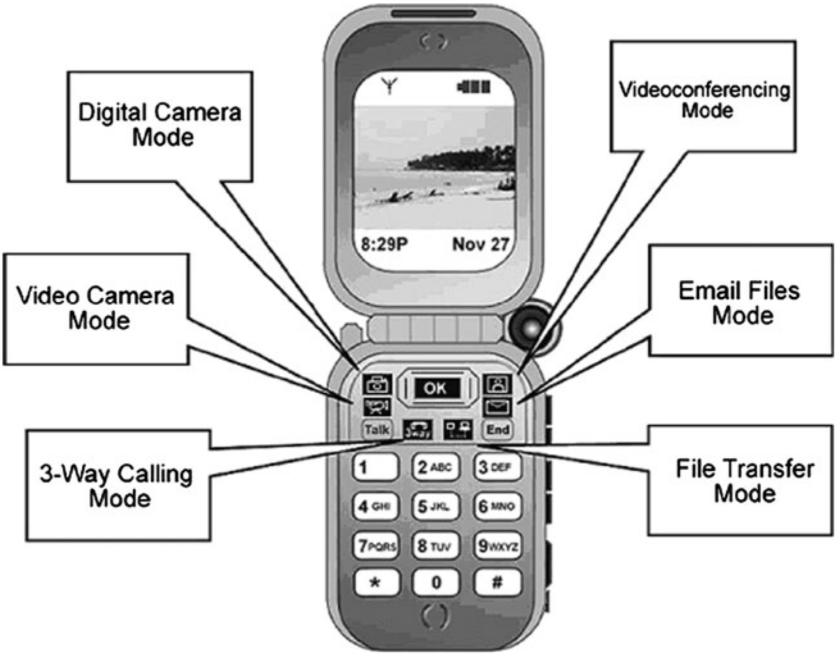

Fig. 3 Illustration of open view of dynamic prototype

manipulation and, more importantly, required setting the product on a flat surface for some of its multifocal utilization. Ultimately, the main goal of the device, mobile use of structured multimedia features, seemed to be defeated by the device design.

Another important drawback of this design was its complexity. The phone relied on a rather traditional clam-shell design. Although well adapted for audio-mode use, it dealt much less satisfactorily with many of the device's other intended functions, making it physically unfeasible for an engineering team to resolve its limitations. Features like the gaming capability and quality video streaming added to the engineering and design challenges. It was obvious that the design team needed significant input from an engineer to achieve technological feasibility.

When students comprehend the application of the social sciences and psychological theory within the life-cycle of technology design, they are more capable to integrate into their learning process theoretical constructs that more clearly link design knowledge to design process. When social scientific theory has a clear design edge, as is the case for affordance theory, student creativity is considerably enhanced. Students are very receptive to theoretical knowledge, because the concepts are directly applicable to design decisions and can be checked against various design solutions. As the solution proposed by the students indicate, the device prototypes created a variety of use scenarios, well received by the expert panel and by the other students.

More importantly, the HCID process we proposed had the ability to achieve a triple educational strategy by: (1) integrating in the learning process the dynamics of socio-behavioural contexts, (2) bringing into the classroom interaction design principles that are directed by a human-centered approach of usability, and (3) embracing and applying those governing principles and best practices to a specific technological context.

Conclusion

As Arias et al. (2000) outline, the history of HCI has brought about “new challenges that center on the long-term theories of design, systems, technology, and media” (pp. 85–87). Artifact creation, however, must be supported with knowledge of design processes and the ability to manage large amounts of information relevant to the design task in the context of different (disciplinary) perspectives of the problem. It is from this perspective that HCID educators should deliver a broader range of tools, techniques, and theoretical models that are unified under a single framework (Carroll 2003).

Traditional HCID theory and methods are foundational but limited for delivering a full range of knowledge that can equip students for future trends of emerging technologies. Moreover, HCID programs that provide a broader curriculum must avoid the disconnect that often frustrates students from forming a clear comprehension of the various domain areas within the discipline. Hence, the challenge HCID faculty face is building design technology programs that demonstrate a shift to a broader but more cohesive model that can address new knowledge domains that are well managed processes for designing new and emerging technologies.

Faculty involved with core courses that center on HCI and/or design must help students to learn that designing interactive products draws upon multiple knowledge domains, while learning the interplay between form, function, human need, and social context. Knowledge acquisition and knowledge building are structured processes, controlled by management channels that direct the processes of student learning and instructor evaluation. In this process, students ask questions, obtain answers, and make decisions to build knowledge (Owen 1998). Although these issues are diverse, they are addressable if HCID educators are prepared to provide students with solutions derived from a unified understanding of design as an enterprise of knowledge building. However, this process will demand a broad approach to connect the complexity of user needs, product requirements, and knowledge management.

In the team projects presented here, students learned that affordance means that each function of a device, and its corresponding method of operation, should be immediately apparent to the user and should be looked at as a distinct class of device features. These are characteristics that offer users not only clues about the proper operation of a device, but provide cognitive maps that bridge implicit thinking to explicit action. When students understand affordances, they are empowered to “show how good design can make the appropriate use of a device clear and obvious to a user” (Dourish 2001).

In summary, the mobile device project presented here attempted to show the outcome of HCID theory and best practice strategies centered on physical affordances. Moreover, the authors, through the process of this course project, became profoundly aware that HCI students can conceive and design innovative affordances based on theoretical learning that is directed toward specific practice.

In other words, as students acquire the necessary knowledge and skill-sets, they will bring forth more than new design. They will produce a hybrid of new knowledge about the design process with outcomes that engender intellectual inquiry that expand their understanding of complex problem spaces. As DeBono (1990) noted, the process of bringing forth new ideas, with regard to human knowledge, is a method of science. For HCID, however, to advance as a pedagogical discipline, it must have a branch of thinking that can move beyond the formal models of design that still embrace conventional technology problem solving. Rather, as students broaden their domain knowledge (e.g., in the social sciences and usability engineering), their design thinking will evolve, venturing beyond traditional boundaries. Ultimately, this will provoke new dialogues about and solutions for the ever-evolving needs of global users, who will increasingly demand unending connectivity and a diversity of media options at their finger tips.

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