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From the Editor in Chief**LOOKING AT THE NATURE OF IDEAS
THROUGH NEW LENSES**

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What sets humans apart from other animals is not the use of technology: Many mammals are innovative in making simple tools to assist in life. But it is the sheer scale of technological development that distinguishes humans. Over the millennia, people have invented technologies, used them, and enhanced them. The once-innovative technologies become mundane elements of everyday contemporary life as human societies progress. The technological developments of the last decades have dramatically altered most humans' way of life and perceptions of the myriad elements of the immediate and distant environment. It would not be an exaggeration to view humans as standing at the cusp of profound social changes that are in line with those following the invention of writing or the steam engine. Therefore, now is a good time to stop for a moment and ponder the forces that make such new developments possible. What should we pay specific attention to when we attempt to make sense of where we have succeeded as a species, and where we have failed?

Certainly this complicated, multifaceted, and intangible question cannot be answered in the next three pages, or even in a thousand times that many: There are simply too many interrelated forces that form the necessary conditions for progress. But I can isolate one particularly relevant force to contemplate, one that underscores the human role amid the multitude of other factors: That force is the reception of new ideas.

Humans are a creative sort, continually imagining new ideas to address common and uncommon problems in daily life. But the success of an idea depends not solely on its conception: An equal partner of the potential of an idea is its social acceptance. The lack of ideas is certainly not an ideal situation, and one must remember that even a bad idea is better than no idea at all. Many bad ideas have been rethought, reworked, and reinvented into pretty good ideas. But new ideas are also a double-edged sword: While innovative thinking may propose a solution to a perceived problem, the inventor often finds that his or her "big idea"

causes problems too. For example, the questioning begins with the assessing the originality of the idea, and then moves to include logistical questions such as how to make the idea a reality, to economic and philosophical questions such as whether there is commercial or human value for it, as well as environmental questions such as whether this solution harms existing biological, interpersonal, or mechanical systems, and on and on.

These questions arise, however, only if the idea has some greater outlet than the inventor him- or herself. For example, the revolutionary ideas on genetics outlined in Mendel's laws could not assist farmers in their hit-or-miss hybrid farming practices of the mid-1800s because the concepts weren't generally known (O'Neil, 2006). Decades later, Mendel's work was rediscovered and, through experimentation over the last century, has been refined into common practices that allow for successful and replicable cross-breeding practices.

Other times, it is simply a matter of others not being intellectually sophisticated or astute enough to understand the value of the idea. Centuries before the Renaissance, the idea of experimental variation was invented. The study of phenomenon by means of systematic variation to and measurement of the effects on the phenomenon was devised by the Pythagoreans of the 5th century B.C. to prove that numbers are the essence of the world. This may have been revolutionary thinking, but no one understood what to do with it before Galileo Galilei (1638/1954) adopted it and began his study of the behavior of a pendulum using systematic variation. Thus a very old idea applied within a new context helped open the path to modern science and industry. Unfortunately, many generations of potential creativity built upon the Pythagoreans' inspiration have been lost.

Certainly ideas are not good simply because they have been created. The history of humankind is littered with instances of engineering and social science ideas that failed or never rose beyond disappointing levels (Petroski, 1994). As a result, many people remain skeptical about new ideas. On the other hand, if all new ideas were deemed valuable simply because they are new, our modern societies would be quite troubled and dangerous places to live. So, what should we do about new ideas?

The ultimate challenge, of course, is deciding whether an idea is good, is not good but has potential for development, or is simply inappropriate or invalid. Some of the decisions are relatively minor; all of us make these nearly every day, occasionally without much thought. Some decisions are larger, conscious, and can involve other people. Sometimes we find the decision on an idea difficult, and are happy to let others be responsible for deciding its goodness. And some decisions are so large that only a few people can play a role in their outcome. Yet, our general attitudes toward ideas, as individuals within a society, have substantive impact on every assessment of an idea by decision makers within our society. Our laziness toward the process of considering ideas from various perspectives can doom otherwise useful and beneficial ideas, which can have a long-lasting social impact. The example of Galileo remains valid today: Progress can move onward if we develop the right ideas at the right time. Had Galileo not accepted his responsibility to view the appropriateness of an idea—past or present—perhaps our world might still be awaiting a new Galileo, but awaiting from within a far more primitive society.

One of the benefits of modern ICTs is that they enable us to communicate faster and further than at any time in human history. The good news in this is that ideas—the good, the bad, the undeveloped—can reach new “Galileos” around the world perhaps in minutes, as compared to centuries. The bad news is whether modern societies are truly prepared—

mentally, critically, alertly—for this new culture of discovery. If we turn blind eyes and deaf ears to new ideas, if we are unable or unwilling to seek out new concepts and visions, if we cannot be imaginative in exploring new applications for old or underdeveloped ideas, then progress is slowed and we may miss an opportunity to develop our societies and our futures. Surely if a society is unable to recognize, evaluate effectively, and adopt in various ways new ideas and new ways of thinking, then improved communication is of little use.

An ICT society can be seen as simply a technical revolution and little else if its members cannot understand that the technologies themselves are only part of the equation. Equally important is the mental revolution that must accompany technology: the creative ability to use the mechanisms to enhance social well being. ICT societies are new idea societies only when the new ideas are allowed to make progress possible. However, to make practical and creative use of new ideas, some old attitudes toward ideas must fall away.

For centuries, some have viewed knowledge (i.e., augmented true opinions) as eternal truths. All of science has pointed toward discovering these truths and to evaluating anything new within a framework built around these pillars of our culture. Whatever did not coincide with what we held as truth was promptly discarded. Yet this approach limits the potential for innovation and progress.

Perhaps what is needed today is simply a new approach, a new way of thinking. Without rejecting the established laws, we can look at ideas more dynamically. By using multiple lenses we can begin to imagine different possibilities for innovation, potential solutions for currently unsolvable problems (Laudan, 1977). But most importantly, we must be able to look at ideas with an eye toward tomorrow. This presupposes that we are wise enough to recognize that not all ideas are in usable form today. We must be able to see the potential in an idea: The decision should not be “This idea is useless to us today,” and then not only allowing the idea to die but also become forgotten; rather, the decision should be “This idea is okay,” and so it is allowed to progress. We must allow for the evolution of ideas, for the re-tooling of ideas, for the taking of current ideas to new levels, for seeing how more than one underdeveloped idea can be united with other ideas to form a greater good, and even allowing an impractical idea for today to survive long enough for it to have value and use in a more receptive and appropriate future.

We must make decisions about ideas, but we must do so from a more open-minded, imaginative, and thoughtful stance. Our societies are progressing at an incredible pace: We must find a way to capture the potential of ideas of today that will provide the necessary potential for development and progress in our societies of tomorrow.

Our current issue of *Human Technology: An Interdisciplinary Journal on Humans in ICT Environments* shows how looking at current practices and research a bit differently can enhance new knowledge and create new advantages. Each of the articles reflects the authors’ inspired thinking in raising the understanding of a concept to a new level or different application. The first article, by Mäyrä, Soronen, Koskinen, Kuusela, Mikkonen, Vanhala, and Zakrzewski, looks at the human experience of smart home technologies of the future. However, since these technologies currently do not exist, they innovatively created small experiences to help the users gain a feel on a limited scale of what embedded smart technologies could be, especially in the comfort of home environments that the study’s informants have. And they approached this research from multiple scientific disciplines,

thereby allowing new ideas and their potential to be collaborative. Looking at the concept of flow in relation to games is the focus of the article by Kiili. Building on prior research in the gaming world, he seeks out the elements of flow that might have implications for creating educational games. The third article by Linja-aho looks at the learnability of complex systems. She posits that the process for learning is more complex than the current literature indicates, and provides guidelines to assist developers in creating systems and training that are more learnable, particularly for novices. Finally, Chesney extends the current research on the technology acceptance model (TAM) by testing the relationships between perceived enjoyment, ease of use, usefulness, and intention to use for “dual” systems, those information systems used for both utilitarian and pleasurable purposes.

Research such as this demonstrates the social benefit of looking at current science and current human needs through the lenses of many disciplines, as well as creativity, open-mindedness, and the potential for the future. Good ideas are needed for human progress, but even good ideas can be enhanced, rethought, and taken to a new level when society looks at the ideas from a new stance.

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PROBING A PROACTIVE HOME: CHALLENGES IN RESEARCHING AND DESIGNING EVERYDAY SMART ENVIRONMENTS

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Abstract: *Based on the results of a 3-year interdisciplinary study, this article presents an approach in which proactive information technology was introduced into homes, and discusses the derived design principles from a human-centered perspective. The application of proactive computing in homes will face particularly sensitive conditions, as familiar and reliable household elements remain strongly preferred. Since there is considerable resistance towards the increase of information technology in homes, both the calm system behaviors and the degree of variety in aesthetic designs will play major roles in the acceptance of proactive technology. If proactive technology will be an embedded part of a home's structures and furniture, it needs to blend with the normal, cozy standards of a real living environment and aim to enhance the homeliness or the key social and aesthetic qualities of homes.*

Keywords: *proactive computing, user-centered design, home technology.*

INTRODUCTION: CHANGING ECOLOGIES IN HOMES

In a way, it could be a quite nice idea that there would be coffee ready and waiting when you wake up, or if the lights would be automatically switched on. But on the other hand, there is a certain enjoyment in doing it yourself: closing the curtains, lowering the Venetian blinds, and switching off all the contraptions. And, in a way, when you think about it, I have no need for any change. (M, 35¹)

Modern homes are becoming increasingly laden with various technologies, ranging from new-generation kitchen utensils and domestic appliances to home computers, digital televisions, and wireless media servers. The sales of consumer electronics in industrialized countries like the USA appear to rise to record heights every year (Consumer Electronics Association [CEA], 2006.). One vision of the future repeatedly evoked by the electronics industry is the creation of the *smart home*, a new kind of technologically enhanced living environment. Yet, there are different versions of what “smartness” means in this context, depending upon whom you ask. Planning a home around a complex entertainment center may represent smart for some, whereas others emphasize home security systems, or even more ambitious home automation solutions, where numerous home elements, such a lighting, door locks, or window shades, are programmed to behave in certain ways.

Home automation is not near reality in most homes, not even in the highly technological West. Additionally, there is also some resistance towards the whole idea, as the quote above from one individual from our study illustrates. One can question whether there exists an actual need for which a smart home (as it is currently marketed) would be a solution. Perhaps, therefore, the issue should be approached from a different angle. It appears that we already are living in relationship with various devices and technologies, and our living is influenced by them even while we make decisions and apply these technologies in ways that shape their value and usefulness to us. These kinds of interdependent connections, and the networks they form, can be conceptualized as *ecologies*. While ecology is traditionally defined as a study of organisms and their environments, this concept has revealed its usefulness beyond the field of biology to encompass other entities and their environments, such as community ecologies, information ecologies, and media ecologies, among others. For example, Nardi and O’Day (1999, p. 49) define information ecology as “a system of people, practices, values, and technologies in a particular local environment.” They emphasize that, when studying information ecologies, the spotlight is not so much on the technology as it is on human activities that are served by the technology.

One of the main conclusions from our research is that because the relationship between humans and their technology is complex, we need to develop a multidisciplinary approach to study our increasingly intensive and intimate relationship with technology. It is insufficient to regard the people who are adopting or rejecting new technologies as just passive consumers, since their attitudes and practices have a powerful effect on the success or failure of particular devices or services. It also would be a failure to overlook the important ways in which the design, distribution, and marketing of new technologies are affecting the relationship between the humans and the technology. As research and development practices become more closely informed by user studies, the clear-cut separation and opposition of the realm of production from that of consumption is no longer necessarily valid. For example, assuming that producer

roles are distinctive from consumer roles might have been appropriate for an industrial society, but as much of modern production involves designing information systems and media content that is collaboratively produced, involving networks of people in various roles, the opposition between consumer and producer does not stay as clear. As participation and interaction are becoming the new standard of design, there is an increasing need for evolving further the practices for codesign and coproduction, where users and designers are conceiving and developing new concepts and products in a more collaborative and interactive manner.

The starting point of our research was the need to provide a human-centered view on the development of proactive technologies for homes. *Proactive technology* is related to a particular information-technology-industry-driven vision of the future, where omnipresent computing, sensors, and other technologies have been developed to the point where they anticipate our needs and act on our behalf (Tennenhouse, 2000; Want, Pering, & Tennenhouse, 2003). There are obvious commercial reasons for companies like Intel and IBM to focus on such a processor-saturated view of the future. But when such views are raised to the agendas of researchers and developers, these visions also may carry some self-realizing power. It was our aim to confront the concept of proactive computing, adapt it to concrete local environments in real homes, and thereby produce a better understanding about the related acceptability, usability, and feasibility issues should such technologies indeed be adopted and installed in homes. In this way, our research is both a contribution to the critical studies of science and technology, as well as a call for more ethical and sustainable ways of developing new home technologies.

Actually, certain reasons exist for why we might have need for such technologies in the future. Some claim that the aging of population will necessitate the development of smart home environments (e.g., Baillie & Schatz, 2006; Dewsbury, Taylor, & Edge, 2001). However, as we argued in our book, *The Metamorphosis of Home* (Mäyrä & Koskinen, 2005), there are serious ethical considerations that must be taken into account if human contact, independence, and autonomy are becoming replaced by proactive technologies, as compared to assistive technologies, where humans themselves take actions with the help of technology. We claim that the perhaps most crucial need for proactive technologies in homes will be related to the information ecologies themselves and with their evolution. It is already becoming an observable reality and common problem that the omnipresent media and communication technologies also create stress and increase the complexity of life rather than just help us to cope (Edmunds & Morris, 2000). As information network connections become more prevalent in such ubiquitous devices such as televisions, stereo systems, and games consoles, as well as in mobile phones and cars, there also will be a related surge in e-mail, instant messaging, and other communications, much of it likely unsolicited (spam) or otherwise undesirable. As a result, the overall cognitive load on individuals must be taken into account in every context. Essentially, our information ecologies are rapidly becoming over-saturated or even polluted by nonessential information (Koski, 2001), and perhaps most needed will be proactive technologies to control and supervise all the other technologies that are fighting for our limited time and attention. Thus, one of our directives for proactive home technology design was that, if adopted, these technologies should enhance the homeliness of homes: to support and protect those qualities that are central for people in their homes, including peace, relaxation, intimate human relationships, and shelter from the pressures of modern life.

This article will seek preliminary answers to questions such as what design principles should be established for how proactive technologies are built and implemented in future homes and how can we develop a human-centered methodology for researching a technology that has not yet been fully implemented by industry or adopted into use. In our case, researchers with backgrounds in electronic engineering, sociology, the humanities, and industrial design collaborated in studying the multidimensional issues related to the changing user cultures and design challenges in the context of home technology development. Since our approach involved interventions within real homes (we introduced a prototype design of new home elements into existing home ecologies), our approach is in many ways similar to action research. In an early work, Robert N. Rapaport (1970, p. 499) claimed that *action research* “aims to contribute *both* to the practical concerns of people in an immediate problematic situation, and to the goals of social science by joint collaboration within a mutually acceptable ethical framework” (italics in the original).

There are numerous practical issues related to the approach we adopted that will be discussed below. In a wider perspective, however, our research was designed to combine all three key knowledge interests identified by Habermas (1968/2004) in his *Knowledge and Human Interests*:

- technological (providing solutions for new and innovative uses of the potentials of emerging technologies)
- hermeneutical (aiming at mutual understanding)
- critical (aiming at the disclosure of errors in our systems).

In our research, this wide coverage of interests was only achievable with the help of broad-based interdisciplinary collaboration. As a result, while experimental designs and technologies were innovated, social and cultural studies into the significance of home were conducted.

Our research project was titled “Living in Metamorphosis: Control and Awareness in a Proactive Home Environment” (“Morphome” for short), and it was devised and carried out in close collaboration among three Finnish universities: the University of Tampere, the Technical University of Tampere, and the University of Art and Design in Helsinki. The project’s original research question focused on investigating how distributed, nonintrusive technological access and input could be designed and implemented so that it facilitates adaptive control and awareness in a proactive home environment. But as the work progressed, we gradually moved into defining some key design principles for developing proactive technologies that we felt are appropriate for and acceptable in domestic environments by actual occupants, yet are also interesting in design research terms. The methodological challenge remained a constant concern as we approached the issue of engaging the human-centered research of future home technologies.

Some previous research offered models for the main alternative directions into studying smart homes (see Edwards & Grinter, 2001; Harper, 2003; Intille, 2002). The key issues relate to the role of control and how the human agency is being defined within the human–smart home relationship. Therefore, it’s important to define whether, in this heart of the home automation,

1. the user is in control, in which most tasks are consciously triggered;
2. the home (technology) is in control, in which most tasks are automatic;
3. learning models are applied, in which either the user is adapting to the principles of the environment or the environment learns from and adapts to the user.

It should be noted that all of these relationships are reciprocal, and highlight the symbiotic relationship humans have with their environments. Yet, we were not only following the line of study of “situated actions” (Suchman, 1987), but also were looking into technologically codetermined actions and relationships within situations in which the technology itself starts to exhibit adaptive, reactive, and proactive (“intelligent”) traits.

We will first discuss our methodology, and how it was implemented in the various phases of research. Then we present our derived results. Finally, we discuss the lessons learned from the entire 3-year research process.

THE INTERDISCIPLINARY METHODOLOGY

We have mentioned briefly the overall interdisciplinary character of our research, and how it intersects and combines the human sciences (hypermedia research), design research (industrial design), and personal electronics (research into information technology). Since the phenomenon of powerful and intelligent computing technologies cohabiting homes with human occupants is still mostly futuristic, our approach could not focus solely on a methodology that describes and analyzes existing user behavior. Still, the research group wanted to understand how the functioning of proactive or somehow autonomous technologies would be experienced and approached by informants as a part of their actual living environments. As a result, our research required implementation of some kind of prototype systems, at least up to the point where an experience of “intelligent-like” features would be achieved. In the design research field, this approach is called *experience prototyping*, which means researching the user’s reactions to representations that are devised to convey a sense of what it might be like to engage with future, not-yet-existing technologies, services or environments (Buchenau & Suri, 2000).

We posit our work at the cross-section of three perspectives, where practical, applied, and theoretical interests take the form of three intersecting viewpoints: technology-potential oriented, human-interest oriented, and design-research oriented. The research also was divisible into different phases or dimensions in terms of its application and implementation. Thus, the descriptive phase of a user study aimed to gather information that would help us define how our informants understand “home” in the first place, and what their relationship is to technology within the home. From an applied angle, the results of the user study then were used as background research to guide the design principles for use scenarios or prototypes that were created and tested in the subsequent phases of the research. We used both *scenario studies*, where possible use situations of proactive home technologies were illustrated for and discussed with our informants, and *prototype studies*, which required construction of functional implementations. The prototype studies consisted of research into technologies and design approaches suitable for researching proactive technologies in homes. We concluded the research process with another user study in which the user informants interacted within a home environment modified by our prototype design. The hermeneutic circle was closed with the analysis of the results from the prototype study that provided inspiration and data for new designs, prototypes, and user studies.

The data gathered in the user studies have been analyzed in a qualitative way. The aim has been to understand the diverse elements affecting people’s attitudes toward proactive

computing in home environments. It should be noted that the number of informants in prototype studies has varied in the different phases of research; there were 27 households in total participating in the research, but the number of households per single phase of study varied from 2 to 12. In terms of size, the participating households also had a great range, from a single person household, to families, to a commune of five adults living together, but not all persons in a household necessarily participated actively in the study. All informants were Finnish people, varying in age from preschool children to working people around 60 years old. Almost all of these different compositions of households were living in a specific block of flats in Tampere or Helsinki. The results from these descriptive user studies should not be read as giving statistical information about Finnish people's attitudes toward new domestic technologies. Rather they should be construed as the researchers' interpretations about the participants' adopted and, to some extent, unquestioned stances towards their homes as technological environments in the context of contemporary and forthcoming technologies.

The progress of the research and the different phases where the research methodology was implemented can be listed in the following steps:

1. formulating a pre-understanding of the issues, challenges, and concerns on the basis of earlier research and then defining the research questions
2. conducting the domestic probes study
3. formulating of the first design principles
4. implementing the first design experiment: the pillow study
5. revising the principles as drivers for design and technology implementation
6. implementing the design principles as scenarios of future homes and evaluating them within interviews with the study participants
7. implementing new technology and experience prototypes in two sequential studies, with the focus on light and sound
8. analyzing, drawing conclusions, and finalizing a revised set of design principles.

Each design phase also included its own internal phases of hypothesis setting, prototype design, implementation, testing, and revision of the hypothesis. One practical challenge in working with future technologies has been that such key terms as *proactive*, *ubiquitous* or *context-aware computing* are mostly intangible and unfamiliar to people not working with new computing technology; concretizing them was a challenging task. The scenarios and experience prototypes have served our project as tools, giving participants an illustrating or concrete idea about potential applications for the home environment in near future. These phases were also used as a means to get people accustomed to the ideas and potentials of novel technologies. Although the attitudes emerging from the scenario studies and prototype testing are not equal to living with proactive technology constantly, they do make people more aware of their existing domestic environments and the technologies already included. For instance, the existing devices, furniture, and other objects were considered in a new light when product concepts were brought into the home by means of scenarios and prototypes.

The participants remarked themselves that it is difficult to imagine living in a home surrounded by proactive technology. Most likely, this difficulty relates to the nature of the home as a place in which many habits are often carried out in a distracted or routine manner. Thus it can be challenging for people to assess the consequences of new technologies for domestic practices or way of living because these dwellers are not necessarily aware of their

everyday activities and the role of technology in them. However, scenario and prototypes studies can make domestic routines and the embedded or underlying values more visible when people must consider why they are willing to try one technology while unwilling to try another. Therefore, providing an illustrating idea or allowing personal experience of new technology not only works as an inspiration for discussions but also can enable people to become more aware of their domestic habits and chores.

Because the home is such a familiar and taken-for-granted environment, it can be beneficial to give people tools to enable them to see their own homes through new eyes. The prototypes can be used as a means to introduce something ambiguous or strange into the familiar everyday environment. Gaver, Dunne, & Pacenti (1999) consider *ambiguity* a resource for design that can be used to evoke personal and interpretative relationships with technologies. They describe ambiguity as a property of interpretative relationship between people and artifacts that require people to participate in making meaning. One idea is that such designs encourage people to question the presumptions they have about technological genres, but they also spur people to imagine how they might personally use and appropriate these artifacts and what their everyday lives would be like as a consequence. Bell, Blythe, & Sengers (2005) call a fairly similar approach *defamiliarization*. Defamiliarization was originally introduced as a literary technique utilized in design processes as a tool to call into question conventional interpretations of everyday objects. The aim is to outline those cultural, political, and familial assumptions that are often built into domestic technology designs that simultaneously constrain the design space. Thus, examining these assumptions can open new and more reflective directions in which to design (Bell et al., 2005). As applied in our studies, the aims of defamiliarization and ambiguity were to facilitate people's reflection on their perceptions that seem natural and self-evident within the context of domestic technologies.

People's discussions about their experiences in a modified home environment provides designers and researchers with the opportunity to consider the existing cultures of the home life and to develop new alternatives for domestic technology design. In our study, for example, the participants felt sometimes strange while testing the prototypes, such as the decibel lamps, because by changing the ecology of home in this way we made some aspects of domestic life more visible than before. The visualization of auditory information was a new experience that made the participants more aware of the soundscape of their homes, and its silent and loud moments. In the same vein, the gradually rising sounds of the singing bird used in the waking sequence of our final study made our informants conscious of what effect the typical sounds of alarm clocks had on their feelings during the waking process. It also got them to ideate alternative ways for waking in the morning or retiring in the evening.

Meanwhile, the adapted home lighting automation system increased the participants' awareness of movement in their homes. Especially in the beginning of the test period, the participants felt some of the features intrusive, such as the audible snaps coming from motion sensor switches. Lights reacting to movements made the dwellers prominently aware of others walking in the space or changing position while sitting on the sofa near to the test lamp. Just as the decibel lamps helped make the soundscape of the living environment more visible, so the lighting sensors drew attention to the usually unnoticed movements within the space.

STUDIES INTO HOME TECHNOLOGIES

The Domestic Probes Study

The starting point for the first research phase was the realization of how complex the social and material environments of homes really are. Each person perceives multiple private and public dimensions of significance in the home, with an increasingly complex network of meaningful relations overlaying that when several people inhabit and share the same space. As we were interested both in producing qualitative understanding about peoples' relationships to their homes and home technologies, as well as to produce qualitatively driven data that would also be suitable for inspiring our design research for concept exploration, we applied a design research approach called *cultural probes*. Originally created by Tony Dunne and Bill Gaver at the Royal College of Art (see Gaver et al., 1999), the cultural probes method facilitates user creativity through the philosophy and practice of codesign, rather than treating informants simply as sources for knowledge that only the researcher is able to derive. We devised a group of self-documentation tasks, materials, and the accompanying instructions adapted from the cultural probes method to provide our informants with a rich set of tools to explore meanings, values, and emotions that they relate to their home and the technologies it contains (see Figure 1). The probe packages were given to the participants when they were first contacted, at which time the contents of package were briefly introduced to them. After the participants had worked on their assignments using the provided camera



Figure 1. The domestic probes package included personal and shared workbooks, disposable cameras, drawing pens, glue, and animal stickers. Participants used these items to complete assignments to probe and concretize their personal and communal perspectives of their home environments and the various technologies contained there.

domestic technologies. Media technologies were perceived as authentic technologies while kitchen and bathroom appliances were regarded more as fittings of those rooms than as technology per se. This can be explained by the various presumptions and experiences that people associate with these technologies. Domestic appliances are often perceived as simple devices that one can use without effort or the study of manuals, even though many of them involve complex electronic and digital controls. People also expect that these stand-alone appliances do not crash easily (as do computing systems), and this reliability has enabled people to forget that these technologies are complex entities (Edwards & Grinter, 2001). Perhaps the most important thing, however, is that media technologies are perceived as status devices that tell about the technological standard of one's home. This relates also to the stereotypical notions about "white goods" (referring to most appliances) as feminine and "brown goods" (referring to most electronics) as masculine. As time-saving technologies related to domestic work and hygiene, white goods are typically associated with cleanliness, simplicity, transparency, and utility. Alternately, brown goods are for leisure and entertainment, and they seem to signify complexity, cleverness, opacity, and rich content (Cockburn & Ormrod, 1993, pp. 100-104).

Because of its elusiveness, a person's experience of the domestic atmosphere is challenging to study empirically (Pennartz, 1999). In our interviews, people frequently had no words for describing relevant elements of their domestic atmosphere, but the tasks of the probes package made the process easier to approach. By means of the probes kit, people could concretize and illustrate which aspects produced homeyness in their homes. Tasks also encouraged people to consider both the personal and familial significance of domestic technologies and their uses. Thus, the tasks illuminated shared and personal meanings within the domestic environment. Further, the probes made people question some taken-for-granted aspects of domestic life or technologies. In this respect, the probes together with the interviews opened up new ways for researchers not only to perceive the domestic technologies in the informants' existing contexts but also to ideate promising directions that proactive technology could take in order to support a cozy ambience and sociality within the home.

The Pillow Study

While the probes study was underway and the researchers' understanding of the homes was getting deeper and more multidimensional, the first prototype study phase was started. After establishing that technology use to enhance the sense of homeyness would be a key design goal, our team decided to experiment by introducing smart technology in the shape of a pillow. This was based on our analysis of pillows and cushions as intimate and personal elements, ubiquitous in homes, and, in their softness, also as things that appear to be situated at the opposite end of the mental spectrum of stereotypical conceptions of the high-tech home of the future (Mäyrä & Koskinen, 2005) that we were interested in challenging. Rather than stressful and hard, pillows are associated with comfort, relaxation, and softness. On the other hand, many traditional smart home concepts rely on the use of screens and other explicit interaction interfaces to facilitate the control of these complex environments. Based on our prestudy and probes investigation, the decision was made to take the design research into a direction that would explore ambient and tangible interfaces. Cushions and pillows were perfect objects from this perspective.

A simple technical prototype was implemented, which operated as an embedded context-aware interface. It consisted of a pillow fitted with hidden electronics: batteries, power supply, microcontroller, amplifier with voice input and output (loudspeaker) connected to a recording and playback circuit, and a serial (RS-232) transceiver. The last component was essential for the operation of a RFID (Radio Frequency Identification) connection that was used to provide the pillow with a crude means for sensing its surroundings. As soon as a RFID tag was within range of the reader, the embedded electronics emitted a prerecorded sound. The pillow was covered by fake animal fur, and the sounds it produced imitated animal sounds. This was related to the hypothesis that the limited sophistication level of the test system would be suited better by a perception of animal intelligence rather than by human intelligence, which the use of human voices for interaction would have suggested. The test users were provided with several things. First, they were given several beanbags with embedded RFID tags, each of which elicited a different sound associated with it from the reader when it was brought within range. A pillow with the embedded reader was also provided. The participants also received a loose set of instructions detailing various ways of interacting with the beanbags and pillow. And, finally, they were provided a video camera to record the run of events (see Figure 3). The pillow was field-tested with three families with children.

There were some technical issues in the testing that limited the sensitivity and range of RFID reader, and it was not possible to combine the different sounds as freely as was originally intended. Nevertheless, some basic interaction between the subjects and the prototype was possible. The main finding from the testing in real homes was that integrating interactions with smart home technologies can indeed be perceived with positive affect if they are embedded in familiar and soft home elements such as cushions or pillows.

The informants appeared quite creative in their uses and ideas for further development of such technologies. When interviewed, the child informants suggested uses where a smart pillow could become the “emotional companion” for the occupants of their home. Such an interface for a smart home could comfort its user and provide companionship and access to



Figure 3. A child informant uses a beanbag to experiment with the sounds that the pillow prototype makes.

house services as the occupant relaxes, hugs, or rests on the pillow while watching television or reading. In this concept, touch and sound, and the mere proximity of the pillow, provided rather natural and nonintrusive modalities for control in the shape of a pillow. The adult informants suggested that a proactive system, in general, should provide services as a secretary or manager, assisting the family members in the challenges of organizing their daily lives. For example, a future version of the pillow companion could make sounds to remind or motivate children to do their homework before their favorite television show starts, or even somehow communicate more complex messages, like alerting them when books are due to be returned to the library. Such typically messy everyday information management systems that consists of different reminders, notes, calendar markings and mobile phone calls could be simplified if a smart home could offer itself as a helpful companion for this kind of uses.

The First Iteration of Design Principles

After the probes and pillow studies, we had enough experience and information to formulate an initial set of proactive home technology design principles. These served as a basis for further research, as we pursued to implement them in scenario and prototype studies, and to collect feedback about them from our informants. The principles are presented in Table 1.

Following the creation of these principles, we determined two basic directions our research could have taken: focus on the interactions and cohabitation in a home augmented with

Table 1. The Design Principles for Proactive Home Technology (Mäyrä & Koskinen, 2005).

Main Principles	<ol style="list-style-type: none"> 1. <i>The principle of consistency.</i> If a function or element is delegated to be controlled by a proactive system, that function or element should demonstrate similar behaviors consistently. 2. <i>The principle of personalization.</i> Smart home technology should follow the “rules of the house,” reflecting practices and preferences adopted and followed by this particular individual or family within their private space.
Additional Principles	<ol style="list-style-type: none"> 3. <i>The principle of embedded media interface.</i> The main goal and task for proactive technologies in homes are providing filtering and control in negotiating the charged boundary between the home-as-shelter and the need for staying in contact with the world “out there.” 4. <i>The design principle of animism for advanced proactive functions and services.</i> The easiest and most natural way to interact with a proactive home would be to treat it as if it had some kind of persona or other social interface of its own. 5. <i>The principle of open-ended tangible designs.</i> Proactive services are joined with physical objects to afford multimodal, sensory-rich interactions, as well as to provide usable and aesthetically pleasing interactions for future homes.

strongly proactive technology, or follow the “weak” interpretation of proactivity. A strongly proactive home system operates in the background and completely without human awareness, combining input from various sensor systems, applying computation into the situation, and advancing from these into autonomous actions. As a human interface design research issue, this was not as interesting a case as the “weak” alternative, which is a bit closer to the situation of interactive computing. Here, the state and operations of smart technology need to be conveyed to the human occupant: The system will notify the user and offer alternatives, but the choice of accepting or cancelling actions remains with the occupant, rather than completely removing the user “from the loop.” Weak proactivity is not as efficient as its alternative if the primary consideration is reducing the users’ cognitive load. However, based on our interviews and other user studies, the human-supervised direction of smart home technologies was considered more acceptable and ethically sound than the totally unseen and autonomous operation of technologies in homes.

The design of weakly proactive home technologies is related to the research into “calm technology,” as approached from within the field of ubiquitous computing (see Weiser, 1993; Weiser & Brown, 1996). The challenge can also be phrased in terms of an ambient display of and access to information: The increasing computing power and complexity of distributed and networked smart components of a future home are counterbalanced by the design principle of the “disappearing computer,” an environment where collections of artifacts link together and provide new behaviors and functionalities to users while also supposedly easing the everyday life and demanding only peripheral awareness (see *The Disappearing Computer*, 2002-2003). The requirements, however, appear to be partly contradictory towards each other, at least in the current phase of development in technology and related user cultures.

A Scenario Study of Light and Sound

Light and sound were chosen as the focus areas for the second phase of our research, based on the users’ responses in our earlier probes, prototype, and scenario studies. In the scenario method, possible proactive home designs and applications were discussed with the help of illustrations that described various use situations in the future. Twelve households participated in the scenario study phase. One of scenarios presented a concept where the smart home would monitor the sound levels in the home and inform occupants, via changes in the home lighting, when the noise rises to a certain level. By increasing the inhabitants’ awareness of sound levels, the process also would guide them to change their behavior and lower the sound level (see Figure 4).

In this phase, a home technology system that takes actions related to the lighting and soundscape of home was perceived as a more easily acceptable way of implementing proactive behaviors than a scenario in which a system would try to infer human intentions or to provide, for example, entertainment suitable for the given situation. To some degree, this can be related to the reluctance or aversion of the subjects towards change in familiar and reassuring contexts. But equally important was the subjects’ general lack of confidence capacity in a computing system perceived as too limited to start making deductions about the human mind and intentions, particularly in complex and intimate social situations involving several people and their (sometimes conflicting) preferences. The assessment of our informants, based on previous experience, could be described as realistic.



Figure 4. An illustrated scene from a late night social, with the smart home providing sound level feedback via changing colors of a table lamp.

The Light and Sound Prototype Studies

Based on the results from the scenario study, the research group decided to experiment with home lighting as a potential field for an ambient interface design for smart homes. The first constructed prototype was a large standard lamp² (see Figure 5). The lamp was reconstructed around two pairs of 36W fluorescent tubes, each pair chosen from opposite color temperatures. The tubes were aligned in opposite internal corners to emit an even light when all tubes were lit. The fluorescent tubes were built with a dimming capacity and the on/off switch was operated by the microcontroller inside the lamp. In addition, multicolored light-emitting



Figure 5. The large lamp prototype in use in an informant's home.

diodes (LEDs) were installed in the interior. The fluorescent tubes and most of the electronics other than some control electronics visible at the top of the lamp were covered by the paper shade. This study involved testing in two households.

A light level sensor was installed on top of the lamp so the light output could be adjusted better to the changing light levels in the environment. When in use, the LEDs would light up simultaneously and in intensity directly proportional to the sensed sound level. The LEDs faded away within few seconds if further loud sounds were not measured. The microphone connected to the microcontroller at the top of the lamp prototype sensed the surrounding ambient and direct sounds, which the microcontroller then used to light the LEDs.

The concrete research question at this point was focused on the interface between the smart environment and its occupants. Our hypothesis was that a familiar design (the well-known lamp style) would ease the adoption of new technologies, while new functionalities related to light reacting to the sound level would promote new behaviors. In actual use, however, the sound-reacting behavior of the prototype proved so subtle that it did not provoke strong reactions or new behaviors among our informants. We realized that in order to derive interesting answers to our research questions, the prototype needed to have more diversity both in terms of its design and behavior. Still, this first-round lamp-shaped prototype had demonstrated that smart functionalities could be hidden in, or made more easily adaptable into, a regular home environment when embedded in familiar forms (Kuusela, Koskinen, Mäyrä, & Soronen, 2005).

After analyzing the users' experiences and lessons from the design of the first sound-level reactive lamp experiment, a new collection of lamp prototypes was designed and implemented. The design-related research questions were made easier to control and focus on by applying clearly distinct lamp designs while the basic behavior of sound levels causing lighting changes was kept the same. The four lamp designs (Figure 6) reacted to sound levels by changing the intensity and color of the light. These systems were installed in two homes in Tampere and one home in Helsinki. Each lamp stayed one week in each home, one lamp at a time. To collect informants' experiences and see how presuppositions changed with real contact with this kind of technology, the people were interviewed before and after the study.

In the earlier scenario study phase, most of the participants assumed that a sound-reacting lamp system's red color indicating the loudest sound level could be obtrusive because it would draw a lot of attention, and informants claimed that sometimes it would be impossible to avoid loud voices or noises at home. However, during the 4-week lamp-testing period, none of the informants perceived the red color as too obtrusive, even though the four prototypes differed in their design and intensity of light. In fact, some participants thought that if there are powerful voices at home, the lamp should come to the center of one's awareness and, in that sense, the red color worked well. Their point was that lamps remained in their usual role until, by becoming red, they effectively functioned as decibel meters for a while.

The lamp prototypes indicating an approximate volume level were interesting in the sense that they made invisible information visible. The participants told how surprised they were during the first test days when the lamps turned red when they were laughing or sneezing. Their expectation had been that the prototype would indicate only steady sound levels in the home, and its reaction to sudden loud voices was a surprise. However, as lighting artifacts, the prototypes became visible parts of the spatial order and technological ecology of the home and simultaneously operated as experience prototypes, providing the

participants with an idea how it feels when technology steers your attention to invisible sensorial issues. The role of domestic technology is often ambiguous because domestic appliances and media technologies dominate the domestic space. Yet their roles as aesthetic elements are not typically established in decoration magazines (Routarinne, 2005). Our lamp prototypes blurred the distinction between decoration and technology items: They were interpreted as both. Some participants considered the lamp prototypes primarily decorative elements while others perceived them more as decibel meters. The appearance and placement of the prototypes were felt much more important in one home whereas informants from another home focused mostly on the ways the prototypes reacted to different voices and noises. A playful attitude to interior decoration was prominent in the first case, whereas more conventional attitudes towards metering devices were central among the informants from the latter home. In any case, if the visual design of the lamp was felt pleasing, it also increased to some extent the participants' interest in the decibel measuring action.

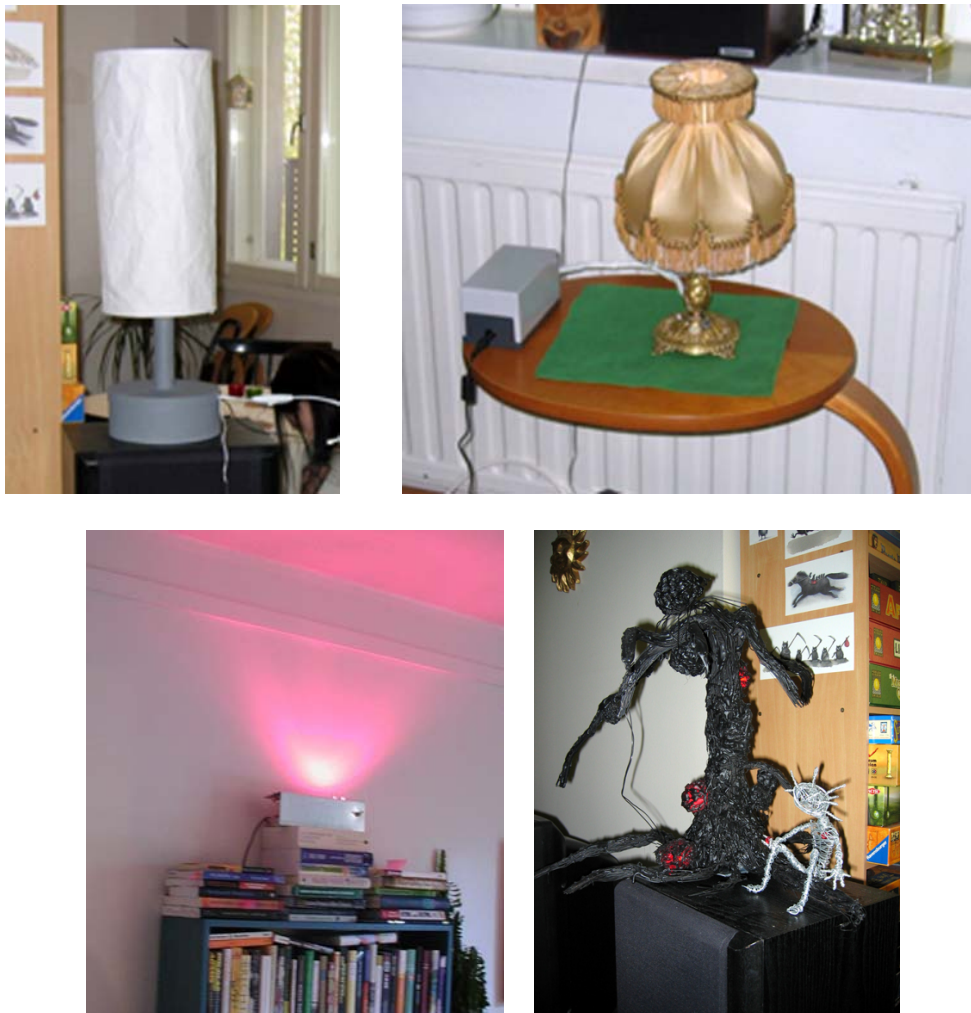


Figure 6. The four different sound-reacting lamp designs. Clockwise, from top left: “IKEA,” “Granny,” “Giger,” and “Glow.”

A young couple determined, already in the scenario phase, that they would like to use a decibel lamp system in their home and, after the testing period, this opinion strengthened. However, their results demonstrated that they would not take just any smart lamp, but only those fitting in their interior decor. For instance, they argued that the Granny version represents a dated style they do not want in their home. Although they felt the technology interesting, the visual design of this prototype made it inappropriate for their home. Reasons for disliking certain domestic technologies were diverse and people's mode of living, phases of life, and socio-historical backgrounds played a central role in their reasoning. Although there were some differences in preferences of style among household members, they all shared an opinion about the prototype they wanted least.

Ambient Home Automation Study

In trying to obtain actual user information about proactive home systems, we found that researching different ways of implementing smart home interfaces is not enough. We needed to set up a larger scale test environment, where real homes were augmented with sensors and programmable behaviors that would provide residents with an overall experience of what it means to be living in a proactive home environment. At the same time, numerous technological, resource, and even ethical constraints set limits on how strong and active a hold on people's lives our prototype system could have.

The key focus was on the acceptability of proactive technology in real homes, which was studied by providing our informants concrete and personal experiences of the functionality of a larger proactive system within their homes. Primarily we wanted to provide our informants with an example of how different devices could autonomously interact with each other in their homes, thereby highlighting proactivity as a feature of technology that acts on our behalf and anticipates our needs. We also wanted insight into how the experience of domestic space potentially changes with new ambient elements.

The starting point for implementation of this research phase was that it had to be able to be installed as straightforwardly as possible into real homes. We wanted to minimize the need to install new apparatuses in homes, so the idea was to use existing lighting and other devices that are familiar elements to the users. Also, the design of devices or their acceptability was not the focus of this phase; rather we emphasized the new functionalities and how they are perceived and accepted when combined with the familiar existing devices within the home. One effect of this decision was that it decreased the set of possible functions that could be used in the prototype. We chose only very basic tasks and functions for proactive augmentation, such as lighting control and the waking and retiring routines. Furthermore, all the devices had to be removed without a trace after the test, which presented the team with a further challenge in research design. Since all permanent mounting methods had to be rejected, we were forced to use a set of temporary mounting methods (such as suction cups and adhesive pads). The control interface (Figure 7) was designed to resemble a clock radio and thereby to fit easily in a bedroom. This study involved two households.

We chose a commercial home automation system known as X10³ to meet our requirements since it offers the possibility for using existing technology and for retrofitting some compulsory new devices. One advantage in the X10 is that it uses existing electrical power lines for communication between devices. However, the commercial software of X10



Figure 7. The control interface unit developed for the X10-based home automation prototype system. The unit was a black box, approximately the shape and size of a common clock radio, with several buttons and a LCD screen available for users to make changes to the morning and evening time presets of the home automation system.

appeared to be too rigid, so we replaced it with an open-source software called Misterhouse.⁴ By combining the X10 hardware with a PC, Misterhouse offered a simple user interface, as well as some basic means for programming and necessary object and method libraries (the key elements needed for object-oriented programming). The logic of events and functions were programmed with Perl.⁵

The basic functionalities of the system were lighting control and routines assisting in waking up and going to sleep. These were performed by adjusting the lighting levels of the home according to the time of day and motion sensor information. (See Figure 8 for an illustration of the setup.) In addition to light, ambient sound was used both in the morning and evening: the sound of birds singing in the morning, and the sound of the sea in the evening. Our philosophy for choosing sleep as the part of life subjected to proactive control was related to the fact that people already use sound and light as part of technologies for controlling their state of awareness and arousal, as the ubiquity of alarm clocks proves. The going-to-sleep sequence was the more experimental part of our setup, based on the premise that future home technology will adopt a more strongly proactive stance towards the health of users as well. The relaxing, ambient sounds and dimming lights that became activated when a preset “sleeping time” arrived were designed to have a double function: First, to signal the inhabitants that it is time now to go to bed and, second, to create a relaxing and sleep inducing effect in the atmosphere of the home.

The lighting of the home was adjusted according to motion sensor information. The time of day also affected the lights in the bathroom and hallway: In the daytime, the lamps operated at their maximum, but at night, the lamps could be brightened to only half of the maximum power. The purpose was to avoid the blinding effect that occurs when the user enters these areas from a dark bedroom.

On the basis of our earlier interviews, subjects emphasized the extreme importance that the atmosphere of a home be warm and homey. Finnish homes are often furnished with warm

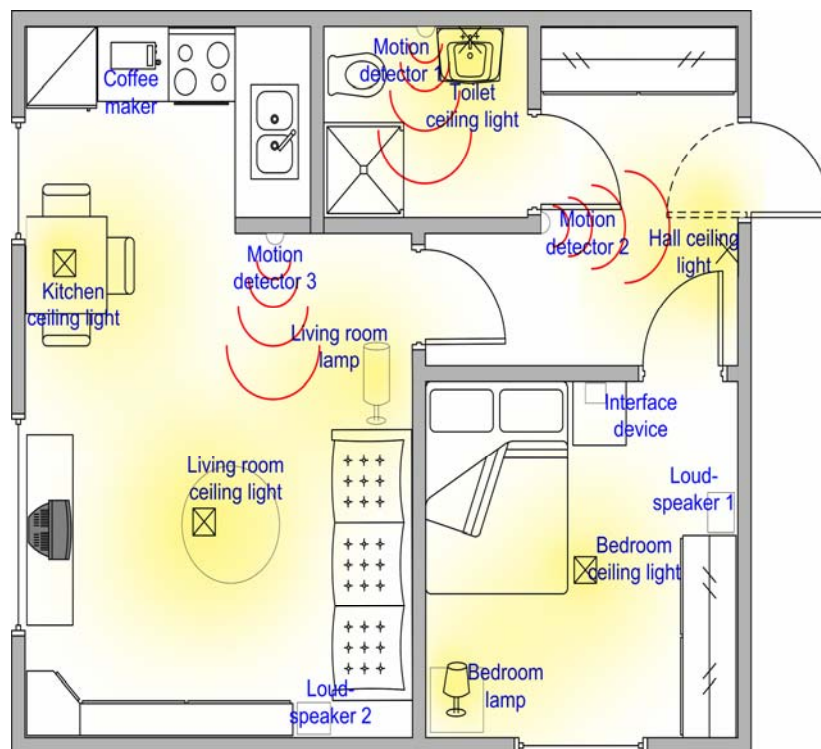


Figure 8. An imaginary floor plan showing the placement of devices attached to the proactive home system. The operational elements are named in the floor plan.

colors, soft textiles, and light wood furniture. Especially in the evenings or when people expect guests, they wish that the lighting of the home has a warm tone. In that sense, the home environment differs immensely from, for example, an office environment. When we think of the visions of smart home as popularized in the media and advertisement, the atmosphere is often pictured to be rather cold and centered on a hard technological, almost businesslike, element (see Jokinen & Leppänen, 2005). The visionary illustrations of smart homes are dominated by various electronic components enclosed in black or grey boxes, large displays, and gleaming glass surfaces. We see here a contradiction between the visions of smart home interiors presented to the public and the actual appearance of today's Finnish homes. In our research, we sought to challenge this stereotypical image of smart homes and to look into whether bringing new functionalities to the home necessarily means that the atmosphere of the home has to change. We believe that new devices can give the user the feeling that these technologies are designed and intended to be used precisely in common, everyday home environments. This is an important perspective because, in our study, the interviewees were not willing to compromise the cozy feeling in their homes. Therefore, this was and should be taken into account when designing novel devices and smart services for homes.

In the beginning of 1990s, Mark Weiser (1993) presented the idea of ubiquitous computing. It is unlikely that our informants were familiar with the principle, yet, the attempt to embed technology was well known among them. The interviewees expressed the wish to have technology only if it was implemented as embedded, unobtrusive devices, as is demonstrated by the following quote:

I definitely don't want here any evidence of those things that remind me about technology. Maybe then if they could be somehow hidden or so tiny that they would be out of my sight. (F, 33)

As pointed out in the interviews, the informants could accept technology more easily if it would follow the concepts of ubiquitous computing and calm technology. Because the idea of proactive computing suggests that people should be completely outside the control loop, the emphasis for designers and engineers should be to make such technology also embedded, ubiquitous, and calm. Screens and keyboard interfaces that are familiar from the world of interactive computing would multiply in homes, if they would also accompany the arrival of proactive home systems. In that sense, the requirements of calm, embedded computing should be met prior to developing proactive technologies into homes.

During the home automation study it became clear that reaching the optimum adjustment of lighting within the home environment was a much harder task than it seemed in planning. Even though the system already contained various regulations or adjustments in the bedroom, living room, and bathroom lighting, the actual controlling logic was not even close to the optimum when experienced by users in their living environment. These shortcomings of automation are due to numerous issues. For example, the distinctly different natures of various domestic spaces and rooms set varying requirements for lighting. In addition, the time of day, week, and year bring changes in the use of spaces and these would also need to be considered. Responding to such challenges, there are researchers like Mozer (1999) who consider that a smart home should always also be truly adaptive. Central to the concept of an adaptive home is that it observes the lifestyle of the inhabitants and adapts its operation to accommodate to their needs. In our study, the participants occasionally felt the need to manually override the inappropriate behaviors of lights that were controlled by the automation system. The X10 system comes with a remote control intended for such purposes, but the users felt that this was just another unnecessary layer of technology because their homes were relatively small to start with and they usually could locate a regular wall switch more easily than a remote control that would often go missing. Some participants stated a preference for a room-specific adjusting point (e.g., a small touch screen) on the wall that would enable control of all the lights of the room from one place. However, this would also add screens and visible control technologies in an undesirable manner.

It also became apparent that the optimal placement of the motion sensors and lamps is difficult to know without experimentation within the home environment. People are rarely conscious of their or others' movement within the domestic space and the use of motion sensors activating lamps, especially in small apartments, can make this movement or simple body repositioning annoyingly obvious. Further, homes can involve areas (e.g., a balcony) that people want to be kept free of electric light, opting to be in darkness or in natural light without external lighting switching on whenever that space is entered.

The participants regarded as a most surprising or exceptional feature of the experimental home system its ambient sounds and how these sounds affected their mood. They brought out that the bird sound slowly growing louder had a positive influence on the atmosphere during the mornings and made the moment of waking more smooth. However, one participant also noticed that the sound was almost too gentle for him, encouraging him to use the snooze function too many times. He felt that the waking sound would be more efficient if it would

include some sort of abrupt, irritating effect in the end. In regard to the retiring routine, some felt it annoying that they had to input the time for going to bed in advance, whereas others did not find any problem in it. The test setup also had the effect of imposing the same sleeping rhythm to all family members, which might have been experienced as a nuisance by some. In any case, the sounds were considered the elements that most changed the experience of the home during the test period.

As a method, the prototype testing in people's homes succeeded well in elucidating the user experiences, both in the case of the decibel lamps and the home automation system. Because the test period lasted at least one week, the prototypes started to become more or less a part of daily life and, in this sense, the experiences and attitudes towards them were not so much dictated by the first impression any more. We noticed that introducing a foreign element into a home interior helped make more visible the often elusive and ill-articulated dimensions of home life and domestic settings. Moreover, while living with the prototypes, some informants changed their views on smart technologies and concluded that intelligent home technologies in fact do not need to be something radically different from their contemporary homes. Even simple lamps equipped with motion sensors can provide new experiences that reframe what constitutes a smart home.

In general, one should note that the user-centered study of proactive computing has its challenges. First, setting up a larger scale proactive system for the home environment presents substantial technological challenges since no commercial solutions are available to support complex or adaptive functionalities. Second, making these designs user centered often requires users' involvement to the degree that it may appear contrary to the basic philosophy of proactive computing, which aims to get humans out of the loop (Tennenhouse, 2000). There are no patent solutions for these and other such challenges at the moment, and we need more research that presents and tests models of life with humans and technological agents coexisting and cooperating in various combinations.

Approaches to Smart Home Design

The results presented next were produced by analyzing simultaneously the scenario study's data about the smart home concept and the interviews conducted after the test of home automation prototype. The two households involved in the home automation study participated also in the scenario study that was conducted the year before. During this process, different responses emerged when these people discussed the functionalities of smart home systems first in theory and then assessed the acceptability and suitability of such systems for their own homes in practice. In the scenario study, the product concepts of proactive computing were represented as sketchy drawings illustrating use situations or functions of technology. Thus, those visual scenarios did not employ designated users or a linear narrative form. We presumed that this kind of open-ended and flexible implementation of the scenarios would enable people to better imagine uses of new applications in their own lives (Soronen & Kuusela, 2005).

The participants emphasized that they wanted to keep control of their domestic spaces regardless of the conveniences the new proactive technology would make available. This sense of control was related to their sufficient awareness of the functionalities of the proactive systems. The border between a sense of control and obtrusiveness seemed to be a

fine line, with the participants more highly valuing tranquility in their homes. In this sense, tranquility did not mean that it should be quiet at home but rather that the domestic space was represented as an area where one was able to be at one's leisure without worries about the technical infrastructure of the home. Tranquility was also related to a pleasing and well-planned interior decor. Although many participants liked the idea that domestic technology would be hidden under surfaces and inside furniture, some emphasized that they would not want to be reminded by the system's workings, that they were living in a home surrounded by invisible technologies. This concern was directed at the idea of the homedweller as the active participator or decision-maker in the smart home environment all the time (see also Jokinen & Leppänen, 2005). On the other hand, human-like features, such as a speech user interface, were typically felt as making the home system too active and simultaneously decreasing the dweller's control over the living environment.

As we expected, the participants were most wary of proactive technologies that make decisions on their behalf, primarily because they felt the possibility for misinterpretations was very high. Many participants emphasized that it is almost impossible that any computing technology would be able to presume their state of mind or the activity they want to do next (Soronen & Kuusela, 2005). The participants claimed that in order for these technologies to be acceptable, it should be possible to switch off the proactive system whenever needed or desired. They were also concerned about the accessibility of user support and help desk services after these systems have been introduced, large-scale, to the consumer market. Thus, the smart home was perceived as a rather big computer affecting the home rather than a place where one could live. Frustrations and problems they had encountered previously in the PC world evoked doubts that the home would work any better than a typical computer. In summary, this common view holds that the smart home is regarded as an unstable and obtrusive technology that one cannot trust in and control, feelings they currently do not have in a home free of smart technologies.

This view of smart homes could be related to the implicit notion that the interior of a smart home has a specific appearance. A few participants referred to the popular conception of the smart home full of flashing lights, small screens, and an interactive wall. A common notion of the smart home as an environment that looks futuristic, ascetic, cold, and too technical (see Leppänen, 2001) leads easily to the presumption that one cannot organize and freely change the domestic order because of the embedded computing technology. The approach was based on the idea that a smart home cannot look nice and be cozy, and that the technology inside a home constrains the interior decor. In this sense, the smart home technologies are perceived as the opposite of coziness, which is expressed by a particular look and feel of furnishings, color schemes, textures, and their physical comfort (see Garvey, 2003). This approach was seldom mentioned explicitly although some participants said that it is difficult to imagine invisible smart technologies embedded within the furniture and surfaces similar to those in their contemporary domestic environment.

Somehow... I think the home is just for the human, and to me this means that there are perhaps some candlelight and wooden materials, and softness [...]. But of course it can be that my notion [of technology] is a little bit stereotypical because apparently the technology doesn't have to look as hard and glossy and steel-like. It can probably be something else also. (F, 33)

Thus, people presupposed that the functionality of smart technology embedded within the domestic environment is in some way reflected in the appearance of the home interior. Usually this meant that the smart home was conceived with features that are familiar to people from current media technologies. From a design perspective there appears to be a substantial challenge in how to communicate to the users of smart homes the fact that familiar domestic objects (sofas, pillows, tables, walls, floors, etc.) have some new, technology-induced affordances and control functions (Kuusela et al., 2005).

Another common attitude among the participants was that a smart home would make life easier. Most of the participants claimed a willingness to live in homes that facilitate or automate some predefined chores or routines. For instance, waking was seen as a fairly regular routine during the weekdays, and was seen as a process that could be automated more. In the scenario interviews, almost every participant hoped for a system that could increase light gradually, simultaneously playing pleasant music (replacing the now common beep of an alarm clock), and that would have coffee or tea ready for them by the time they are awake. However, differences emerged when the informants started to assess whether or not the curtains should open automatically before or during the waking period. From these comments, we can see the smart home technologies were regarded as making some dull routines more pleasant while increasing the flexibility of information and communication technologies around the house. An underlying idea was that smart home technologies enable enjoyment and conveniences that facilitate domestic life. This approach also involved the evaluation of the smart home as something luxurious, an unreachable fantasy that is nice to dream about but impossible to obtain for most people.

One negative association that informants attached to the smart home was the belief that it could make people lazier. Some of the participants remarked that smart home technologies can lead to people's increasing helplessness by weakening their memory, thinking, and other faculties that are related to actions carried out while at home. They assumed that smart home technologies would involve many automated functions that would make decisions on behalf of the occupants or remind them about things they should do next, and all this would change negatively how the home environment currently encourages human initiative, reflection, and action and, in other words, make the people lazy. This line of thinking was based on an idea that when people become used to life surrounded by smart home technologies, their functional modes and mental capacities will become reduced. It should be noted that this view can be linked to the concept of technological determinism (Chandler, 1995), which suggests that technology inevitably influences humans, because people will adjust themselves to the new features and behaviors suggested by smart technology.

These above-mentioned approaches to smart homes emerged from almost every interview conducted during scenario and home automation study phases. They could be read as commonly recognizable conceptions that contemporary Finnish people interested in new technology used explicitly or implicitly as associated with the smart home. It was typical that the participants brought out both negative and positive sides of a smart home. Although all of these attitudes were identifiable in the informants' conversations, it did not mean that they always agreed upon all of the points included in the discussion above. Some participants brought out particular situations and exceptions that questioned the dominant perception. They also wanted to stress that the effects of new technology are often complex and some generally shared notions concerning forthcoming technology can change after personal experience.

If people adopt and purchase proactive domestic technologies, it is evident that it will change their domestic lives. But it is equally likely that people will modify the technologies, domesticating them into their homes and innovating new uses for them. Commonly, the smart home is understood as a mixed-use environment in which residents still have some visible terminal devices. When discussed from the perspectives of calm and embedded technology, which means that computing resources are distributed and hidden in microprocessors within domestic appliances and furniture, the idea of a smart home seems to be more easily accepted among users. They are, after all, already living with numerous, ever-increasing variations of home electronics, and can tolerate their presence to a certain degree. However, people also have pieces of furniture that they want kept free of any embedded technology. For example, some participants mentioned rustic style furniture or antiques as artifacts that they would not want spoiled with embedded computing technology. The invisibility of electronics, in itself, does not make the home environment calm if issues such as furnishing preferences, household compositions, or social use contexts are not sufficiently considered.

THE MAIN FINDINGS: FACING THE CHALLENGES OF PROACTIVE TECHNOLOGY IN HOMES

The methodology of this research already has provided beneficial lessons: Setting the home as the context for research and maintaining a long-term contact with the informants through various iterations of research create fruitful environments for interdisciplinary research and innovation. On the other hand, the selected methods required substantial researcher resources and a wide combination of competencies, as it involved work at the theoretical, methodological, and implementation levels that draw together the strengths of the human sciences, art and design studies, and technology research. The initial set of proactive technology design principles (see Table 1) still appear as valid conclusions, even as we must emphasize that there are common design principles for furniture and other home elements that need to be taken into account, not the least of which is that proactive homes would continue to function in their traditional residential roles. However, the results highlight further challenges that proactive technology faces when being implemented in homes.

One of the general findings of our research is that the home is a sensitive environment where people often hold rather conservative attitudes towards smart technologies. This can be partly explained by the visions of the smart home technologies in the media and popular culture. The idea of smart home typically is associated with a futuristic and ascetic interior in which display walls and other very visible technical elements dominate the space. Because of that image, it is difficult for many people to imagine smart home technologies that are not intrusive and, to some extent, invisibly embedded within the home interior, changing the look of their contemporary homes in only minor ways.

On the other hand, people's notions regarding their awareness of a proactive technology's functionality are typically contradictory: Once they have accepted that functionality, they want to maintain full control of their domestic space while simultaneously not wanting to be aware of the constant sensing and gauging actions of the system. In order to increase a sense of control, the system should offer its users some sort of log files for checking what it has done, as well as alternative setup options and installations if users are not satisfied with existing ones.

Another important finding is that when access to and interfaces for the advanced and internally complex technologies are provided via familiar, comfortable, and reassuring designs, the social acceptability and usability of the technologies in a home context are clearly enhanced. Therefore, domestic technologies with diverse designs must be offered because decor preferences vary. When embedded computing in furniture becomes more common, both the design of the furnishings and the usability of the technologies will be key factors in domestic acceptability.

One promising research direction that may lead to successful integration of smart technologies in homes is that of animistic decor elements, meaning an approach into future home design where cushions or other soft and familiar home objects are seemingly “brought to life” and given some degree of personality through technological means. As technological systems continue to develop in complexity and start displaying their own initiative and decision-making potential, it is very important to enhance their social and psychological acceptability. There is a long tradition of dystopian fictional stories that display the ambivalence and distrust many humans hold towards intelligent machines (Mäyrä, 1999, p. 209). The simple interactions with a smart pillow or other familiar home elements embedded with technologies may offer a necessary counterbalance towards these initial fears or lack of trust.

Our research appears to demonstrate that the control of lighting and sound with motion or sound level sensors is mostly acceptable, as long as people retain a sense of control over the behavior of technologies in their living environment, in our case via traditional backup interfaces. However, differences in interior spaces and household compositions should always be taken into account when devising functions that are activated by various sensors. For example, in small homes with more than one dweller, lights based on motion sensors can be perceived as obtrusive if they switch on and off too often. Therefore it is beneficial to think carefully about where to place such light functionality and to always test the appropriateness of the locations of sensors and lamps before installing them. Introducing sound sensors to the living environment was also faced with a mixed response. For example, while many families living in apartment buildings liked the idea of having visible information about the sound level of their environment, other families considered sound level information unnecessary and questioned the whole idea of integrating a decibel meter and a table lamp. Of course, there might be much more capable proactive home technologies available in the future to address this area, such as proactive noise cancellation systems. Such developments, again, need their own user-centered studies before they are commercially introduced.

CONCLUSION: RESEARCHING FOR THE FUTURE

The role of smart technology is unlikely to stop its advancement in homes. We believe that as future generations of homeowners become increasingly technologically savvy, they are likely to welcome additional functionalities into their homes. Still, our research uncovered substantial resistance towards smart homes. Our subjects voiced concern about the potentiality of their homes no longer being sites of relaxation and shelter from the world, but rather becoming increasingly complex, needing endless updates, and facing periodic malfunction, causing increasing unreliability and user stress associated with information

technologies. Therefore, the technologically robust, fail-safe, and nonintrusive character of smart home technologies is a key priority.

We also found that some functionalities in homes are currently more feasible for proactive implementation than others. For example, ambient elements, such as air conditioning, heating, security, and, to a certain extent, lighting and ambient sound, are features that inhabitants have a rather low threshold for delegating to proactive technology's control. However, our informants were skeptical about the potential of smart technology taking a strongly proactive, intention-anticipating role in their personal lives. When a particular real-life situation needs to be interpreted and reacted to in a correct way, even knowledgeable humans such as family members sometimes have problems in deducing the right way to act. Misunderstandings are a common part of human life. Whether people would indeed be able to accept such applications if the technologies actually were accurate in their predictive operations remains for future research to solve. Using a team of professionals operating a specifically rigged house remotely and covertly would be a "Wizard of Oz" approach (Gould, Conti, & Hovanyecz, 1982) into studying human-level intelligence as experienced in a proactive home setting prototype. But this kind of research, of course, would include its own considerable challenges.

The main derived lessons for research practice focus particularly on the necessity of interdisciplinary collaboration and multiple methodologies if changes to and developments in technologies are investigated. A study that utilizes only interviews as its method, for example, and tries to deduce some conclusions about the acceptability of future technologies from informants who have experienced only current technologies is inherently unreliable. The preconceptions of the subjects and various popular ideas will have a dominating effect on results of such a study. But if human science researchers, designers, and engineers work together to realize some concrete experiences of such future technologies for users, and the users have enough time to live with these technologies and thereby domesticate the prototypes as parts of their lives, then the results will have much more relevance for all parties involved. (For a fuller explanation of the domestication of technology, see Pantzar, 1996, and Silverstone & Hirsh, 1992.)

The subject of proactive technology has proved to be a complex and controversial issue to study. Methodologically, it was challenging to investigate because the phenomena needed are indisputably intelligent services that would be able to deduce human needs and intentions and thereby genuinely anticipate and take action in a proactive manner on our behalf. Yet, most of these intelligent services remain beyond the capabilities of current state-of-the-art information technologies. Rather than attempting to implement such high-powered computational systems, the research goal here was focused on the human interface and coexistence of humans and "living" technologies in the context of real homes. Embedded processors, sensors, and network capabilities were applied to everyday objects such as pillows, lamps, and alarm clocks in order to learn more about the acceptability of various smart functionalities, the relation between design and technology within a home context, and about the applicability of our methodology. From a research angle, the results appear promising, and apparent benefits are to be gained by involving real users in the different stages of a research process, both as informants and codesigners, by inviting and eliciting their ideas for the potential applications of emerging technologies. The combination of cultural probes, scenario studies, minidesigns, and implemented prototype systems provided the

interdisciplinary research team with a suitably wide set of tools from which to derive rich data and to build the basis for knowledge and theory formation.

For a developer or designer of smart technology, the lessons of this research particularly focus on the proactive home technology design principles and their underlying case studies that we have created during our research. It would be most welcome to see examples of industry approaches where the users' key priority of "feeling homey" that we have reported here are implemented as the driving principle for smart home designs. A different kind of finding is derived from a more action-research-oriented angle. As the informants became more familiar with the opportunities offered by contemporary home technology during their participation, one family actually decided to purchase and install a home automation system. Thus, in at least one case, the participation in research led to changes in informants' lives. In more general terms, the increasing speed of the development and complexity of home automation and electronics has raised an apparent need for a "home technology consultant," who would help people to make informed decisions, based on their unique needs, about which technologies would be genuinely valuable in their case.

There is also a level of "techno-politics" that can be derived from this research, which concerns most directly the decision and policy makers. Contemporary citizens are in sharply unequal situations concerning the marketing and availability of home automation and proactive technologies. The possibility exists that, without public discussion and proactive measures by means of recommendations or even regulations, there might be developments that are either unethical or provide various groups in society unequal opportunities for taking advantage of technology's benefits. There has been active interest and encouragement from public research policies towards technical and commercial exploitation of opportunities opened up by ambient intelligence and advanced computer systems. Our research points out how important it is to listen to actual users, both on the technological and regulatory levels, regarding the development of new technology, and involve them when deciding on the directions and uses of these technologies for the future. The consequences, after all, are going to influence everyone in the society.

ENDNOTES

1. Quotations are cited with the informant's gender and age. All interviews were conducted in Finnish with native-speaking Finns. Informants' quotes have been translated into English by the authors.
2. The lamp is a model from IKEA, an international chain of home furnishings.
3. X10 home page (2006). Downloaded August 24, 2006, from <http://www.x10.com>.
4. MisterHouse home page (2006). Downloaded August 24, 2006, from <http://www.misterhouse.net>.
5. Perl is a programming language that has become particularly popular in implementations of different Internet services; see <http://www.perl.org/about.html>.

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EVALUATIONS OF AN EXPERIENTIAL GAMING MODEL

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Abstract: *This paper examines the experiences of players of a problem-solving game. The main purpose of the paper is to validate the flow antecedents included in an experiential gaming model and to study their influence on the flow experience. Additionally, the study aims to operationalize the flow construct in a game context and to start a scale development process for assessing the experience of flow in game settings. Results indicated that the flow antecedents studied—challenges matched to a player's skill level, clear goals, unambiguous feedback, a sense of control, and playability—should be considered in game design because they contribute to the flow experience. Furthermore, the indicators of the actual flow experience were distinguished.*

Keywords: *flow experience, educational games, game design, engagement.*

INTRODUCTION

Computer games are a quite new form of media (Salonius-Pasternak & Gelfond, 2005), but today they have already established themselves as an everyday phenomenon. In addition to providing entertainment and diversion, games satisfy the basic requirements of learning environments that have been identified by Norman (1993) and can provide an engaging environment for learning as well. Unfortunately, educational games have been used primarily as tools for supporting the practice of factual information learning. In fact, it can be argued that most educational games too often resemble digital exercise books and do not utilize the power of games as interactive context-free media. The reason for this may be that the field of educational technology lacks research on how to design game environments that foster knowledge construction and deepen understanding (Moreno & Mayer, 2005) and problem-solving while engaging and entertaining the user at the same time.

However, Kiili (2005a) proposed an experiential gaming model that may end this trend since it helps designers to understand the learning mechanism in games by integrating

pedagogical elements into the design process and distinguishes the factors that make game playing enjoyable. The flow theory is emphasized as a design principle because it provides a universal model of enjoyment, detailing the common aspects of the process that takes place when anyone experiences enjoyment. Kiili (2005b) evaluated the experiential gaming model through the IT-Emperor game, which was employed in a usability course. Kiili (2005c) revised the experiential gaming model to better address the needs of educational game designers. The revised version of the model is illustrated in Figure 1.

The experiential gaming model can be used to design and study educational games and gaming in general. It consists of a gaming cycle and a design cycle. The gaming cycle provides a description of the gaming process and the learning process in games. It aims to focus the efforts of designers toward enhancing the most important factors that influence the gaming experience and learning with games. Meanwhile, the design cycle describes the main phases of game design and works as a guideline in the design process. The design process is presented abstractly because it may vary among the different game genres. The model emphasizes the importance of considering several flow antecedents in educational game design: challenges matched to the skill level of a player, clear goals, unambiguous feedback, a sense of control, playability, gamefulness, focused attention, and a frame story. The ambition of designing the sort of games that enhance experiencing flow is justifiable because previous research indicates

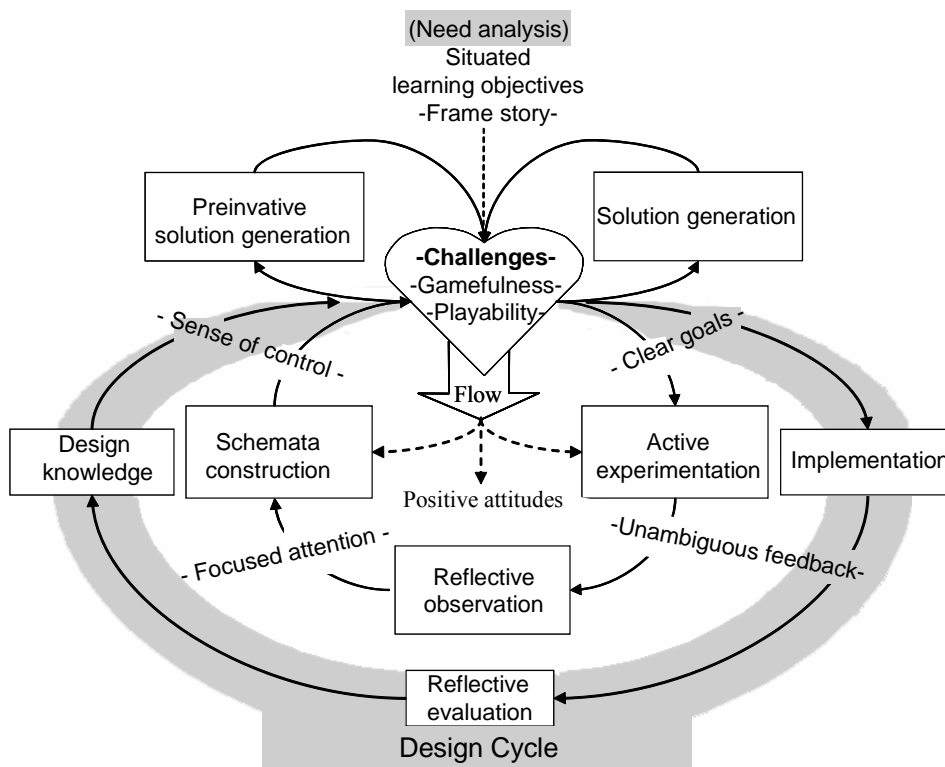


Figure 1. The experiential gaming model developed to bridge the gap between game design and pedagogy. (A fuller description is provided in Kiili, 2005c).

that flow has a positive impact on learning, exploratory behavior, and the attitudes of players (Ghani, 1991; Kiili, 2005b; Skadberg & Kimmel, 2004; Webster, Trevino & Ryan, 1993). A more detailed description of the model is provided in Kiili (2005c).

In this paper, the usefulness of the experiential gaming model is studied through a problem-solving game. Two main goals can be distinguished. The first goal is to validate the main flow antecedents included in the experiential gaming model and to study their influence on the flow experience. Second, this study aims to operationalize the flow construct in a game context and to start a scale development process for assessing the flow experience in game settings. Although Csikszentmihalyi (1991) defined flow as a multidimensional construct consisting of nine dimensions, he relied primarily on the challenge–skill balance to measure flow (Jackson & Eklund, 2002), which is not an adequate measurement method alone. Thus, this paper focuses on developing a flow scale that takes all relevant flow dimensions into account. This paper begins with a brief discussion of the flow experience and the methodology used to measure flow before turning to the evaluations of the experiential gaming model.

FLOW EXPERIENCE

Flow describes a state of complete absorption or engagement in an activity and refers to the optimal experience (Csikszentmihalyi, 1991; Ghani & Deshpande, 1994). During the optimal experience, a person is in a psychological state where he/she is so involved with the goal-driven activity that nothing else seems to matter. Csikszentmihalyi (1991) defined the phenomena of flow state as having nine dimensions. The first five dimensions can be considered flow antecedents and the rest indicators of flow experience (Kiili, 2005c).

1) *Challenge–skill balance*. When experiencing flow, a person perceives a balance between the challenges of the activity and his or her skills, with both operating at a personally high level (Jackson & Marsh, 1996). In the other words, a person's skill is at just the right level to cope with the situational demands.

2) *Action–awareness merging*. The flow state is so involving that, during it, activity becomes spontaneous and automatic. This dimension is problematic from the point of view of educational games because the ultimate aim of educational games is to support knowledge construction, which requires cognitive processing (Kolb, 1984; Winn, 2004). Thus, in this context, the action–awareness dimension should be applied to the playability of the game rather than to the entire gaming activity. Pilke's (2004) argument that the goal of flow-inducing interface design is to design good usability and vice versa supports this view.

3) *Goals of an activity*. The goals should be clearly defined in order to be able to achieve flow (Novak, Hoffman, & Duhachek, 2003). However, the goals of some activities cannot be always clear, as in the case of creative activities. Still, a person can develop a strong personal sense of what he/she intends to do.

4) *Unambiguous feedback*. Unambiguous feedback is related to the goal dimension because it allows a person to know how he/she is succeeding in a specific goal. A reasonable feedback system is easier to develop if the main goal is divided to subgoals.

5) *Control*. A sense of control is experienced without the person actively trying to exert it. Csikszentmihalyi (1991) has stated that this is more a sense of the possibility of control

rather than the actuality of having control. A person senses when he/she can develop skills sufficient enough to reduce the margin of error to close to zero, which makes the experience enjoyable. According to Ghani and Deshpande (1994), this sense of control is one of the most important flow antecedents in games.

6) *Concentration*. Concentration on the task at hand is the most frequently expressed flow dimension (Csikszentmihalyi, 1991). While in flow, a person concentrates totally on the activity and is able to forget all unpleasant things beyond the game. Because flow-inducing activities require a complete focusing of attention on the task at hand, the person has no cognitive resources left for irrelevant information processing.

7) *Loss of self-consciousness*. The self disappears from one's awareness during flow because when a person is thoroughly engrossed with an activity, few cognitive resources are available to allow the person to consider either the past or the future. In other words, flow allows no mental room for self-scrutiny (Csikszentmihalyi, 1991).

8) *The transformation of time*. According to Csikszentmihalyi (1991), the sense of time during the flow experience tends to bear little relation to the actual passage of time as measured by the absolute convention of a clock. Time seems either to "fly" or to "drag." Csikszentmihalyi (1991) argued that losing track of the clock is not a major antecedent of flow and it may be just a by-product of the intense concentration required for the activity at hand.

9) *Autotelic experience*. Autotelic experience refers to an activity that is "done, not with the expectation of some future benefit, but simply because the doing itself is the reward" (Csikszentmihalyi, 1991, p. 67). According to Kiili (2005c), this is the most important final result of flow in educational gaming: Students undertake studying activities not necessarily with the expectation of some external future benefit, but simply because playing the game is enjoyable, a reward in itself. This nature of the flow experience supports the ideology of life-long learning and is a priceless goal in education.

Whenever people reflect on their flow experiences, they mention some and often all of these characteristics (Csikszentmihalyi, 1991). The combination of these elements causes a sense of deep enjoyment that is so rewarding that people feel it's worthwhile to expend a great deal of energy to experience it.

Measuring Flow Experience

Flow has been studied in previous research using several methods. These methods can be divided into two main approaches.

1. The activity–measurement method begins with involving participants in a selected activity. Afterward, participants evaluate their experience either through an interview or by completing a survey instrument (Ghani & Deshpande, 1994; Pilke, 2004; Skadberg & Kimmel, 2004; Webster et al., 1993).
2. The Experience Sampling Method (ESM) gathers information during certain activities. Participants are interrupted for a short period throughout the day activity to evaluate their experience with a survey instrument (Csikszentmihalyi, Larson & Prescott, 1977; Csikszentmihalyi & LeFevre, 1989; Csikszentmihalyi & Nakamura, 1989; Havitz & Mannell, 2005).

In spite of some criticism, both approaches have been successfully utilized in flow studies. An important question in the first approach is whether the respondents can reliably evaluate

flow after, rather than during, an activity. On the other hand, the ESM can be criticized for interrupting a participant's experiences and normal behavior, which may decrease the ecological validity of the study (Loomis & Blascovich, 1999). However, it is apparent that different activities and contexts require different methods for use. Although the ESM provides continuous information about the experiences of the participants during an activity, it is not the appropriate approach for short experiments like the small problem-solving games utilized in this study. For that reason, the first method was selected in this study. The most significant challenge for this study was to operationalize the flow experience appropriately.

Operationalization of the Flow Experience

For the past two decades, researchers have strived to understand how the flow model fits the experiences of people (Voelkl & Ellis, 1998). The nine dimensions of flow outlined by Csikszentmihalyi (1991) have been used as a framework to operationalize flow in various contexts. In spite of that, most of the formed operationalizations of flow branch off quite distinctively from one another. For example, Ghani and Deshpande (1994) used a 15-item scale measuring only the dimensions of enjoyment, concentration, challenge, control and exploratory use. Exploratory use refers to amount of experimentation with tools available. On the other hand, Webster et al. (1993) studied the experiences of an accounting firm's employees who attended a course with a 12-item flow scale measuring the amount of control, focused attention, curiosity, and intrinsic interest they experienced. In sport and physical activity settings, flow experience has been assessed using the Flow State Scale (FSS) questionnaire developed by Jackson and Marsh (1996). This 36-item instrument provides scales of all nine dimensions of flow outlined by Csikszentmihalyi (1991). Internal consistency estimates for the nine FSS scales were reported to be reasonable.

Although the operationalizations of flow diverge from one another, almost all flow measuring instruments include the challenge–skill dimension that has been argued to be the most important flow antecedent (Csikszentmihalyi, 1991). However, Chen, Wigand, and Nilan (1999) have argued that researchers studying the flow phenomenon in a Web environment too often operationalize the perceived challenge too generally. Researchers tend to ignore the original concept of flow as a construct that induces human beings to grow in the sense of fulfilling potentialities and going beyond those limits (Csikszentmihalyi, 1975). Thus, it is not reasonable to assume that we can develop digital environments where users experience flow throughout the entire time they are interacting with or in the virtual environment. In fact, the states of anxiousness and frustration should be understood more as the triggers or driving forces that motivates a user to strive for the flow state rather than as a plague that should be eliminated entirely.

Another important question is how valid users' evaluations of perceived challenge are. In fact, Chen et al. (1999) found in their study that a great number of the participants were confused with the questions measuring challenge. These results indicate that the ways of measuring the skill–challenge balance should be studied more exhaustively.

In spite of efforts to operationalize flow in different contexts, several researchers maintain that much work remains to be done in the operationalization of the key concepts of flow before valid empirical research can be conducted (Chen et al., 1999; Novak, Hoffman,

& Yung, 2000). One aspect that should be considered, in particular, is the partition of flow dimensions into flow antecedents and the flow state. It can be argued that it is not always appropriate to blindly use all nine dimensions of flow before considering the aims of one's study. Is the aim to study the flow state or the factors contributing to the flow experience? In this paper, both flow antecedents and the flow state are studied. The flow dimensions are divided to antecedents and flow state according to previous research (Kiili, 2005c).

METHOD

Participants

Participants ($N = 221$) were recruited by e-mail from university students and staff and their families. The gender breakdown was 56% males and 44% females. The ages of participants were distributed as follows: 9% were over 30 years old, 72% were 21–30 years old, 14% were 16–20 years old, and the rest were 11–15 years old. Fifty percent of the participants played digital games almost daily, 22% played once a week, and the rest played rarely or not at all. All were native speakers of Finnish.

Materials

The game used in this study was based on a Japanese crossword, which is a puzzle also known as nonogram, griddler, and paint-by-numbers. The puzzle genre was selected for this study because solving mental puzzles is one of the oldest forms of enjoyable activities (Csikszentmihalyi, 1991). Generally, the aim in Japanese crossword is to solve the image encrypted with numbers. The numbers are clues that can be interpreted by using logical deduction in order to color the correct squares of the grid. As Figure 2 shows, clue numbers are located at the left and top of the grid. Each number indicates the number of contiguous cells to be colored (length of the filled block). The blocks of cells to be colored are arranged from left to right and from top to bottom according to clues. At least one empty cell must exist between the filled blocks.

The experiential gaming model's design phase was utilized to extend the traditional Japanese crossword into a new game called Day Off. The crossword was embedded within a story line that gives meaning to the puzzle to be solved. The actual game space consisted of 15 columns and 9 rows (Figure 2). The image to be revealed was the Finnish steamship *Piiparinen*.

The game, which was conducted in Finnish, starts with an introduction implemented as an animation that describes the ordinary world of the main character (hero), who is a professional chess player. He has just won the world championship title in chess and is enjoying his vacation by fishing in a national park. Suddenly military troops kidnap him and transport him to their base. The hero is compelled to help military officers solve an encrypted message that contains information about the location of a bomb that terrorists have primed to go off in 20 minutes. The hero hesitates but decides to cooperate because the officers inform him that his son is working in the very harbor where the bomb is located.

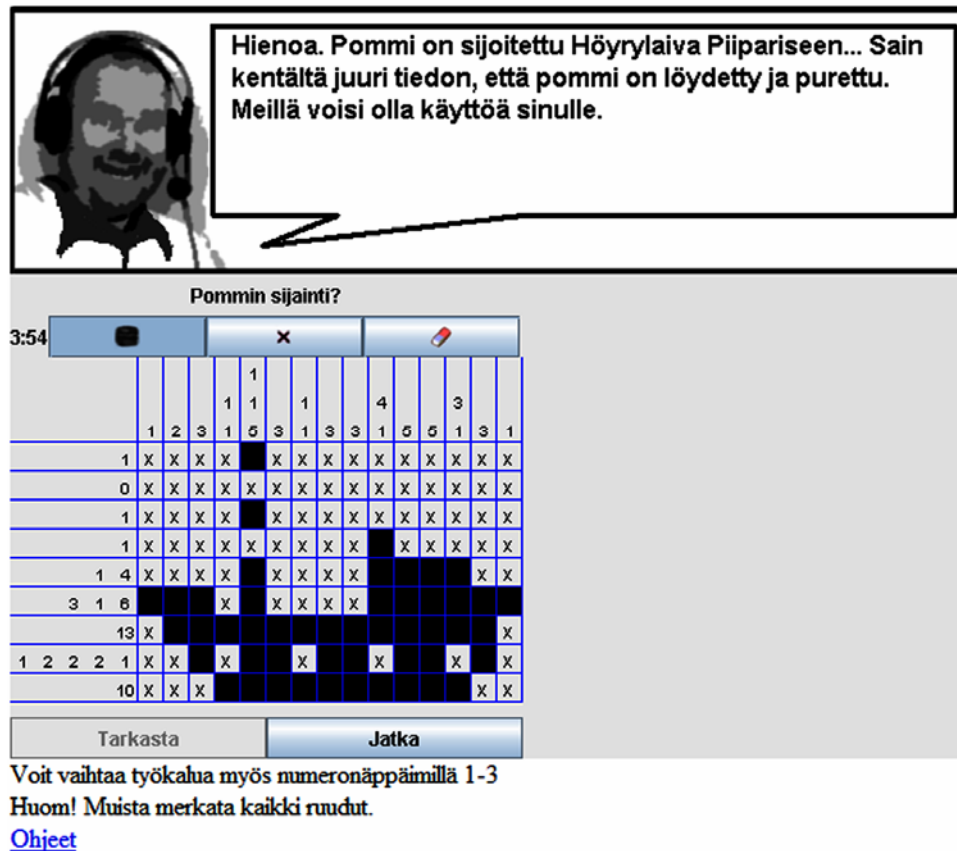


Figure 2. A screenshot of the solved game. (Agent Bob informs that the bomb has been found and disposed of.)

The aim of this scene-setter is to explain the events that have happened to the hero to this point and establish the context for what is going to happen. More importantly, however, the introduction tries to make the player identify with the hero's desperate situation and to get the player committed to and immersed in the task at hand.

The user interface of the game was assumed to be easy to use because there were only three different tools that could be used, two fill-in tools and an eraser. Furthermore, an Agent Bob, who observed the hero's performance and provided feedback and information from the field to the player, was included. When the game begins, Bob introduces himself and explains his role as an assistant in this mission. After 3 minutes of playing time, Bob comments on player's performance at the start of every minute. If the player has not made any mistakes, Bob informs the player that he/she is doing well and should continue accordingly. On the other hand, if the player has made mistakes, Bob informs the player of the number of mistakes made. Bob does not give any specific information about where the mistakes are; the player alone must find the mistakes to be corrected. This type of practice requires the player to reflectively consider his/her problem-solving strategies and may lead to a better understanding of the problem domain. In addition, such feedback minimizes the possibility of participants solving the puzzle using a trial and error method.

One noteworthy characteristic of the game is its low-level adaptivity. If a player has solved 80 % of the puzzle using only 8 minutes, Bob informs the player that a field agent has reported that the bomb will go off sooner than was originally thought. To be more precise, the

player is notified that only 4 minutes are left to solve the remaining 20% of the puzzle. The purpose of this characteristic was to make the game more challenging for those users who otherwise would have perceived the game as too easy.

Measures

The data were gathered with virtual observation and a questionnaire. Successfully completing the puzzle, the time used to solve the game, Bob's remarks regarding any mistakes, and the number of mistakes made were virtually observed and recorded to log files. The Flow Scale for Games (FSG) assessment instrument, a condensed and contextualized version of the FSS developed by Jackson and Marsh (1996), was created and used 5-point Likert-type response format (5 = *agree*, 1 = *disagree*). The FSG (see Appendix) consisted of all nine dimensions that Csikszentmihalyi (1991) proposed, except that the action–awareness dimension was implemented as a playability dimension. Included within the FSG instrument were three background questions, two open-ended questions, and a control question of flow experience.

Before analysis, each participant was labeled with a combination of alphabetic letters. This was done to cover participants' identities.

The mean scores and standard deviations of each question were calculated as well as the reliability of each dimension. The reliability was calculated using Cronbach's alpha estimates. In addition, a correlation was used to study the relationship between the dimensions that represent flow antecedents and those that represent the flow experience.

Procedure

The experiment can be divided into three phases; 1) introduction to the study and login, 2) the completion of the Day Off game, and 3) the assessment questionnaire. In the first phase, some background information of the study was presented to participants. When a player logged in, the game started with the animation and some guidelines embedded in the story format, then the actual game playing session began. Players had 20 minutes to solve the game. If the player could not decrypt the message in time, the bomb went off (explosion sound). Then the correct answer was revealed to the player. On the other hand, if the player succeeded in solving the game, Bob informed the player that bomb has been found and dismantled. No matter what the outcome of the game, all players completed a questionnaire aimed at measuring their playing experience.

Results and Discussion

Table 1 shows the means and standard deviations of the items included in the FSG, as well as the reliability estimates of the instrument. The flow dimensions are divided into flow antecedents and indicators of flow experience. The high mean values of the antecedents indicate that the game was well designed and provided good circumstances for the players to experience flow. Despite the playability antecedent, however, the reliability of other antecedents was found poor. This means that the questions measuring the challenge, goals, feedback, and sense of control dimensions need to be further developed. Nevertheless, the reliability of flow antecedents as a construct was acceptable ($\alpha = .71$).

Table 1. Mean Scores, Standard Deviations and Reliability Estimates of Flow Dimensions Included in the FSG ($N = 221$).

Item number	Flow dimension	Mean	Standard deviation	Reliability
FLOW ANTECEDENTS				.71
1	Challenge	4.30	0.98	.43
10	Challenge	3.62	1.26	
3	Goal	4.17	1.04	.49
12	Goal	4.35	1.00	
4	Feedback	4.05	1.04	.55
13	Feedback	4.01	1.04	
6	Control	3.94	1.04	.39
15	Control	3.35	1.24	
2	Playability	4.05	1.12	.78
11	Playability	4.34	0.99	
INDICATORS OF FLOW EXPERIENCE				.74
5	Concentration	3.94	1.13	.75
14	Concentration	4.04	1.13	
19	Concentration	3.82	1.08	
21	Concentration	3.57	1.17	
8	Time distortion	3.09	1.38	.82
17	Time distortion	2.92	1.33	
9	Autotelic experience	4.18	0.89	.87
18	Autotelic experience	3.97	1.02	
20	Autotelic experience	3.81	1.00	
22	Autotelic experience	3.35	1.00	
7	Loss of self-consciousness	4.33	1.02	.57
16	Loss of self-consciousness	3.53	1.28	

Flow experience was measured in two different ways. First, a description of flow experience was given to players and they were asked directly to rate if they had experienced flow on a 5-point Likert scale (control question). The mean score of flow experience was 3.3. Further, the flow experience was measured as a sum of the concentration, time distortion, loss

of self-consciousness, and autotelic experience dimensions that can be considered as indicators of flow experience. Results indicated that the correlation between these two measuring methods was very significant ($r = .62$). Further, the Cronbach's alpha estimate of reliability of constructed flow experience was found reasonable ($\alpha = .74$). Only the reliability of loss of self-consciousness dimension was poor. This constructed flow experience will be used in further analyses. The gaming experience, age, and gender did not have an influence on the flow level perceived.

Table 2 shows the relationship between the flow antecedents and the flow experience. All correlations are significant, which indicates that a challenge matching the players' skill levels, clear goals, unambiguous feedback, a sense of control, and playability dimensions should be considered when trying to design flow-inducing games. Although, these results were achieved through studying a small problem-solving game, the results provide some baseline evidence of the usefulness of flow antecedents, as demonstrated in the experiential gaming model for game design. Now these antecedents are discussed in greater detail.

As previous research (Chen et al., 1999; Kiili, 2005c) has indicated, measuring the perceived challenge is problematic. The results of this study support this finding. As might be expected, people perceive the presented challenge differently. For example, in this study the mean of the perceived challenge of players who could not solve the game ($M = 3.58$) was almost the same level as the mean of players who solved the game ($M = 3.96$). This indicates that the outcome of a playing activity did not have a clear influence on the perceived challenge level. It seems that some people are used to facing more challenging tasks and they appreciate a challenge more than others. Additionally, it may be hard to admit that one's skills are not sufficient to handle the task at hand. On the other hand, according to the t-test, success in the game had a positive impact on the perceived flow level $t(219)=2.15$, $p = .03$ (K-S $d = .09$ and sense of control $t(219)=2.72$, $p < .00$ (K-S $d = .14$).

Generally, the goal of the game was well understood and only few players were unable to catch the idea. It seems that the frame story of the game clarified the goals of the game, as player C reported, "*I felt that the frame story increased the clearness of the goal of the game.*" In fact, some players reported that they felt responsible for saving the people that the bomb was threatening. However, the frame story also aroused totally opposite feelings in others and was considered a ridiculous and needless feature in small games like this. In this study, playability was considered from the usability point of view. Players' experiences pointed out that the user interface of the game was functional and did not induce any confusion. Playability had a clear relationship to the sense of control ($r = .36$). Surprisingly, the feedback that Agent Bob provided negatively affected both the sense of control ($r = -.24$) and playability ($r = -.26$). Some of the players felt that Bob did not allow them to solve the puzzle in peace, but disturbed their line of thinking. However, perhaps the clearest reason for negative correlations was the alarm sound used to catch a player's attention

Table 2. Correlations Between Flow Antecedents and Flow Experience ($N = 221$).

	Challenge	Goal	Feedback	Control	Playability
Flow experience *	.31	.28	.30	.47	.31

* All $p = .00$

when a new message appeared. The alarm was experienced as being an annoying feature that disturbed concentration and the whole gaming experience. In fact, the number of incoming messages correlated negatively with the concentration dimension ($r = -.22$), as well as the feedback dimension ($r = -.15$). These results indicate that minor things, such as sound effects that break the harmony of the game, can ruin the enjoyment of the game.

One interesting finding was that several players reported that the feedback was pointless because it simply informed that the player was doing very well or the number of mistakes made. Players would have liked to have more precise feedback, such as the location of mistakes. However, such feedback would not have encouraged the reflective thinking that the feedback system was aimed to support. Furthermore, the feedback was constructive only if the player had made mistakes in the game. Thus, the players who had made mistakes in the game gave higher scores on the usefulness of feedback than players who hadn't made any mistakes.

CONCLUSIONS

In this paper the experiential gaming model, useful for the process of designing educational games, was studied through a small problem-solving game. The focus of the experiment conducted was on flow experience because the game used did not provide means to study all aspects of the model. Although the game studied can not be considered a typical educational game, it provided the appropriate environment to study flow elements included in the experiential gaming model. Overall, the results of the study indicated that the original flow dimensions that Csikszentmihalyi (1975) has presented can be divided into flow antecedents and flow experience as follows.

The flow antecedents studied—challenges matched to a player's skill level, clear goals, unambiguous feedback, a sense of control, and playability—should be considered in game design in order to produce engaging and enjoyable experiences for players. Playability is a new flow antecedent that has not been proposed before. It was constructed to replace Csikszentmihalyi's (1975) action–awareness merging dimension, which is problematic in the educational game context. This replacement is reasonable because, according to Csikszentmihalyi, all flow-inducing activities become spontaneous and automatic, something undesirable from the transfer point of view. In contrast, the principles of experiential and constructivist approaches emphasize that learning is an active and cognitive knowledge construction process (Kolb, 1984; Winn, 2004). Thus, a distinction should be made between the cognitive activities related to solving the tasks of the game as compared to the use of the controls of the game. This distinction is illustrated in Figure 3, which reflects the challenge-based relationships among the player, the tasks of the game, and the artifact (the user interface of the game).

All three components—the player, task, and artifact—should be taken into account when designing educational games. Generally, the aim of an educational game is to provide students with challenges related to the main learning task in a way that the flow experience is possible. When both the task and the use of the artifact are complex, then these may detract the player's attention from the learning goal. A game with poor playability decreases the likelihood of the player experiencing task-based flow because the player has to sacrifice attention and other cognitive resources to some unrelated activity. Because the information processing capacity of

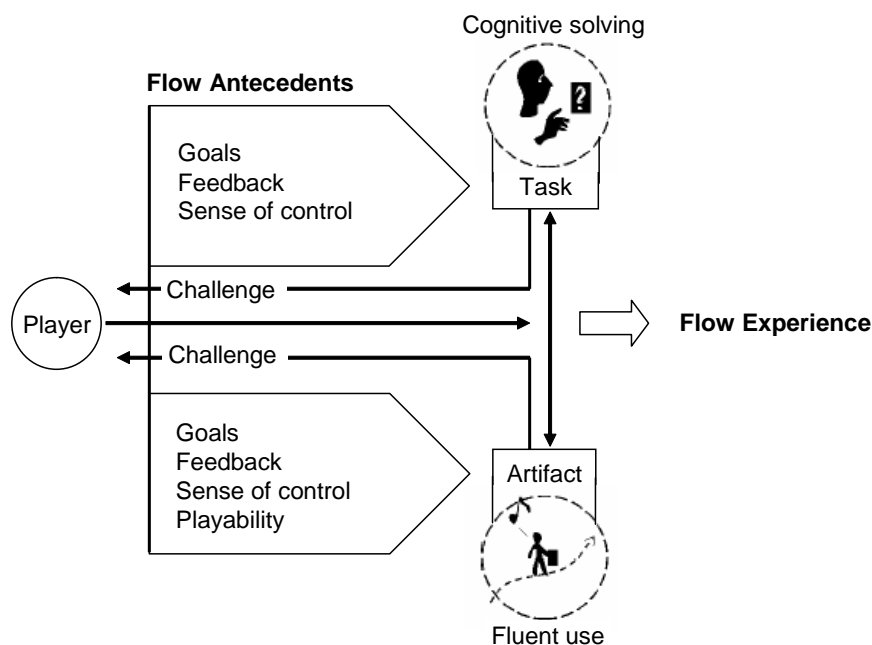


Figure 3. Relation of the flow antecedents to the tasks and the user interface of the game.

human working memory is limited (Miller, 1956), all possible resources should be available for relevant information processing (the main task) rather than for game control issues. Thus, the aim of game designers must be to support the shift from cognitive interaction to fluent interaction. In an ideal situation, the controls of the game are transparent and allow the player to focus on higher order tasks.

The user interface of the Day Off game was quite simple and did not confuse any players. However, an important lesson of this study was the fact that even minor aspects that break down the harmony of the game can ruin the entire playing experience. For example, in the Day Off game, a sound effect that players found annoying disturbed their experiences and inhibited their flow experience.

The results of the study supported the assumption that the concentration, time distortion, autotelic experience, and loss of self-consciousness dimensions can be considered indicators of the flow experience. The interplay of these dimensions facilitates the flow level experienced by players. Furthermore, the results indicated that the flow experience was independent of gender, age, and prior gaming experience. This result is consistent with Csikszentmihalyi's (1991, p. 49) argument that the optimal experience and the psychological conditions that make flow possible seem to be the same the world over. Thus, it can be argued that the flow antecedents included in the experiential gaming model presented here provide an appropriate design framework for various kinds of games and players.

It is important to note that the flow experience usually occurs when a person's mind is stretched to its limits in a voluntary effort to accomplish something difficult and worthwhile. Therefore, supporting the flow experience toward a state of enjoyment does not require that educational gaming to be effortless. On the contrary, educational games should stretch a player's mind to its limits in his/her effort to overcome worthwhile challenges. This nature of flow supports the premise of using flow as one design approach in educational game design. However, perhaps the most important final result of flow is that flow-inducing learning

activities are not undertaken by the player with the expectation of some future benefit, but rather because the playing of an educational game itself is the reward. This type of attitude supports the ideology of life-long learning and is a priceless goal in education.

This study is a part of an ongoing attempt to develop a usable and valid scale for assessing the flow experience of players in educational games. The results of the experiment described in this paper demonstrate that the constructed FSG instrument provides a satisfactory tool for assessing the gaming experiences of players. However, this work is still in its very initial stages and the FSG instrument needs further development and validation with more complex educational games.

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Appendix

Flow Scale for Games (translated from Finnish to English)

Please answer the following questions in relation to your experience with the Day Off game you just played. These questions relate to the thoughts and feelings you may have experienced during playing. Think about how you felt and answer following questions. When you have answered all the questions, press the Send Form button. Thank you!

		Agree					Disagree				
1	I was challenged, but I believed my skills would allow me to meet the challenge.	5	4	3	2	1					
2	I could use the user interface of the game spontaneously and automatically without having to think.	5	4	3	2	1					
3	I knew clearly what I wanted to do and achieve.	5	4	3	2	1					
4	I was aware how I was performing in the game.	5	4	3	2	1					
5	My attention was focused entirely on playing the game.	5	4	3	2	1					
6	I felt in total control of my playing actions.	5	4	3	2	1					
7	I was not concerned with what others may have been thinking about my playing performance.	5	4	3	2	1					
8	My sense of time altered (either speeded up or slowed down).	5	4	3	2	1					
9	I really enjoyed the playing experience.	5	4	3	2	1					
10	The challenge that the game provided and my skills were at an equally high level.	5	4	3	2	1					
11	The use of the user interface was easy to acquire.	5	4	3	2	1					
12	The goals of the game were clearly defined.	5	4	3	2	1					
13	I could tell by the way I was performing how well I was doing.	5	4	3	2	1					
14	It was no effort to keep my mind on game events.	5	4	3	2	1					
15	I had a feeling of control of my actions.	5	4	3	2	1					
16	I was not worried about my performance during playing.	5	4	3	2	1					
17	The way time passed seemed to be different from normal.	5	4	3	2	1					
18	I loved the feeling of playing and want to capture it again.	5	4	3	2	1					
19	I had total concentration while playing the game.	5	4	3	2	1					
20	The playing experience left me feeling great.	5	4	3	2	1					
21	I was totally immersed in playing the game.	5	4	3	2	1					
22	I found the experience extremely rewarding.	5	4	3	2	1					
23	Read the description of flow experience and answer to the following statement: I experienced a clear flow experience during playing.	5	4	3	2	1					
	Description of flow: The word flow is used to describe a state of mind sometimes experienced by people who are deeply involved in some activity. For example, a football player may experience flow when nothing else matters but the game itself and it is going very well. Activity that induces flow totally captivates a person for some period of time, in which case time seems to distort and nothing else but the activity seems to matter. Flow may not last for a long time on any particular occasion, but it may come and go over time. Flow has been described as being an intrinsically enjoyable experience.										
24	If you experienced flow, what factors in the game contributed to flow experience?										
25	If you did not experience flow, what factors in the game disturbed achieving a flow experience?										

CREATING A FRAMEWORK FOR IMPROVING THE LEARNABILITY OF A COMPLEX SYSTEM

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Abstract: *When designing complex systems, it is crucial but challenging to make them easy to learn. In this paper, a framework for improving the learnability of a complex system is presented. A classification of factors affecting the learnability of a building modeling system as well as guidelines that refine the factors into practical ways of action are introduced. The factors and guidelines include issues related to the user interface, conformity of the system to user's expectations, and training. The classification is based on empirical research during which learnability was assessed with several methods. The methodology and the classification of learnability factors can be used as references when analyzing and improving the learnability of other systems. System developers and training providers can utilize these guidelines when striving to make systems easier to learn.*

Keywords: *learnability, ease-of-learning, complex systems, grounded theory, guidelines.*

INTRODUCTION

As complex systems get more and more common in various problem domains, it becomes necessary to make them easily learnable. Good learnability will lead to acceptable learning times, sufficient productivity during the learning phase, and greater satisfaction in new users. However, designing complex systems that are easy to learn is challenging. Complex systems need to provide a wide variety of functionality and to support complex task flows and object structures. There is a danger of complexity leading to long and unproductive learning times.

Another challenge with improving the learnability of complex systems is that the changes made in the system must not decrease the efficiency of use (Santos & Badre, 1995). It has been discussed whether learnability and efficiency actually support each other or rather, in fact, contradict. Several studies have indicated that learnability and efficiency are congruent. Whiteside, Jones, Levy, and Wixon (1985), for example, noticed in their study concerning several command, menu, and iconic interfaces that the best system for novice users was also the best for expert users, and the worst system for novices was the worst for experts.

However, some researchers (e.g., Goodwin, 1987) have pointed out that experts and novices may have different requirements for a system: Abbreviations and shortcuts, for example,

will improve the performance of experts but may slow down the learning of novices. Thus, balancing learnability and efficiency requires careful consideration.

In any case, novices are an important user group and therefore the learning dimension should be taken into account when designing a system. Compacting the learning process and reducing the length of training needed and the number of problems that new users face will save costs for the organization that has taken the system into use and, in many cases, the system provider as well. If users consider the system easy to learn, they are more likely to pass through the learning stage and continue using the system regularly. Satisfied learners may also tell other prospective users about an easily learned system and thus perform efficient peer-to-peer marketing.

To improve the learnability of a system, a general understanding of the factors affecting learnability is needed. In this paper, a classification of learnability factors related to a building modeling system is introduced. Practical guidelines that can be used by product developers who design new systems or redesign existing ones are presented as well. I believe that the classification of factors and the guidelines are useful for developing complex systems that are easy to learn.

LEARNABILITY

In this article, the word *learnability* signifies how quickly and comfortably a new user can begin efficient and error-free interaction with the system, particularly when he or she is starting to use the system. It can be seen from this definition that both objective and subjective facets of learnability are considered: the speed of learning (quickly) and the subjective satisfaction of the learner (comfortably). The goal of the learning process is efficient and error-free interaction. In the literature, the terms *ease-of-learning* and *learnability* often have been used interchangeably.

Multiple other definitions for learnability exist in the literature, and they differ from each other slightly. For example, Bevan and Macleod's (1994) definition of learnability comprises the usability attributes of satisfaction, effectiveness, and efficiency that are evaluated within a certain context, namely the context of a new user. In the ISO 9241 standard (International Organization for Standardization [ISO], 1998a and 1998b), learnability is also defined through the three attributes of efficiency, effectiveness, and satisfaction. Dix, Finlay, Abowd, and Beale (1998) define learnability as the ease with which new users can begin effective interaction and achieve maximal performance. In summary, what most of the definitions have in common is that they address the initial usage experience and include a criterion such as effectiveness or efficiency that can be used to measure the learning results. In addition, some researchers have emphasized that the term *learnability* should also cover expert users' ability to learn functions that are new to them (Sinkkonen, 2000). While this perspective is important, I considered it feasible to concentrate on one group of users, namely new users, in this research.

The importance of learnability in determining system acceptability has been noticed early (e.g., Butler, 1985). Lin, Choong, and Salvendy (1997) found that learnability is correlated with user satisfaction. The learnability of complex systems is especially critical, as the complexity tends to make the unproductive learning period longer than what is desired by the user and the managers in the organization.

The Relationship of Learnability and Usability

There are contradicting views of how learnability relates to usability. Some researchers consider learnability to be a subconcept of usability (e.g., Elliott, Jones, & Barker, 2002). Nielsen (1993) presents five subattributes of usability: learnability, efficiency, memorability, errors, and satisfaction. In the same book, Nielsen presents 10 usability heuristics that should be considered when designing user interfaces. Dix et al. (1998) in turn divide usability into the three attributes of learnability, flexibility, and robustness. Lin et al. (1997) list eight attributes: compatibility, consistency, flexibility, learnability, minimal action, minimal memory load, perceptual limitation, and user guidance.

Elliott et al. (2002) have discussed the relationship of learnability and usability in their publication. They refer to several studies indicating that the concepts of learnability and usability are strongly related and even congruent. Roberts & Moran (1983), for example, found that procedural complexity underlies both the performance of experts and the learning of novices. Whiteside et al. (1985) have also stated that the concepts of usability and learnability are congruent. Based on these studies, Elliott et al. (2002) made the conclusion that elements from models for usability can be incorporated to models of learnability as well. However, other researchers (e.g., Paymans, Lindenberg, & Neerinx, 2004) have noted that sometimes learnability and usability may be contradictory: that issues that improve learnability actually reduce usability. This is related to the question of how learnability and efficiency relate to each other, which I discussed earlier in this article.

Based on the literature review and my experiences, I expected learnability and usability to have several issues in common. However, I expected during the study that I would also notice issues that affect learnability but are not included in common models of usability. I will discuss the relationship of learnability and usability later in this article after presenting the empirical results.

Aspects of Learnability

Learnability studies have often concentrated on the effect of the user interface design on learnability (see Elliott et al., 2002; Lin et al., 1997). Naturally, the user interface is crucial for learnability, as it essentially forms the link between the user and the system. Different researchers stress various issues as determinants of user interface learnability. Rieman, Lewis, Young, and Polson (1994) emphasize the effect of consistency. Green and Eklundh (2003) in turn emphasize the naturalness of interaction. Dix et al. (1998) have presented five principles that support user interface learnability: predictability, synthesizability, familiarity, generalizability, and consistency. Elliott et al. (2002) found four factors that determine the learnability of a system: transparency of operation, transparency of purpose, accommodation of the user, and the sense of accomplishment. The two first elements are determined by the user interface design and, according to Elliott et al., (2002), the accommodation of the user and the sense of accomplishment follow them causally.

Applying these principles to user interface design helps in designing systems that are easy to learn. However, to improve learnability, the correspondence between the system and users' expectations must be analyzed too, as expectations have a remarkable effect on learning. Users' expectations may cover the scope, underlying concepts, and basic functionality of the system.

Kellogg and Breen (1987) among others, have stated that differences between the users' expectations and the actual system can cause learning difficulties. I decided to use the theory of mental models as a basis for analyzing these differences.

Mental models are internal representations of entities with which we interact. According to Fein, Olson, and Olson (1993), a mental model of a computerized system may contain information on the system functionality, components of the system, related processes, and their interrelations. Fein et al. (1993) write that learning can be viewed as a process in which the user processes information and thereby his or her mental model is changed. According to Shayo and Olfman (1998), a user's mental model helps him or her to plan how to interact with the system, interpret the behavior of the system, and perform correctly when problems occur.

As the goal of this study was to provide tools to make the learning process faster, I needed to analyze the entire learning process, from the first interaction with the system, through the training process, and into the post-training phase. In this study, I paid special attention to the training arrangements, as changes in training are a rather quick and easy way to improve learnability. To analyze the effect of training, it is useful to know something about the human learning process and different learning theories.

Multiple theories of learning exist, developed by different schools of scientists. The current HCI (human-computer interaction) research has tended to adopt a cognitive perspective on learning (Elliott et al., 2002). Cognitive theorists stress the importance of internal thought processes and mental structures, as opposed to behavioral scientists' emphasis on behavioral patterns, reinforcement, and conditioning. In this study, I adopted a cognitive perspective to learning and adjusted it with the ideas presented by constructivists. Constructivism is based on cognitive science, and cognitive scientists and constructivists see learning rather similarly. According to constructivists, learning can be defined as a process of building and reorganizing mental structures. Constructivism also states that knowledge is never independent of the learner and the learning context. The learner combines new information with his or her existing knowledge to form a more accurate model of the subject (Marton & Booth, 1997). This view of learning is closely related to the theory of mental models, as both stress the importance of changes in a human's internal knowledge structures. I saw the constructivist learning theory combined with the concept of mental models as a good basis for analyzing the learning process and the effect of training.

In this study, I concentrated on analyzing the three aspects of learnability that were mentioned above: user interface design; differences between users' expectations and the system, which can be analyzed through the theory of mental models; and the effect of training on the learning process. These aspects are later referred to as user interface, conformity to user's expectations, and training. Figure 1 illustrates this approach to learnability.

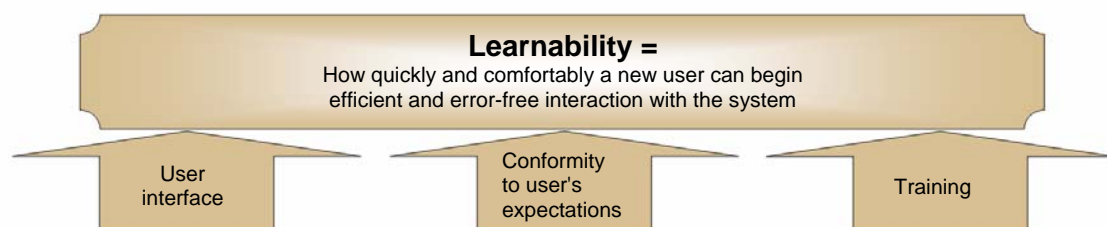


Figure 1. A definition of learnability and the aspects addressed in this study.

THE BUILDING MODELING SYSTEM

In this study, I analyzed the learnability of the Tekla Structures program, a building modeling system that has been developed by the Tekla Corporation. The primary users of the Tekla Structures system are structural engineers. With Tekla Structures, structural engineers can create a three-dimensional model of steel and concrete parts, connections, and other details of a building. Structural analysis can be done using the information contained in the model. The system is very complex in that it provides a wide selection of functionality and supports complex task flows and object structures. My expectation in undertaking a case study on the Tekla Structures program is that it would provide information that could be used to improve the learnability of this particular system as well as be used as a reference when improving the learnability of other complex systems. A typical user interface state of the Tekla Structures system is shown in Figure 2.

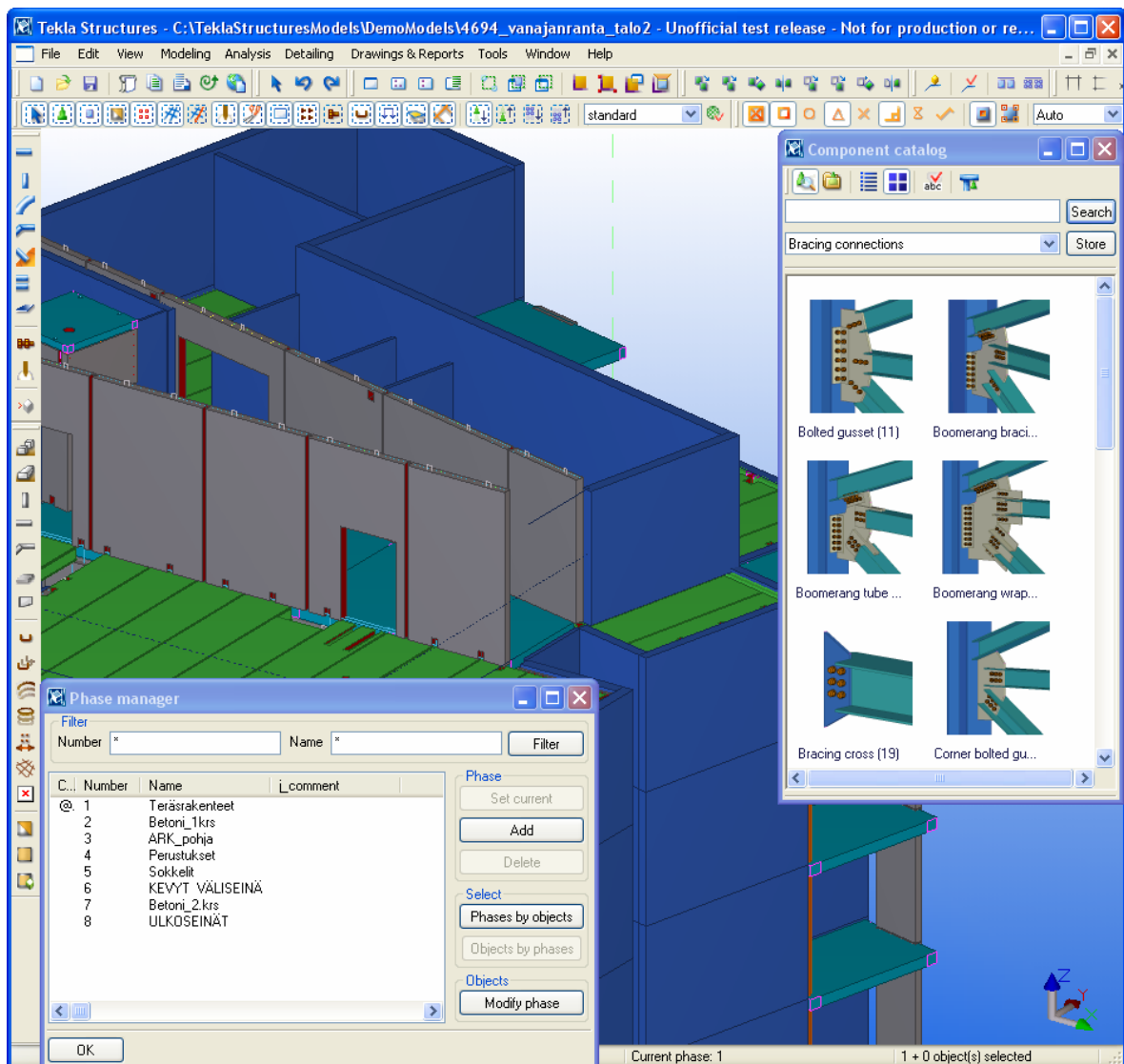


Figure 2. User interface of the Tekla Structures system. (Model by Antti Pekkala, A-Insinööri, 2003)

To support learning, the Tekla Corporation organizes a three-day training course. However, because of the complexity of the system, only a small subset of its features can be addressed in the training and the learning period continues after the formal training. Improving learnability would result in a desired reduction in the learning time.

The training course was a good opportunity to observe the beginning of the learning process. I also observed and interviewed users before and after the training. I describe these research activities in the following section.

RESEARCH METHODS

The purpose of the empirical learnability research was to identify the factors that affect the learnability of the Tekla Structures system and to develop ways to improve learnability. This research was spread over a 3-month period in order to obtain information on different phases of the learning process.

Six novice users who had an engineering or technical drawing background were chosen as subjects. Two of them had worked in the building-modeling domain for only a few months, two of them for about 2 years, and two of them for more than 20 years. All of them had some experience with CAD (computer-aided design) systems but five of them had no experience with Tekla Structures and one of them had tried the system for only a day.

Four research methods were used at different phases of this study in order to collect versatile information and to capture as many different issues affecting learnability as possible. The four research methods are presented in the following sections. The choice of the research methods was highly dependent on the definition of learnability presented in the beginning of this article. I wanted to address both the objective and subjective facets of learnability and to observe how efficient and error-free the users could be in performing tasks with the system in each learning phase.

Pre-Training Interviews

The purpose of this research method was to acquire information on the mental models that users had before interacting with the system. This information is useful because differences between users' mental models and the system may explain learning difficulties.

An interview method similar to the one employed in this study was used by Dykstra-Erickson and Curbow (1997). They studied the learnability of a document management platform called OpenDoc. In the interviews that they conducted, they asked users to comment on user interface prototypes. Their goal was to address users' expectations on how to use certain system features.

In this study, the six subjects were interviewed individually and in-person for about 45 minutes. Interviews were conducted during a two-week period before the training. During the interviews, the user interface of the Tekla Structures system was shown to the users and questions were asked about the user interface elements. Subjects were also asked how they expected certain basic modeling tasks to be performed. They were allowed to test some procedures briefly with the system and comment on them. Interview questions included, as a sample, the following:

- Which icons do you find familiar? What do you think the others represent?

- Which do you expect to be the biggest differences between this system and the software you used before?
- How would you start creating columns and beams?
- How do you think you can copy and mirror elements?
- How do you expect changes in the model to affect drawings?

The interviews were audio recorded. The comments were transcribed to a written form after the interview. The interview language was Finnish and I translated users' comments into English for this article.

Training Observation

A basic training course organized for new users was observed to acquire information on the beginning of the learning process. The purpose was to see which functions were difficult to learn, what kind of problems users faced when learning to use the system, what training methods were used, and how training affected the learning results.

Training observation as a method for studying learnability has not been widely discussed in literature. However, it has been mentioned by Karn, Perry, and Krolczyk (1997) as one method for collecting learnability data. Because training sessions are organized regularly for new Tekla Structures users, training observation was an easily arranged and efficient method for evaluating learnability.

The training course that I observed lasted 3 days. All six users who attended the training course had been interviewed prior to the course. The training course consisted of demonstrations given by the instructor and exercises that the subjects performed according to the instructions in the training material. The training material was available in both printed and electronic form. The instructor helped the subjects with the problems they faced while doing the exercises.

I observed the six subjects while they performed the exercises and took notes on an observation template, which was a table with the following columns:

- main topics covered in the training (which corresponded to chapters in the training material)
- time that was spent with each main topic
- subtopics covered in the training (corresponded to subsections in the training material)
- teaching methods
- concepts that were explained
- concepts that were not explained
- references in the training material to additional learning resources (the references were available as links in the electronic version of the training material)
- questions that the subjects asked
- behaviors of the subjects.

Usability Tests

The purpose of the scenario-based usability tests was to assess the outcome of the training and the self-learning phase that followed. The tests were expected to reveal issues that are problematic for new users.

Elliott et al. (2002) and Roberts and Moran (1983), for example, have evaluated learnability with scenario-based tests in which users were observed while completing test tasks. Corresponding methods have been used by numerous other researchers for evaluating usability.

In this study, the usability test consisted of 19 test tasks. The tasks contained the most essential phases of a real modeling project, but on a smaller scale. The subjects received the same initial information as in a normal project, and a task scenario was presented to indicate the goal of the modeling task.

Each subject was observed individually while completing the tasks with the system. The usability test lasted about 1 hour and was organized at each subject's office. The subject was asked to think aloud while completing the tasks (see Salter, 1988, for the think-aloud method). The researcher observed the behavior of the subject and took notes on the performed steps, errors, and subject's comments. The test sessions were also audio recorded.

The test was repeated twice for each subject, immediately after the training session and 2 months later. The tasks in these two usability tests contained the same essential phases but the details of the tasks differed slightly.

Subjective Satisfaction Questionnaire

After the usability test sessions, the subjects were asked to fill in a two-page questionnaire. The purpose was to address subjective opinions on issues that affect learnability. The need for assessing subjective satisfaction can be inferred from the definition of learnability that contains the word *comfortably*. The use of a questionnaire for measuring the subjective satisfaction dimension of learnability has been suggested in the ISO 9241 standard (ISO, 1998b).

The questionnaire was divided into four sections: general questions, learnability of the user interface, materials and training, and function-specific questions. The questionnaire contained 30 questions in total. A 5-point Likert scale (see Lewis, 1995), with a pair of polar adjectives as anchors, was used. The questionnaire answers were scored and average grades were calculated for each question.

RESULTS

Pre-Training Interviews

The pre-training interviews provided evidence that the users had rather detailed assumptions about the Tekla Structures system but their assumptions were often partly incorrect. I noticed that users based their expectations mainly on the software they had used earlier. For example, when users were asked about mirroring objects or modifying part marks, they explained how the operation was performed with the software they were familiar with and that they expected Tekla Structures to work similarly. This is in line with the theory of mental models. The users' mental models were based on familiar software programs; their mental model would change, then, as they learn more about the new system.

It was also observed that users guessed the functionality of and could use the simplest features of the system surprisingly well without any training. For example, users were able to create a model with some columns, beams, and connections. In these cases, the system seemed to direct the user to perform the right sequence of actions. On the other hand, users

could not perform more complex tasks without instructions, such as controlling the connection parameters or changing the drawing layout.

A sample of issues that were surfaced in the pre-training interviews as well as the number of users with whom each issue was noticed are listed in Table 1.

Table 1. A Sample of Issues Noticed in the Pre-training Interviews.

Issues noticed	# of subjects
The meaning of the basic command buttons used in the system--OK, Apply, and Modify--were not intuitive to the subjects.	4
The subjects expected that objects would be mirrored similarly in a 3D environment as in a 2D environment, which is not true.	2
The subjects were not familiar with the concept of numbering.	4
The subjects could easily place building elements in the model without any training.	5

I formulated the issues that were surfaced in the pre-training interviews as “observations on learnability.” In total, 41 observations concerning learnability were collected. In some cases, several related issues were combined into one observation sample. Presenting related issues as one chunk made it easier to analyze the data after completing all the research activities.

Training Observation

In similar fashion to the pre-training interviews, it was observed that the subjects could create basic objects rather easily during the training sessions. They had difficulties with advanced modification tasks and tasks with several phases. When doing those tasks, they often needed help from the instructor, even if very detailed instructions for performing the tasks were given in the training materials.

The observed group was very active in the training. They asked questions about user interface elements, the meaning of concepts, task sequences, and problems they faced when doing exercises. They commented about things that they considered difficult. During the training, 289 questions and comments about difficult things were raised by the subjects. The questions and comments proved to be especially useful in analyzing learnability. A sample of the subjects’ questions and comments are listed in Table 2. The six subjects are marked with the letters A to F.

Table 2. A Sample of the Questions and Comments Recorded During the Training Observation.

Questions posed
(D) “What is the difference between ‘From plane’ and ‘On plane’?”
(E) “What did it do? ‘Pick object’?”
(B) “Why can’t I see the hollow core slabs?”
(F) “Why aren’t all the connections created?”
(A) “Does it accept both capital and small letters? In what form should the profile be given?”
(D) “What did ‘n’ in the drawing list mean?”
(C) “What is the difference between the ‘Save and freeze’ and the ‘Save’ command?”
(C) “And all these windows... It depends on so many things.”

By placing related issues together, a total, 118 distinct observations concerning learnability were gathered. Many of these were based on the users' questions and comments. Some observations were based on the analysis of user behavior, task sequences, and related problems.

Usability Tests

All subjects had some difficulties when working on the test tasks, even if they had completed similar tasks in the training. There were certain problems that confronted a remarkable number of subjects, sometimes even many times during one usability test. Some of the problems that were surfaced in the usability tests had also been identified during the training observation, but usability tests also revealed some new problems. The problems that the users faced allowed me to identify several issues that degrade learnability. However, during the tests I also recorded several things that support learnability, as well as design suggestions for the user interface and training proposed by the subjects. A sample of the problems that the subjects faced is listed in Table 3.

Table 3. A Sample of the Problems Subjects Faced During the Usability Tests.

Problems observed or raised by subjects	# of subjects
The subjects did not remember that object combinations could be stored as a custom component.	5
The subjects had difficulties with entering points for a custom component.	4
The subjects often forgot to run numbering before creating drawings.	5
The subjects were confused about Tools and Setup menus, since both have a numbering item.	3
The subjects wondered if they had succeeded in creating drawings as they saw nothing happening on the screen.	4
The subjects did not understand the difference between the drawing mode and the modeling mode.	4

In total, 137 observations on learnability were made during the usability tests. Of this total, 60 observations were unique to the test right after the training and 36 were unique to the test two months later; 41 of the observations were present in both tests.

Subjective Satisfaction Questionnaire

The questionnaire results revealed how the subjects saw the learnability of the system, the quality of the support materials, and which operations they considered difficult. The questionnaire answers were scored from 1 to 5. The average scores ranged from 1.0 to 4.7, which means that there were clear distinctions between different items.

The scores that the subjects gave for different system functions were in line with the observations made during the training and usability tests. The subjects gave low scores for the functions that had been observed to be problematic and high scores for the ones with fewer problems. A sample of the questionnaire results are shown in Table 4.

In total, 18 observations concerning learnability were extracted from the subjective satisfaction questionnaire results. The questionnaire did not produce quite as much information for the analysis of learnability factors as the other research methods presented above, but this method was important for validating whether the observations and the subjective opinions were in line.

Table 4. A Sample of the Questionnaire Results.

Questionnaire results
<i>Questions related to the user interface:</i> The subjects considered "Remembering names and use of commands" to be the most difficult.
<i>Questions related to training material:</i> The subjects considered the instructions on the computer screen and the actual training sessions the most useful. They considered the training material CD and context-sensitive help the least useful. Help pages and training sessions got a medium score for usefulness.
<i>Function-specific questions:</i> The subjects indicated that creating grids and concrete or steel parts were easy. They indicated that updating and modifying drawings, exporting and importing data, specifying model properties, and modifying material catalogs were difficult. The other eight phases of the modeling process got a medium score for usefulness.

DISCUSSION

The empirical research activities produced a good quantity of data and allowed me to understand the issues affecting learnability rather well. My goal was to process the data further and group the observations into a set of factors affecting learnability. I also wanted to turn the observations into guidelines that could be followed to produce systems that are easy to learn. Next, I describe how I used the grounded theory method to further process the data, and introduce the learnability factors and guidelines that I extracted from the data.

Use of the Grounded Theory Method

After completing the empirical research, a large body of data was available. To compare the data found with different research methods, all the observations were collected into a large table and related observations were combined into one. As a sample, if a subject had stated in the pre-training interview that a certain user interface element was misleading, and in the usability tests, the same element was observed to cause problems, these two items were presented as one observation. After combining the items, there were 237 observations altogether in the table. The table also contained references regarding the research methods used and the subjects from whom each observation was made.

Next, the observations were classified in order to find a set of learnability factors that would cover all the observations. The grounded theory method was used for this. The analysis using the grounded theory method starts with an unorganized set of data and with no predefined theoretical framework. Themes and patterns are identified from the data. As the analysis proceeds, more evidential data for the themes and patterns is sought. In this case, I identified several classes that the observations fell into and tried to identify learnability factors that covered all the observations within one class.

Elliott et al. (2002) used the grounded theory method for creating a model of learnability for hypermedia authoring tools. According to them, the grounded theory method is useful in that it can produce a theory that fits the available set of data, which was the goal in this research as well.

As an outcome of the classification process, 18 factors affecting learnability were identified. The factors were divided into three main categories, namely the user interface, conformity to user's expectations, and training.

The classification of factors affecting learnability and the list of observations were then used to create guidelines for improving learnability. When creating the guidelines, the observations related to each learnability factor were treated one at a time. The observations

were arranged into subgroups such that one guideline could cover all of the related observations. I made sure that the guidelines were not overlapping but covered all the observations. In total, 64 guidelines were created to encompass the 237 observations.

As a sample, the observations that led to the identification of the factor Continuity of Task Sequences as well as the related guidelines are presented in Tables 5 to 7. Each table contains the observations related to a specific guideline. The research methods and the number of subjects that each observation was based on are also noted. The supporting data for the learnability factor Continuity of Task Sequences originates mostly from the training observation and usability tests because many problems related to the continuity of task sequences only arise when users perform their tasks with the system.

Table 5. Observations Supporting the Continuity of Task Sequences and Guideline 3.1.

Guideline	Observation	Subjects' comments	Empirical research method	# of subjects
3.1 Provide links between the different steps of a task.	Values on several dialog boxes affect numbering, which increases users' memory load. Subjects were not able to define the numbering settings.	(D) "I don't know at all where I can modify anything. If I change it here, does it do everything again?"	Training observation	3
		(E) "How can I see how the parts have been numbered? What are the numbering settings?"	First usability test	4
	The task sequence for filtering objects out of view requires too much memorization. Subjects had difficulties with remembering the sequence.	(D) "What was the name of the command? I had to filter something. That was rather difficult."	Training observation	3
			Second usability test	1
	The task sequence for defining drawing classifier settings requires too much memorization. Subjects needed help, as they could not memorize all the steps.	(C) "And all these windows... It depends on so many things."	Training observation	5
			Second usability test	1
	The task sequence for creating fittings requires too much memorization. Subjects needed help, as they could not memorize all the steps.	(E) "Why doesn't it let me fit this?"	Training observation	3
			The task sequence for creating cuts requires too much memorization. Subjects needed help, as they could not memorize all the steps.	(D) "How do I create cuts?"
	The task sequence for cutting parts requires too much memorization. Subjects needed help as they could not memorize all the steps.	(C) "What should I do? I chose first properties and then scissors. Is it now ok? Have the properties (of the silo) changed?"		Training observation
			The task sequence for importing components requires too much memorization. Subjects needed help, as they could not memorize all the steps.	(F) "How do I know where the component will be placed?"
The task sequence for creating AutoConnections requires too much memorization. Subjects needed help, as they could not memorize all the steps.	(D) "What does the whole thing do?"	Training observation		4
		The task sequence for binding components to planes requires too much memorization. Subjects needed help, as they could not memorize all the steps.	(F) "How can I bind it?"	Training observation

Table 6. Observations Supporting the Continuity of Task Sequences and Guideline 3.2.

Guideline	Observation	Subjects' comments	Empirical research method	# of subjects
3.2 Integrate the tasks if they need to be completed sequentially.	Tools and Setup menus both have an item with the same name (Numbering). This confused the subjects.	(B) "There is numbering in two places? This is confusing."	First usability test	2
		(C) "Ok. It was wrong numbering."	Second usability test	2
	There is no link from the Custom component creation tool to the catalog of components. Subjects were not able to find the Custom component that they had just created.		Training observation	1
		(E) "I don't remember where I can find it now."	First usability test	3
			Second usability test	1
There is no link from the Export file dialog to the directory where the file is exported. Subjects were not able to check the exported file.	(E) "Where was it then... .. I cannot find it anywhere."	First usability test	2	

Table 7. Observations Supporting the Continuity of Task Sequences and Guideline 3.3.

Guideline	Observation	Subjects' comments	Empirical research method	# of subjects
3.3 Make the basic steps of a task easily visible and do not complicate them with advanced options.	There are too many controls on the Create report dialog. Subjects were not able to identify the correct button and they had difficulty creating reports.	(D) "So what are we looking for now? Material... .. Is it this one (Create from selected)? ... No, do I need to select them?"	First usability test	2
			Second usability test	1
	There are too many settings on the Create basic view dialog. Subjects had difficulties with creating a basic view.	(C) "What does it need now? ... If I press this [OK], does it create it or do I need to save first? ... And I cannot make the view that I want in any way? ... If I take this away, or do I need to take it away?"	Pre-training interview	1
			Training observation	2
			Second usability test	2
	Too many complex settings are shown for drawings. Some of the subjects could not create a basic drawing without instructions in the usability tests, but they only remembered that a lot of complex settings need to be defined.	(A) "I will not succeed in it. I think that was a very complex thing to create drawings. ...The most difficult thing was creating drawings. I had a lot of difficulties with it."	First usability test	2
			Second usability test	2

Learnability Factors

Applying the grounded theory method led to the identification of 18 learnability factors. Seven of them are related to the user interface, four to conformity to user's expectations, and seven to training. An overview of the factors is presented in Figure 3.

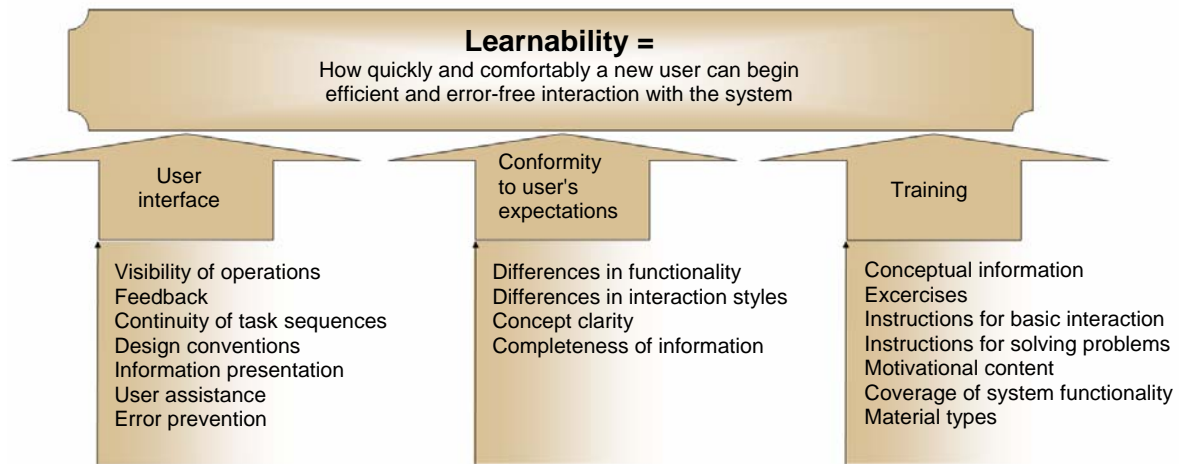


Figure 3. Overview of learnability factors.

Factors Related to the User Interface

The supporting data for the factors related to the user interface arose from situations in which the user interface was misleading or not understandable. Some of these factors are familiar from usability checklists (e.g., Nielsen, 1993). However, the factors in my classification concentrate specifically on the issues that are important for a novice user.

It is indicated in Table 8 how many of the 237 observations support each of the factors. A summary of the supporting observations is presented as well. Each factor is presented in more detail below.

Table 8. Learnability Factors and Observations Related to the User Interface.

Learnability factor	# of observations	Summary of observations
Visibility of operations	68	Subjects had problems finding commands that were not clearly visible near the object with which they were interacting. In addition, the subjects did not necessarily remember command names or locations of commands in the user interface.
Feedback	23	Subjects were often unsure about whether they succeeded with a certain operation in the absence of a confirmative feedback message. They would also have needed feedback about the current system state.
Continuity of task sequences	16	Discontinuities in task sequences were problematic for the subjects. They often did not recognize the way to proceed and, as a result, failed to complete the task.
Design conventions	14	User interface elements that were designed conventionally were easy to understand but unconventional ones caused problems.
Information presentation	45	Graphical presentations or fields without explanations caused problems for the subjects.
User assistance	10	In many problematic situations that were observed in the training and learnability tests, users sought properly designed user assistance to help them overcome the problem.
Error prevention	6	A large portion of the observed errors were made by many, and in some cases all, of the six subjects.

- *Visibility of operations.* An essential requirement for a learnable user interface is the visibility of possible operations. Whereas expert users can rely on experience, novice users must deduce possible operations and inputs from the hints given by the interface.
- *Feedback.* Feedback is useful for experienced users but especially important for novices. They need feedback on the results of operations and the system's state.
- *Continuity of task sequences.* A desirable situation is that when users start a command from a menu or by clicking on an icon they are directed by the system until the desired end result is reached. Users should not be required to jump from one menu item or dialog box to another while performing a single task.
- *Design conventions.* If design conventions are followed, users can easily grasp the meaning and usage of one program's elements from those they have seen in other applications. Design conventions arise from user interface standards and the most common office, Web, or domain-specific software.
- *Information presentation.* Novice users need more detailed descriptions for commands, input fields, and image details than experts do. Special attention should be given to the amount and clarity of information as well.
- *User assistance.* The system should instruct the user and provide additional information on the user interface elements and the related tasks. Current technologies allow user assistance to exist as part of the user interface rather than as a separate help system.
- *Error prevention.* A large portion of the most common errors could be prevented by making small changes in the user interface. In general, the most common causes of errors can be identified by observing new users interacting with the system.

Factors Related to Conformity to User's expectations

The learnability factors in this group reflect the effect of differences between the users' existing mental models and the actual system. These differences may cause learning difficulties. The evidential data for these learnability factors arose from situations in which the subjects expected the system to function differently than it did, and therefore faced problems. In those situations, the subjects had formed their mental model mainly on the basis of a system they had used earlier.

The numbers of observations supporting each learnability factor as well as summaries of the observations are presented in Table 9. Next, each factor is then described in more detail.

Table 9. Learnability Factors and Observations Related to the System Structure.

Learnability factor	# of observations	Summary of observations
Differences in functionality	9	When the subjects described their expectations for new software, it turned out that they based their expectations on their experiences with software they are familiar with. Differences in the functionality between the old and new software caused problems for the subjects.
Differences in interaction styles	16	It could be deduced from the subjects' comments that mental models concerning interaction styles were based on the subjects' experiences with other applications, most commonly office software or operating systems. Subjects expected interaction styles to be domain-independent.
Concept clarity	30	Concepts that had not been used elsewhere caused problems unless they were very self-explanatory, communicated clearly in the user interface, and contained familiar terminology.
Completeness of information	60	Lack of information about the user interface elements, system concepts, and causes and effects of operations caused difficulties with using the system.

- *Differences in functionality.* The functionality of different software applications naturally varies. Usually, it is not desirable to avoid those differences; instead, users should be supported in learning the new functionality.
- *Differences in interaction styles.* Interaction styles of various software applications also vary. Some of this variation may be necessary because of the different nature of the applications; however, some of it is avoidable. Designing the software so that it supports common interaction styles makes the software easier to learn.
- *Concept clarity.* When starting to use a new software application, the user usually needs to learn new concepts. To support learning, new concepts should be communicated clearly with familiar and understandable terminology.
- *Completeness of information.* The change in user's mental model can be facilitated by providing enough information about user interface elements, concepts that are present in the system, and causes and effects of operations.

Factors Related to Training

In this section, training factors that were noticed to affect learnability are presented. The information was extracted from the training observation and comments that the subjects made in the usability tests after the training. When designing training courses to support learning as best as possible, these issues should be considered.

The number of observations supporting each of the factors and a summary of the observations are presented in Table 10. Each factor is then described in more detail next.

Table 10. Learnability Factors and Observations Related to Training.

Learnability factor	# of observations	Summary of observations
Conceptual information	45	Missing conceptual information made the subjects face problems when completing tasks.
Exercises	44	Several subjects commented that they learn best by completing exercises. However, completing a task according to step-by-step instructions provided did not always lead to a persistent learning result.
Instructions for basic interaction	14	Subjects were not familiar with all the basic interaction strategies even after the training, which caused problems.
Instructions for solving problems	16	Subjects were not very well prepared for solving problems themselves but asked for external help when facing problems.
Motivational content	3	It could be deduced from the subjects' comments that they were weighing the advantages of learning the software against the effort spent using it.
Coverage of functionality	9	Some tasks that are central to users' work had received only a little attention in the training and thus the subjects had problems with performing them in usability tests.
Material types	13	Several observations concerning the appropriateness of different material types were made. Users' opinions on the usefulness of different material types varied in different phases of the learning process.

- *Conceptual information.* Conceptual information helps the user to build a revised mental model of the system. For skill learning, mere memorization of procedures is not enough; it is desirable that one truly understands the procedure on a conceptual level as well. Therefore, conceptual information should be included in the training process.
- *Exercises.* For skill learning, it is necessary to practice operations by completing exercises. However, the nature of the exercises also matters. Training should contain exercises that encourage users to process new information and to apply it to new situations.
- *Instructions for basic interaction.* Teaching basic interaction strategies thoroughly in the training will raise productivity during the post-training learning period. This is because users will not need to spend time with simple interaction problems.
- *Instructions for solving problems.* Users will usually face problems when starting with a new software application. To moderate this, users should be equipped with problem solving skills during training. This would help them to use the application competently and independently when no instructor is available to help.
- *Motivational content.* Motivational content is important because it affects the learning behavior of users both during and after the training. Motivational content encourages the users to devote effort to learning more persistently.
- *Coverage of functionality.* Training should concentrate on the system functions that are essential for the users. This can be done only after carefully analyzing user needs.
- *Material types.* The type of the material that is used in training and provided for additional support should be carefully considered. The quality of the material also naturally affects users' perception of its appropriateness.

Learnability Guidelines

Based on the observations and the learnability factors, 64 guidelines for improving learnability were created. They cover issues related to the user interface, conformity to user's expectations, and training. The guidelines are presented next.

Guidelines Related to the User Interface

Altogether, 28 guidelines were formulated for improving the learnability of the user interface. The guidelines are presented in Table 11, and can be used as a checklist when designing new user interface elements. Existing parts of the user interface can also be compared against the

Table 11. Guidelines Related to the User Interface.

Factor	Learnability guidelines
Visibility of operations	1.1 Place related operations within the same location.
	1.2 Make all controls visible.
	1.3 Distinguish visually the items that cannot be used in a certain situation.
	1.4 Support direct manipulation.
	1.5 Direct the user to give the right input.
	1.6 Avoid modes, or if that is not possible, then indicate the mode clearly.
Feedback	2.1 Provide a system response when the user performs an action.
	2.2 Provide a directive system feedback if the user tries to perform an operation that is not possible in a certain situation.
	2.3 Indicate the existence of hidden information.
Continuity of task sequences	3.1 Provide links between the different steps of a task.
	3.2 Integrate the tasks if they need to be completed sequentially.
	3.3 Make the basic steps of a task easily visible and do not complicate them with advanced options.
Design conventions	4.1 Use controls that are familiar from other applications.
	4.2 Use familiar task sequences for operations that are not domain specific.
	4.3 Provide templates to direct the user to the desired design style.
Information presentation	5.1 Organize menus so that they support user tasks.
	5.2 Design descriptive labels.
	5.3 Avoid system-oriented symbols or abbreviations.
	5.4 Avoid any unnecessary information.
User assistance	6.1 Provide information on existing objects.
	6.2 Inform the user about errors.
	6.3 Give instructions for solving a problem.
	6.4 Design clear instructional texts.
	6.5 Provide advanced and beginner modes.
	6.6 Provide several forms of user assistance.
	6.7 Integrate user assistance into the system interface.
Error prevention	7.1 Automate operations that do not require user action.
	7.2 Change errors to alternative paths of operation.

guidelines and necessary adjustments can be made. Naturally, applying the guidelines requires careful consideration of the user interface elements in question and possibly some expertise in human-computer interaction.

Guidelines Related to Conformity to User's Expectations

Ten guidelines concerning conformity to user's expectations were formulated and they are summarized in Table 12. The guidelines can be referred to when designing new features or introducing new concepts to the system. The guidelines address the issues that may affect the adaptation of users' mental models. As these guidelines are related to the system's structure, underlying concepts, and basic functionality, they must be taken into account early in the system development process.

The problem with creating guidelines for the learnability factor Differences in Functionality was that those differences can seldom be avoided. The very reason to have a new software application is that it meets distinct needs not met by other software applications. Therefore, it is desirable to make the new software application different from others. Clarity in instruction can help bridge the differences between the former mental model and the new mental model.

Table 12. Guidelines Related to Conformity to User's Expectations.

Factor	Learnability guidelines	
Differences in functionality	1	Do not avoid introducing new kinds of functionality but assist the user in learning them.
	2.1	Follow design conventions for controls and task sequences.
Differences in interaction styles	2.2	Allow the user to interact with objects as in other similar software applications.
	2.3	Use menu titles that are familiar from other software applications.
	3.1	Use terminology that is familiar from the real world or other software applications.
Concept clarity	3.2	Avoid terminology that may be cause incorrect associations.
	3.3	Avoid system-oriented terminology.
	3.4	Clarify concepts with symbols and images.
	4.1	Provide explanations for new concepts in the interface.
Completeness of information	4.2	Help the user to perform actions.

Guidelines Related to Training

Table 13 summarizes the 26 learnability guidelines related to training that were formulated on the basis of the observations. They are expected to cover the training issues that have the most significant effect on learning results. The contents and organization of existing training setups can be compared against the guidelines to find the necessary adjustments.

Training sessions differ from each other in terms of the type and number of participants, the duration of the training, the complexity of the subject, practical and physical arrangements, as well as many other dimensions. Therefore, some of the guidelines presented here are intentionally left on a rather abstract level. They present issues that should be checked to assure effective training but the training organizer must also adapt them, as needed, to find the best solution for each training context.

Table 13. Guidelines Related to Training.

Factor	Learnability guidelines
Conceptual information	1.1 Clarify the meaning of unfamiliar terms.
	1.2 Explain the relationship between concepts.
	1.3 Clarify the underlying principles that determine how the system is used.
Exercises	2.1 Introduce the basic form of an operation and require the learner to apply it to new situations.
	2.2 Encourage the learner to actively process the information.
	2.3 State the goal of each exercise clearly.
	2.4 State the conditions in which the operation can be performed.
Instructions for basic interaction	3.1 Demonstrate how to interact with objects.
	3.2 Demonstrate how to adjust the basic settings.
	3.3 Demonstrate how to use the basic controls.
Instructions for solving problems	4.1 Instruct about the available documentation.
	4.2 Demonstrate how to use the documentation.
	4.3 Instruct how to contact support personnel.
	4.4 Address the most common causes of error.
Motivational content	5.1 Summarize the contents of the training at the beginning of the session.
	5.2 Concentrate on practical issues that each learner will need in his/her work.
	5.3 Follow up with learners, if possible.
Coverage of functionality	6.1 Get to know the learners and their needs.
	6.2 Adjust the material to cover all the core tasks.
	6.3 Adjust the time that is spent on each core task according to the difficulty and importance of the task.
Material types	7.1 Provide help that is integrated into the user interface and can be easily accessed from within the system.
	7.2 Provide printed material or dual monitors in training.
	7.3 Provide a limited amount of material to be covered in detail, and supplemental material to be referred to later.
	7.4 Design a clear layout for material.
	7.5 Provide material in the native language of the learner, if possible.
	7.6 Provide search possibilities for digital material.

Comparing the Learnability Factors and Guidelines to Previous Research

Several classifications exist on the factors that affect the usability of a system. In many of those studies, learnability is seen as a subfactor of usability. However, the classifications of factors affecting learnability are less common.

My learnability guidelines and the usability guidelines that have been presented in the literature have some issues in common. For example, I have Error Prevention in the list of user interface related learnability factors, and Nielsen (1993) includes it in his list of usability heuristics. One of my user interface-related learnability factors is Visibility of Operations, whereas Nielsen stresses the visibility of system status in his heuristics.

However, the classifications of usability attributes seldom address the issues that I have in the categories of Conformity to User's Expectations and Training. In the beginning of this article, I discussed how usability has been divided into subattributes by Nielsen (1993), Dix et

al. (1998), and Lin et al. (1997). All of these researchers concentrate on attributes of the user interface and not on user's expectations or training. There may be situations in which training is not available and it is not possible to change the underlying system concepts to correspond to user's expectations. Then, it may be sufficient to evaluate only the effect of user interface on learning. However, in most cases, it is beneficial to take a multifaceted view of the learning process and address also user's expectations and training, as has been done in this study.

Nevertheless, the classifications of usability attributes presented in the literature and my classification of factors affecting learnability do not contradict each other, but rather, in fact, are complementary. My detailed classification can be used to analyze the learnability of complex systems corresponding to the building modeling system, and to identify ways to improve learnability. General usability classifications, such as the one presented by Nielsen (1993), can be applied to a wider range of systems from consumer products to software applications, as it has been left on a more general level than the classification presented in this article.

CONCLUSIONS

In this paper, 18 factors affecting the learnability of a building modeling system have been presented. These factors can be used as a general framework for understanding the learnability of this system. In addition, 64 guidelines for improving learnability have been introduced. By following these guidelines in system development and training, the learnability of the building modeling system can be improved.

Throughout the study, three aspects influencing learnability were addressed: the user interface, conformity to user's expectations, and training. Learnability studies have often concentrated on the effect of the user interface, but I believe that a classification addressing the other two distinct aspects of learnability as well helps to improve the learning process and system learnability as a whole.

The classification of learnability factors and guidelines was based on a body of empirical data collected via several research methods. The classification was created with the grounded theory method that is intended for creating a theory that fits the available set of data.

The classification should have practical relevance to other developers of complex systems as well. The learnability factors and guidelines can be used as a reference when analyzing and improving the learnability of any systems. However, it must be noted that the factors and guidelines are based on the empirical data concerning a building modeling system. Thus, some of the factors and guidelines may not even apply to a system whose scope differs radically from the scope of the building modeling system I studied. Furthermore, the emphasis put on the different factors and guidelines may vary for different systems. However, the grounded theory methodology that was used for analyzing the learnability of a building modeling system can be applied to other systems as well. This would produce corresponding classifications of learnability factors and guidelines that take into account the particularities of each system.

I expect that the results concerning learnability are of interest not only for system developers but also for the body of HCI researchers. Not many classifications of factors affecting the learnability of complex systems have been introduced in the HCI literature. This is true for learnability guidelines as well: Several sets of usability guidelines have been

presented in the literature, but sets of learnability guidelines are less common.

In the future, it would be especially interesting to study in more detail the effect of differences between users' mental model and the actual system. Another future research topic would be to validate the learnability factors and guidelines. This could be done by implementing changes to real systems according to the guidelines and measuring the effect of the changes on the performance of new as well as expert users.

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AN ACCEPTANCE MODEL FOR USEFUL AND FUN INFORMATION SYSTEMS

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Abstract: *Investigating the factors associated with user acceptance of new software systems has been an important research stream in the field of information systems for many years. The technology acceptance model has long been used to examine the acceptance of utilitarian systems. Recently, it has been used to examine recreational or pleasure-oriented systems. Many examples exist of software that, depending on the context of use, can be used for productive and pleasurable interaction. This paper examines the determinants of use of one such “dual” system. A survey of users of a dual system was conducted. Results show that perceived usefulness is more important in determining intention to use than perceived enjoyment, and that perceived ease of use has no direct impact on intention, but still has a strong indirect effect.*

Keywords: *Technology acceptance model, utilitarian system, recreational system, context of use.*

INTRODUCTION

Investigating the factors associated with user acceptance of software systems has been an important research stream in the field of information systems for many years. The majority of this work has, appropriately enough, been focused on productivity-oriented or utilitarian systems (Venkatesh & Brown, 2001, p. 72). Other examples of such studies include Adams, Nelson, and Todd (1992); Dennis, Nelson, and Todd (1992); Doll, Raghunathan, Lim, and Gupta (1995); Hendrickson, Massey, and Cronan (1993); Igbaria, Zinatelli, Cragg, and Cavaye (1997); and Segars and Grover (1993). Recently some work has appeared examining recreational or pleasure-oriented systems (Hsu & Lu, 2004; Van der Heijden, 2004) such as games or, in certain contexts, the World Wide Web (Atkinson & Kydd, 1997). A purely

recreational system is one where interaction with the system is in itself pleasurable for the user, and interacting with the system produces nothing more than this pleasure. The goal of such a system is prolonged use rather than productive use. Van der Heijden (2004, p. 696) states, "In its purest form, interacting with a hedonic system is designed to be an end in itself."

However, utilitarian and recreational systems do not sit at opposite ends of one spectrum. It has been realized for over a decade that much computer technology is used for both work and for fun (Starbuck & Webster, 1991). Many examples exist of software that, depending on the context, can be used for reasons of productivity and are also pleasurable to use. Such systems could include drawing packages, song writing software, video editing software, even word processors. These systems can give productivity and pleasure simultaneously. In addition, other systems may give neither productivity nor pleasure. A scale ranging from productivity-oriented to pleasure-oriented use will not capture this. Instead, a two dimensional scale is needed, as shown in Figure 1. The need for such a scale is supported in consumer research (Babin, Darden, & Griffin, 1994), where it has been long known that products can be purchased for various degrees of recreational and utilitarian purposes.

Where a system will be placed on the scale is highly subjective, and one system can be placed in different quadrants by different people. For instance, using the descriptors given in Figure 1, image editing software might be classed as Utilitarian by a photography student, Dual by someone entering an amateur photography competition, Recreational by someone who is adding captions to photographs of their child, and Useless by someone who just takes snapshots.

Many studies have examined the adoption of utilitarian systems, and some studies have examined the adoption of recreational systems. Studies of systems that are used both for utilitarian and recreational reasons are rare. This paper examines the antecedents of acceptance of such a system.

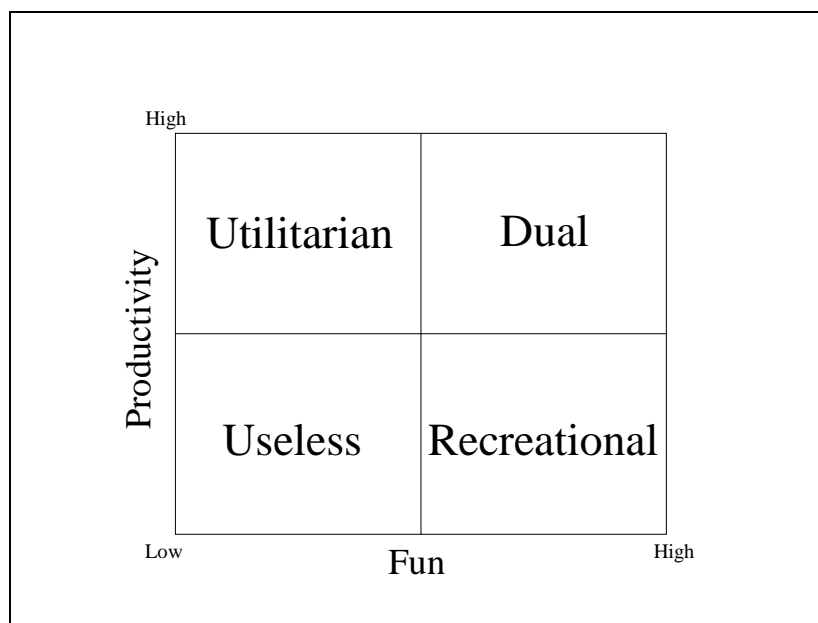


Figure 1. A two-dimensional scale classifying information systems by context of use.

Much of the previous research in this area has used the technology acceptance model (TAM; Davis, 1989). TAM views user acceptance as being dependent upon the perceived usefulness of the system and its perceived ease of use. Significant empirical evidence has built up in support of TAM (for a list see Venkatesh, 1999, p. 240). Perceived usefulness is defined as “the degree to which a person believes that using a particular system would enhance his or her job performance” (Davis, 1989, p. 320). Perceived ease of use is defined as “the degree to which a person believes that using a particular system would be free of effort” (Davis, 1989, p. 320).

When used to examine systems that are used for recreation, TAM has been adapted to include a perceived enjoyment construct. Davis, Bagozzi, and Warshaw (1992, p. 1113) did this when they studied a word processor and a business graphics package. They defined perceived enjoyment as “the extent to which the activity of using the computer is perceived to be enjoyable in its own right.” Van der Heijden (2004) used the same model to study a recreational system.

In a similar move, Moon and Kim (2001) adapted TAM with a new perceived playfulness construct, and applied the resulting model to the World Wide Web. Their study highlights the problem of ignoring context of use. The writers rightly point out that as the Web is used for “education, shopping, entertainment, work, communication, personal information, time-wasting, etc.,” determinants of use may include extrinsic and intrinsic factors (Moon & Kim, 2001, p. 217). They gave questionnaires to 152 students about their use of the Web, yet they failed to report what the respondents were using it for. It is unlikely that a student researching a dissertation will have the same determinants of use as a student who uses it to play games. The third hypothesis they test—that there is a positive relationship between perceived playfulness and intention to use, and for which they find support—only makes sense when it is known what the intention for using the Web is. Such a playfulness relationship probably only exists for a recreational system; it is doubtful to be present if the student is using the Internet to open a bank account, for instance.

Since whether a system is used for utilitarian or recreational reasons will have an impact on the antecedents of adoption, it is important to consider this context of use when applying TAM, or some other model of adoption, such as Rogers’ innovation diffusion theory (Rogers, 1995) or the theory of planned behaviour (Ajzen, 1991). However, few studies consider this. This paper reports work examining the antecedents of use of a “dual” system. The study is unique in that users who are not working within the dual context were removed from the analysis. Other studies select a system and then assume that all of its users are operating in the same context and therefore will have the same model of adoption. This is not necessarily a valid assumption, as shown by the results of Moon and Kim (2001).

The research model used for this study, shown in Figure 2, is the same as used by Davis et al., (1992) and Van der Heijden (2004): TAM with a perceived enjoyment construct. This includes all the elements that might be expected to impact on a dual system. The paths between the variables are as Van der Heijden (2004) describes them.

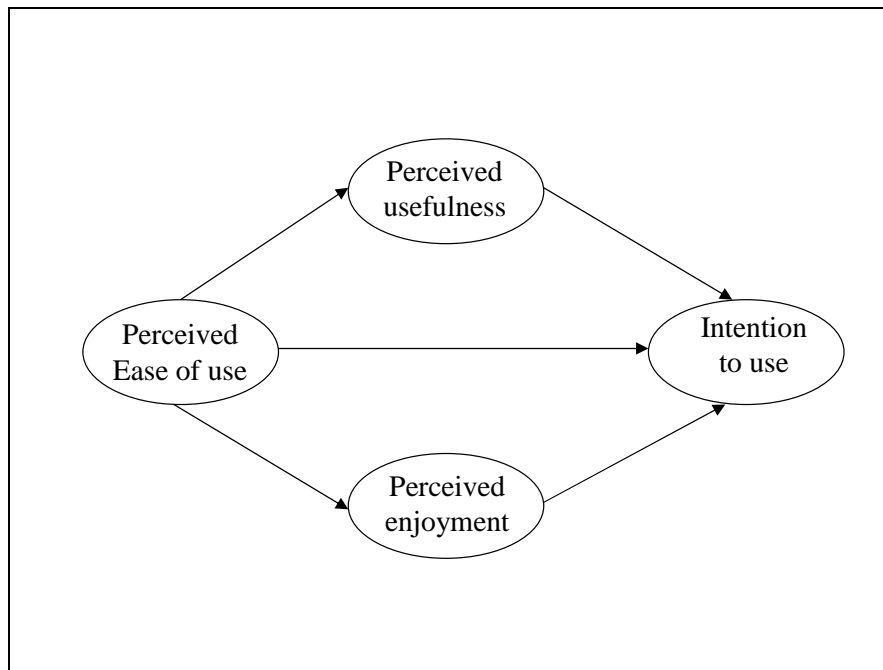


Figure 2. A revised technology acceptance model to include a perceived enjoyment construct, adapted from Davis et al. (1992) and Van der Heijden (2004).

Van der Heijden (2004) found a positive relationship between ease of use and enjoyment, and between enjoyment and intention to use. It is expected that these will hold for dual systems as well, which leads to the first two hypotheses:

- Hypothesis 1. There is a positive relationship between perceived ease of use and perceived enjoyment.
- Hypothesis 2. There is a positive relationship between perceived enjoyment and intention to use.

TAM holds the following relationships, which also should hold for dual systems. As a result, the following hypotheses were tested:

- Hypothesis 3. There is a positive relationship between perceived ease of use and intention to use.
- Hypothesis 4. There is a positive relationship between perceived usefulness and intention to use.
- Hypothesis 5. There is a positive relationship between perceived ease of use and perceived usefulness.

METHOD

A survey of Lego Mindstorms¹ enthusiasts was conducted to test the hypotheses. Mindstorms is a product from the Lego Corporation that is used to build robots. The basic kit consists of standard Lego parts to construct the physical robot and a “programmable brick” known as the RCX. The RCX can be thought of as the robot’s brain. It controls the robot according to

whatever program the user has written and installed in it. It does this by taking input through touch, light, and other sensors, and then producing output in the form of signals to turn motors on and off to make the robot move. The official programming environment is called RCX-code and was developed by Lego and MIT. Several enthusiasts have developed their own programming environments to allow robots to be programmed using mainstream languages such as C, Java and Visual Basic.

Participants

A request for participation was posted on a Mindstorms message board. The request asked people to complete an anonymous on-line questionnaire about their experiences of using their development environment of choice. It is estimated that 170 people saw the post during the two-week data collection period, based on the user statistics of the message board Web site and from the experience of other on-line surveys of hobbyists (see Chesney, 2004). Responses were received from 68 people, giving a response rate of around 40%. Most of the participants (92%) were male. The participants' ages varied from 16 to 67 years ($M = 38$ years, $SD = 11$). A total of 14 answers (1.15%) were missing from the questionnaires. These 14 missing values were replaced with the respondent's average score for the relevant construct, in line with King, Fogg, and Downey (1998).

Material and data

The questionnaire consisted of six items to measure perceived usefulness, five to measure ease of use and four to measure enjoyment. All items are shown in Appendix A and were adapted from Davis (1989) and Van der Heijden (2004), where their reliability and validity have already been established. Only one of the items from Davis (1989), for perceived ease of use ("I find my CHOSEN DEVELOPMENT ENVIRONMENT to be flexible to interact with") was not used in the study because it was felt that "programming language flexibility" was an ambiguous term. One item was used to measure intention to continue using the technology.

It was not assumed that all users were using the program for productivity and for fun, and those who were not were excluded from hypotheses testing. Three approaches were used to verify that the users included in the study classed their system use as dual. First, all respondents were asked to rate, on a scale from 1-10, how much they were programming robots because the programming itself is fun and, separately, how much they are programming because programming is a good way of completing the job of building robots. To be considered as using a dual system, respondents had to score over 5.5 (effectively greater than or equal to 6) on each scale. Of the respondents, 1 classed his system as useless, 7 persons classed it as utilitarian, 48 as dual, and 12 as recreational. The 48 who classed their system as dual were used to test the hypotheses.

Second, five regular contributors to the message board who are considered Mindstoms community leaders—and among them have developed extensive Web content on Lego robots, written books about programming robots, and created some of the development environments being considered—were contacted personally by e-mail and asked if they agreed or disagreed that most users were using their development environment for fun and for

productivity. Four of these individuals agreed with this position, a similar proportion to the respondents who classified their systems as dual.

Lastly, more than a year after the original request for participation was made, another post requested readers to look at a version of Figure 1 and answer questions about the quadrant in which their usage lies. Thirty-four responses were received and 79% of them agreed that their use was dual, a similar proportion as in the original data.

Results

Table 1 shows the reliability and validity of the measurement scales. Using principle factor analysis, and including all the data and not just the dual system data, three factors were extracted after 5 rotations that accounted for 62% of the total variance. There were no cross construct loadings above 0.50, showing good discriminant validity. All factor loadings were 0.5 or above (USE3 and EASE2 were 0.47 and 0.49 respectively), showing good convergent validity. The constructs are therefore unidimensional and factorially distinct, and all items used to operationalize a construct load onto a single factor. Cronbach's alpha reliability scores were all over 0.8, which is considered adequate.

Table 1. Scale Reliability and Factorial Validity. Principal axis factoring was used with varimax rotation and kaiser normalization, $N = 68$.

Scale item	Factor 1	Factor 2	Factor 3	Cronbach's alpha
Ease1	0.88			
Ease4	0.87			
Ease5	0.85			
Ease3	0.51			
Ease2	0.49			0.87
Use2		0.76		
Use4		0.76		
Use3		0.73		
Use6		0.52		
Use1		0.51		
Use5		0.47		0.83
Enjoy2			0.83	
Enjoy4			0.78	
Enjoy1			0.75	
Enjoy3			0.71	0.88
% of variance explained	24.20	19.30	18.60	
Cumulative percentage	24.20	43.50	62.10	

Rotation converged in five iterations.

Ease = perceived ease of use; Use = perceived usefulness; Enjoy = perceived enjoyment; all items are shown in the Appendix.

Factor 1 = ease of use, Factor 2 = usefulness, and Factor 3 = enjoyment.

The research model shown in Figure 1 was tested by multiple regression analysis using SPSS 11. This is consistent with methods used in similar previous studies, such as Davis et al. (1992) and Moon and Kim (2001). The results are shown in Table 2. Consistent with Hypothesis 1, a positive relationship was found between perceived ease of use and perceived enjoyment. Perceived enjoyment and perceived usefulness both impact positively on intention to use, which provides support for Hypotheses 2 and 4. A positive relationship was found between perceived ease of use and perceived usefulness, which is consistent with Hypothesis 5. No positive relationship between perceived ease of use and intention to use was found, meaning no support was found for Hypothesis 3.

To provide quantitative estimates of the relationships between intention, perceived ease of use, usefulness, and enjoyment, a path analysis of the path diagram shown in Figure 2 was conducted. Figure 3 shows the path coefficients that were computed. Since these coefficients are standardized, it is possible to compare them directly (Bryman & Cramer, 2005). It can be seen that perceived usefulness has a stronger effect on intention to use than perceived enjoyment,

Table 2. Results from running regression analyses to test the hypotheses.

Model	R ²	Beta	t	p	Standard error	Result
1. PE = PEOU + errors	0.124	0.352	2.551	0.014	0.661	H1 was supported
2. I = PE + errors	0.242	0.492	3.831	0.000	0.877	H2 was supported
3. I = PEOU + errors	0.063	0.251	1.755	0.086	0.975	H3 was not supported
4. I = PU + errors	0.379	0.616	5.297	0.000	0.794	H4 was supported
5. PU = PEOU + errors	0.239	0.489	3.805	0.000	0.611	H5 was supported

P < 0.05

PE = perceived enjoyment, PEOU = perceived ease of use, PU = perceived usefulness, I = intention to use.

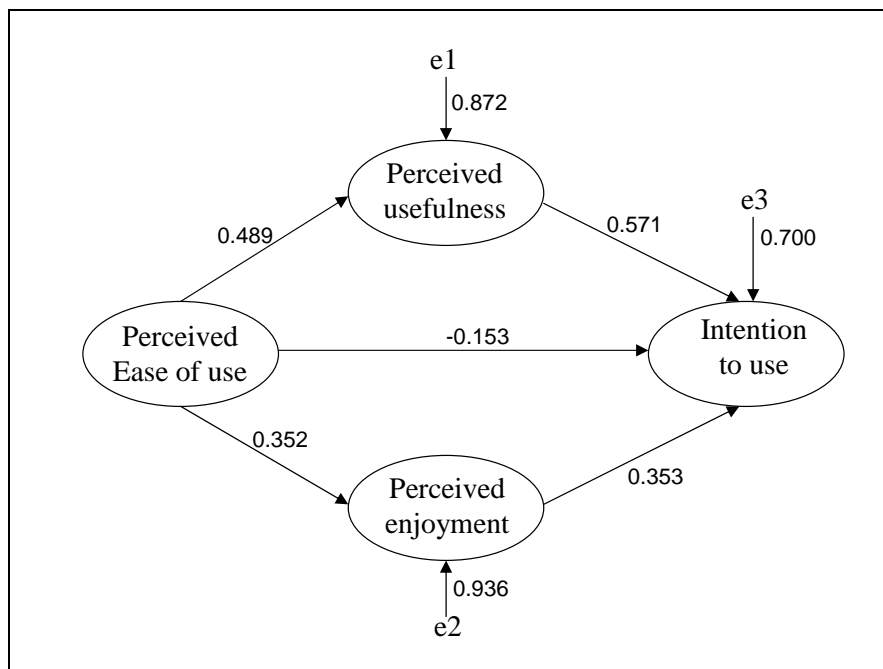


Figure 3. Acceptance model supported by the analysis including the standardized beta path coefficients and error terms.

and that perceived ease of use has a slightly negative direct effect. The indirect effect of perceived ease of use is 0.403; the overall impact is therefore 0.250. Clearly an appreciation of the intervening variables perceived usefulness and perceived enjoyment is essential to an understanding of the relationship between perceived ease of use and intention to use.

DISCUSSION

Hypotheses 1 (There is a positive relationship between perceived ease of use and perceived enjoyment) and 2 (There is a positive relationship between perceived enjoyment and intention to use)—about the relationships between ease of use, enjoyment, and intention, as shown at the bottom of Figure 2—were derived from other studies involving recreational systems. Neither was rejected by the results of this study: Perceived ease of use is significantly related to perceived enjoyment and perceived enjoyment is significantly related to intention to use. Hypotheses 3 (There is a positive relationship between perceived ease of use and intention to use), 4 (There is a positive relationship between perceived usefulness and intention to use), and 5 (There is a positive relationship between perceived ease of use and perceived usefulness) all concern relationships predicted within the original TAM. Hypotheses 4 and 5 were confirmed: There is a positive relationship between perceived usefulness and intention to use, and there is a positive relationship between perceived ease of use and perceived usefulness. However hypothesis 3 was rejected: A positive relationship between perceived ease of use and intention to use was not found.

The acceptance model that these results support is shown in Figure 3. The empirical data show that perceived usefulness does achieve dominant predictive value over perceived enjoyment and perceived ease of use. Further research is needed to see if this result is replicated with other dual systems, although the finding is consistent with Davis et al. (1992). Perceived ease of use loses any direct impact on intention to use but plays an important part in influencing perceived usefulness and enjoyment. Clearly, given the strength of the error terms in Figure 3, there are other unknown factors impacting intention to use, perceived usefulness, and enjoyment, and further work may attempt to identify these. The results also suggest that there may be value in exploring alternative ways to make dual systems more acceptable to users other than by merely increasing ease of use. Increasing enjoyment is one of them. Although ease of use has an impact on enjoyment, identifying the other factors that impact enjoyment would allow investigation into whether these could be exploited to increase acceptance. This study agrees with the finding of Van der Heijden (2004) that purpose of use is important in determining the factors that predict acceptance, and that progress in user acceptance models can be made by focusing on the nature of use. The grid shown in Figure 1 is a useful way of doing this.

This study has a number of limitations. First, almost all of the respondents were male. Future work should repeat the study with a dual system that has an even gender mix. Second, the system studied is very different from a more mainstream system, such as a word processor, not least in the technical ability of the user. Therefore, future work should study more common dual systems. Also, this study, like many other studies, is biased toward users of the technology: The reasons for how and why a technology-minded individual might use a system, or view its context of use, may be quite distinct from someone who is less

technology-minded. Relatedly, the important factors in choosing to use a system may be different from the important factors in choosing not to use a system. These aspects of use should be considered in future studies. Lastly, although the results are consistent with other findings, they cannot be applied to purely utilitarian systems. For instance, the results do not suggest that acceptance of productivity-oriented systems can be increased by adding a fun dimension. The systems studied here were specifically used in part for fun and in part for productivity; for many users, the fun was as important or more so than the productivity. In any case, trying to increase acceptance of utilitarian systems by increasing enjoyment may encourage users to spend their time on frivolous use.

ENDNOTE

1. For more information about Lego Mindstorms see <http://mindstorms.lego.com/>

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Appendix

SURVEY INSTRUMENT

1. Please rate on a scale of one to ten how much you are programming robots because the programming itself is fun.
2. Please rate on a scale of one to ten how much you view programming as a way of getting the job of building robots done.

Perceived usefulness (6 point Likert scale - strongly agree, agree, slightly agree, slightly disagree, disagree, strongly disagree)

1. Using my CHOSEN LANGUAGE enables me to build robots quickly
2. Using my CHOSEN LANGUAGE improves my performance at building robots
3. Using my CHOSEN LANGUAGE increases my productivity at building robots
4. Using my CHOSEN LANGUAGE enhances my effectiveness at building robots
5. Using my CHOSEN LANGUAGE makes it easy to build robots
6. I find my CHOSEN LANGUAGE useful in building robots

Perceived ease of use (6 point Likert scale - strongly agree, agree, slightly agree, slightly disagree, disagree, strongly disagree)

1. Learning to use my CHOSEN LANGUAGE was easy for me
2. I found it easy to get my CHOSEN LANGUAGE to do what I want it to
3. Interaction with my CHOSEN LANGUAGE is clear and understandable
4. It was easy for me to become skilful at using my CHOSEN LANGUAGE
5. I find my CHOSEN LANGUAGE easy to use

Perceived enjoyment (6 point Likert scale – respondents were asked to select where their CHOSEN LANGUAGE lies between each of the two terms)

- Enjoyable- Disgusting
Exciting- Dull
Pleasant- Unpleasant
Interesting-Boring

Intention to use

1. I intend to keep using my CHOSEN LANGUAGE

BOOK REVIEW

Atanu Garai & B. Shadrach (2006). *Taking ICT to every Indian village: Opportunities and challenges*. New Delhi, India: One World South Asia; 133 pages.

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Information and communication technology (ICT) activities can easily be seen as a sort of technocracy, which is not surprising because the focus of attention is often dominated by issues such as the bandwidth, new devices, or the fierce competition between technological companies and their innovative products. In short, the discussion often is restricted to Habermasian technical interest of knowledge. At the end of the day, however, everything in ICT is about people and, more specifically, about the emancipatory application of knowledge for and by the people. This latter perspective on ICT development comes to the fore in a very interesting and thought-provoking way in a book by Garai and Shadrach, titled *Taking ICT to Every Indian Village*.

The book discusses ICT developments in hundreds of thousands Indian villages, presented through four somewhat independent texts that shed light on various practical and research aspects of the status of ICT in India. The book opens with an analysis of Martha Nussbaum's ideas about central human functional capacities, and how these ideas relate to the vision of technological benefit in India. Nussbaum's important humanistic goals—such as bodily integrity, cognitive faculties, emotions, affiliation and control over one's own environment—need to serve as an essential beacon for how technology should benefit human development on both sides of the digital divide. One simply needs to search the Web for any of Nussbaum's humanistic themes to discover how far some technological uses have strayed from obvious benefit to human cognitive and emotional development.

In the balance of the book, the authors develop their themes through assisting the reader to understand the challenges and opportunities for ICTs in India, and through good factual argumentation. They raise important people-centered themes for technological use, such as education, health, governance, community, and business. Garai and Shadrach provide a snapshot of the ICT diffusion in a country of more than a billion people, where ICT access is

challenged by the geography, economy, literacy rate, multilingualism, rural poverty, and so on. The abundance of rural villages that are quite socially, economically, politically and culturally diverse underscores the need for tailored solutions to unique situations. Thus the text presents a concrete picture about the relationship between research and practice, and it discusses with strong expertise the vital issues regarding how technology is applied in rural—sometimes remote—settings. As a result, this book presents a good guide to the ICT development in India—with possible implications for other rural and developing environments—encompassing both the reality and the opportunities.

The realities of rural life in India, and the implications for technology implementation, require solutions to technological needs that, while perhaps quite different from highly technological societies, are obviously very practical for India. For example, information kiosks are commonplace in rural areas, offering calling and Internet services to the public, an effective solution to make limited ICT facilities accessible to many. The lesson provided, of course, is the need for technologies—and, more specifically, technological solutions—to conform to the realities of the people in a particular setting and with particular needs. This book serves well technology designers and strategists who envision technology that is adaptable to and in harmony with the great variation in human need and circumstances throughout the world.

Garai and Shadrach do not limit their discussion to the social aspects of ICT: They raise issues and concerns about technology infrastructure and ICT functionality, which have equal implications for the implementation and use of any technology. In this way, the authors provide an important insider's view to all who are interested in the opportunities and challenges for ICTs in the developing world. On the whole, this small book offers valuable insight on the multidimensional human element of ICTs, and specifically on the unique needs and solutions required for rural communities in developing countries.

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