Investigating human computer interaction issues in designing efficient virtual learning environments

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INVESTIGATING HUMAN COMPUTER INTERACTION ISSUES IN DESIGNING EFFICIENT VIRTUAL LEARNING ENVIRONMENTS

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Today, when an enormous number of computer-based systems exist, the human activities are being computer mediated. Usually, in designing the interface to those systems, the human-computer interaction is left behind without consideration. In this paper, a literature in human-computer interaction is to be reviewed and the technology aspect of human computer interaction is to be analyzed. Also, general design principles are to be reviewed. According to all these issues, recommendations to designing a good human-computer interface for e-learning programming environment are going to be analyzed and proposed.

Key words: Usability, learning environments, java, graphical interface

1 INTRODUCTION

Today, computers and computer and information technologies have an important role in education through utilizing e-learning environments and different computer based systems. So, for their effective use, efficient human-computer interactions must be designed. The involvement of ICT have made a movement in education environments from physical environments to virtual learning environments. The usage of VLEs in learning is a new field of research, because virtual environments become attractive alternative for developing more realistic and interesting user interfaces. According to research literature, the user interface is a crucial component that influences the efficiency and quality of usage and communication between user and the virtual environment as well as in the learning process. Today, there are a number of VLE developed with very advanced graphical user interface, but the role of the human computer interaction is left behind any consideration. This influences to appear a collision among expected learning goals and outcomes, the virtual learning environment and learners.

To overrun these problems a need for research for improving the human- computer interactions emerges, as Jones and O'Shea (1982) claim "that the perceived educational benefits of a computer system have little to do with the amount of use it gets. Instead, it seems that the quality and ease of the interaction are the most important factors. It is therefore argued that if human-computer interface can be improved, one further barrier to CAI use will be removed" (Jones, A. & O'Shea, 1982). In this paper, we search for knowledge how to design good human computer interactions where in Section 2 a literature review in human computer interaction is done, then in Section 3 a research for the interaction styles and interfaces is done where for each interaction advantages and disadvantages are searched, in Section 4 a review of design principles of HCI is presented, and in Section 5 a conclusion is drown and recommendations are proposed. The main contribution of this paper is investigation of advantages and disadvantages of the interaction styles and the recommendations for designing a good human-computer interaction.

2 LITERATURE REVIEW OF HUMAN COMPUTER INTERFACES (HCI)

"Human-computer interaction can be viewed as two powerful information processors (human and computer) attempting to communicate with each other via a narrow-bandwidth, highly constrained interface" (Tufte, 1989).

Human-Computer Interaction (HCI) is defined by (ACM SIGCHI, 1996) as "a discipline concerned with the design, evaluation, and implementation of computing systems for human use and with the study of major phenomena surrounding them" Dix et al (1998). Another definition given by Preece, (1994) that Human-computer interaction (HCI) is "the discipline of designing, evaluating and implementing interactive computer systems for human use, as well the study of major phenomena surrounding this discipline" (Preece, 1994). "HCI involves the design implementation and evaluation of interactive systems in the context of the users' task and work"(Dix et al., 1998).

There is confusion what HCI is, a science, a design science or an engineering discipline. The definition as a science is "HCI is tempered by approximation, providing

engineering-style theories and tools for designers" (Newell & Card, 1985). HCI as a design science, "developing a craft-based approach and new research methods to evaluate existing systems in their intended and tasks context, using the results to inform designers for the next generation of systems " defined by (Carroll & Campbell, 1989). HCI as an engineering discipline, Long & Dowell (1989) define as "...the design of humans and computers interacting to perform work effectively" while they decompose the discipline into design of humans interacting with computers and design of computers interacting with humans.

Human-computer interaction (HCI) studies how people interact with computing technology and how a computer system is designed more easily, more practically, and more intuitively. These interactions have specific emphasis on the 'interaction at the interface' with the technology in a broader sense. Today, HCI has attracted considerable attention by researchers and "it is one of the most critical challenges facing computer science and engineering" (IEEE).

While designing user interface of these systems, the cognitive processes whereby users interact with computers must be taken into account because usually users' attributes do not match to computer attributes. Also we should take into account that computer systems can have non-cognitive effects on the user, for example the user's response to virtual worlds. (Reeves & Nass, 1996) showed that "humans have a strong tendency to respond to computers in similar ways as they do to other humans" Reeves, B., Nass, C. (1996).

HCI is interdisciplinary field that interrelates with many disciplines as psychology, computer science, cognitive psychology, engineering, artificial intelligence, ergonomics end recently other discipline are input as sociology, anthropology, art sciences etc. So, it incorporates the social as well as cognitive aspects of computing. Crucial factor in HCI design is the interrelation between Psychology and Computer science as (Carroll & Thomas, 1982) state:

"Psychological theory and methods ... can provide a foundation for better interface design; but reciprocally, interface design provides a rich and detailed practical domain in which to assess and refine psychological theories of complex learning behavior. Perhaps both disciplines are now mature enough to contemplate a serious relationship."

Due to the rapid development of hardware and software technologies and their decreasing costs and development of new techniques like speech and audio processing and computer vision, people more and more will use computers in their everyday lives, even people that are from other fields not very familiar with computers. Also, "due to one reason or another some users cannot be able to interact with machines using a mouse and keyboard"(Rudnicky, A.I., Lee, K.F., and Hauptmann, A.G., 1992).

This will lead to designing new multimodal human computer interactions that involve different input techniques like speech or voice, paper-like writing or pen, computer vision (giving the computer the ability to see its surroundings and to interpret them), eye-input technology and gesture. A multimodal HCI application responds to input in more than one mode of communication in a sense of sight, touch, hearing, smell that can be input in a computer through respective input devices. Until now, desktop applications have used mechanical input techniques via keyboard, mouse and visual display and using familiar WIMP conventional interfaces. At the beginning there was a single user –computer interaction in the traditional HCI applications. Now, we have multi-user multimodal

interaction to the computer utilizing new hardware technologies (cameras, haptic sensors, olfactory, microphones and other) which give "the promise for effecting a natural and intuitive communication between human and machine" (Jason J. Corso, 2005) (in the new generation of interfaces that include computer vision, he calls the human computer interaction a "communication between human and a machine". Also, (Preece J., 1994) agrees when stating "Virtual environments and virtual realities typically offer a sense of direct physical presence, sensory cues in three dimensions, and a natural form of interaction (for example via natural gestures)".

This implies new quality of interfaces of these systems, as (Faconti, 1996) says: "User interfaces of many application systems have begun to include multiple devices which can be used together to input single expressions. Such interfaces are commonly labeled multimodal because they use different types of communication channels to acquire information". As the number of the interactive computer-based systems is growing, human activities are rapidly becoming mediated by computers. HCI is concerned "with the design, implementation and evaluation of those interactive computer-based systems, as well as with the multi-disciplinary study of various issues affecting this interaction" (Stephanidis, 2001), while the main concern is to ensure 'ease-of-use', operability, discoverability, simplicity, and learnability moreover safety, utility, effectiveness, efficiency, accessibility and usability (Stephanidis, 2001) and flexibility (refers to variations in task completion strategies supported by the system).

3 KEY ISSUES IN HUMAN-COMPUTER INTERACTION

There are some issues that are important in human-computer-interaction (Eisenhauer M. at al., 2002) and that we have to have in mind when designing an interface of a learning environment: practice (the performance improves with practice), transfer (experts are able to transfer previous knowledge to the current task, whereas novice need carefully designed interfaces), exploration (exploration and the factors that ease the exploration has become one of the most important ways to learn an interface), vocabulary (the vocabulary of users (the commands) increase but the use of the vocabulary is somewhat stationary), flexibility (although flexibility in the interface is present it is unlikely to be used because of all the other interaction going on).

3.1 Overview of interaction styles and interfaces

Interaction styles refer to the different ways of communication between a human and a computer based on a technological platform through interaction techniques which are "way of using a physical input/output device to perform a generic task in a human-computer dialogue" (Foley at al., 1990). Interaction style is explained "through prototypical elements of the interface and how they behave, for instance command line, pull down menu, form fill in, or direct manipulation" (Shneiderman, 1992).

The following fundamental interaction styles and interfaces are used:

- **Command line languages**

This popular category covers the interaction between humans and computers using language by typing the commands to a computer which prompts a message meaning ready to

accept input. It provides means of expressing instructions to the computer directly, using function keys, single characters, abbreviations, or whole word commands. The command line interfaces are powerful in that they offer direct access to the system functionality and can be combined to apply a number of tools to the same data. The command lines interactions are disadvantageous because text commands are usually difficult to learn and use as cryptic keywords and a strict associated syntax which a user has to know before using the system and usually this influences to an increase rate of errors. They must be remembered. Mnemonics only can be used as cues. They are therefore better for expert users than for novices.

- **Menus**

Menus are defined as set of options on screen for choosing the action or among options for data entry. There are three types of menus Shneiderman, B (1992):

- Pull-down menus
- Pop-up menus
- Hierarchical menus

(Preece, 1994) defines a menu as "a set of options displayed on the screen where the selection and execution of one (or more) of the options results in a change in the state of the interface. Unlike command-driven systems, menus have the advantage that users do not have to remember the item they want, they only need to recognize it" (Preece, J. 1994). The advantage of using menus is that user needs to recognize rather than recall objects. The menu options need to be grouped logically and meaningful, so the user could easily recognize the needed option. Although traditionally the user clicks with a mouse over the item to be selected or using a keyboard, with the new hardware technologies developed the user can as well respond via voice command. There is evidence that the number of errors decrease, time to perform a task is shorten unless for complex tasks that need more operations to perform, the navigation through menus to find the necessary option needs more time.

- **Direct manipulation**

Direct manipulation interfaces are very popular and successful, especially with new users, because they embed manipulations that are analog to human skills (pointing, grabbing, moving objects in space), rather than trained behaviors and "users have great control over the display and as they select items, the details appear in windows on the slides" (Shneiderman & Maes 1997) Shneiderman B, Maes P., (1997).

Direct manipulation interfaces "present a set of objects on a screen and provide the user a repertoire of manipulations that can be performed on any of them" (Shneiderman, 1983).

Each operation on the interface is done directly and graphically. From programming aspect, writing a program is done by moving icons onto the screen and connecting them together. The "editing-compiling –running" cycle is simply realized by directly clicking icons on the screen instead of strictly syntax-ed commands or operations. There is no need to remember the command name end syntax. This leads to decreasing syntax errors like you can not compile non-existing code since it is not on the screen when you click the compile icon and faster performance of a task.

According to (Shneiderman, 1983), these kinds of manipulations have some meanings:

1. Continuous representation of the object of interest.

2. Physical actions or labeled button presses instead of complex syntax.
3. Rapid incremental reversible operations whose impact on the object of interest is immediately visible.

Shneiderman (1982) numbers the following advantages of direct manipulation to objects:

1. Novices can learn basic functionality quickly, usually through a demon-
2. Experts can work extremely rapidly to carry out a wide range of tasks,
3. Knowledgeable intermittent users can retain operational concepts.
4. Error messages are rarely needed.
5. Users can see immediately if their actions are furthering their goals, and if not, they can simply change the direction of their activity.

- **Form fill-in**

It is "the simplest style of interaction that consists of the user being required to answer questions or fill in numbers in a fixed format rather like filling out a form" (Shneiderman, 1992). In this form, the only kind of user interaction is the provision of information which is useful for data entry into applications. Also spreadsheets are considered as a sophisticated variation of form filling.

- **Natural Language**

The researchers and practitioners are more interested in systems that use natural-language processing as style of human-computer communication, both of speech and written input.

In the case of speech input, the user must learn which phrases the computer understands since computer requires strict instructions and users may become frustrated if too much is expected. The advantage of using this interaction style is to users that do not have access to keyboards or have limited experience. While ambiguities of the language may cause unexpected effects and makes very difficult for a computer to understand.

A good perspective is that "Natural Language systems should be extended to include non-verbal dialogues", since he argues that "Natural" language includes gestures. Gestures can be used to form clear fluid phrases, and multi-threaded gestures can capitalize on the capabilities of human performance to enable important concepts to be expressed in a clear, appropriate, and "natural" manner" (Buxton,1990).

Natural Language interactions are "a perspective on Non-Verbal Dialogues because they are in many ways, more natural than those based on words" (Buxton,1990).

- **Question/answer and query dialogue**

A simple mechanism for providing input to an application in a specific domain. The user is asked a series of questions (mainly with yes/no responses, multiple choice or codes) and so is led through the interaction step by step. These interfaces are easy to learn and use, but are limited in functionality and power.

Query languages on the other hand are used to construct queries to retrieve information from a database.

- **WIMP interface**

WIMP stands for windows, icons, menus, and pointers (sometimes windows, icons, mice, and pull-down menus). These interfaces are probably the most popular and influential for interactive environments. Windows are areas of the screen that behave as if they were

independent terminals in their own right. An icon is a small picture used to represent a closed window, file, or any other object. The pointer is important component of a WIMP interface, since it interfaces the pointing, clicking, pressing, dragging and selection of objects on the screen which could be moved, edited, explored and executed as it better fits to the user's vision. Other tools of computer interface design are menus, dialog boxes, check boxes, and radio buttons and so on. These make use of visualization methods and computer graphics to provide a more accessible interface than command-line-based displays. The fundamental goal of WIMP designs is to give the user a meaningful working metaphor, for example an office or 'desktop' representation as opposed to the command-line interfaces. Its advantages are general application, make functions explicit and provide immediate feedback.

Humans are highly attuned to images and visual information that in other hand can communicate some kinds of information much more rapidly and effectively than any other method., and as is said "a picture is worth a thousand words ".

- **Virtual Reality**

" Virtual environments and virtual realities typically offer a sense of direct physical presence, sensory cues in three dimensions, and a natural form of interaction (for example via natural gestures)" (Preece, J. 1994).

Besides these styles, new interaction styles have emerged: "speech input/output, computer vision based input (e.g., gestures), audio interfaces (e.g., non-speech audio), tactile and force feedback, biophysical signals (e.g., retina scanner)" (Rauterberg, 2003) which bring us the new generation of interfaces that are non-command-based with interactions like eye tracking interfaces, artificial realities, play-along music accompaniment, and agents.

3.2 Input/Output

The conventional input devices used are keyboard, mouse and visual display that are used in command based interactions.

With emerging of new hardware technologies new input devices are used like cameras, haptic sensors, olfactory, microphones and other.

The new input technologies used are speech recognition, gesture recognition technologies, eye tracking technology as non command based interaction, techniques for communication and manipulation of multidimensional data;

Output devices used are the conventional computer desktop display, Head-mounted displays, autostereoscopic displays, touchable three-dimensional displays, non-speech audio output for 'visualizing' data etc.

3.3 Mental (or conceptual) models

Users form mental models or conceptual models of tasks and systems. These are used to guide behavior at the interface. When people encounter new machines, devices or computers, they begin to construct mental models to represent their behavior and operation. These internal models provide a means by which people can understand and predict the world around them. But, these models are individual and very subjective. Every user forms a mental model that depends on number of psychological, cognitive, cultural, educational, and other human factors. This means that users may form different models for one system that can not

be predicted in designing the system. Even though the research literature has shown that the user using own knowledge after experiencing the system forms more precise and representative model of the system that is working with; we construct these models as we go along and as a consequence our models tend to be incomplete, unstable, do not have firm boundaries, and are unscientific.

3.4 Theories and cognitive models

Some may argue that HCI does not need theory. Any discipline that fails to make a principled explanation to justify its practice is building on sand. The HCI's problem is that its theories are shared with and, in many cases, borrowed from cognitive science. The cognitive science theories are complex, "big science" endeavors that can only be carried forward by communities of researchers, notably ACT-R (Anderson, J. R. and Lebiere, C. 1998) and SOAR (Newell, 1990). Both of these theories have been applied to HCI problems, but the range of phenomena that they can account for is narrow. According to (Sutcliffe, 2000) cognitive theories, implemented as computational cognitive models, have a problem of scale.

However, this is away from predicting similar user behavior in a complex multimedia system. The EPIC model (Kieras, D. E. and Meyer, D. E. 1997) provides an architecture of perceptual and cognitive processors with rules that predict the user's attention, recognition, and understanding of user interface features. While EPIC can accurately predict user performance and behavior with simple user interfaces (i.e., searching menu displays), it suffers from an increasing burden of configuration as the complexity of the external artifact is increased.

4 REVIEW OF DESIGN PRINCIPLES OF HCI

"Researchers have shown that redesign of the human-computer interface can make a substantial difference in learning time, performance speed, error rates and user satisfaction" (Shniderman, 1986).

4.1. General principles for HCI

Folow guidelines from Simpson (1985) (Dumas & Redish, 1999)
Define the users
Anticipate the environment in which your program will be used.
Give the operators control.
Minimize the operators' work.
Keep the program simple
Be consistent
Give adequate feedback

Shneiderman (1992)
Strive for consistency.
Enable frequent users to use shortcuts
Offer informative feedback
Design dialogs to yield closure

Dumas (1999) (Dumas & Redish, 1999)
Put the user in control
Address the user's level of skill and knowledge
Be consistent in wording, formats, and procedures
Provide online documentation to help the user understand how to operate the application and recover from errors.
Follow the principles of good graphics design in the layout of information in the screen.

Design principals for HCI (Baeza-Yatez R., Ribeiro-Neto)
Offer informative feedback
Reduce working memory load.
Provide alternative interfaces for novice and expert users

The "eight golden rules of interface design" (Shniderman, 1986)
1 Attempt for consistency.
2 Enable frequent users to use shortcuts.
3 Offer informative feedback.
4 Design dialog to yield closure.
5 Offer simple error handling.
6 Permit easy reversal of actions.
7 Support internal locus of control.
8 Reduce short-term memory load.

4.2 General principles for document design

Follow guidelines from (Dumas & Redish, 1999)
Ask relevant questions when planning manuals.
Learn about your audience
Understand how people use manuals
Write so the users can picture themselves in the text
Use users' words
Test for usability

4.3 General principles for online document design

Follow the guidelines of Horton(1990) (Dumas & Redish, 1999)
Understand who uses the product and why
Adapt the dialog to the user
Make the information accessible
Make messages helpful
Report status clearly

5 CONCLUSION

To design a good, efficient and ease-to-use user-friendly interface for an e-learning environment as a computer-based system, several issues have to be considered.

In the above discussion, human-computer interaction literature is reviewed as well as technological issues like interaction styles are analyzed and advantages and disadvantages are determined searching for higher bandwidth communication between human and computer and better "fit" between a human and a computer.

We can conclude that in order to design a good human computer interaction, we have to appropriately choose the type of interface and interaction style to fit with the class of users it is designed whereas the human factors must be taken in consideration (Fetaji, M., at al., 2007). Thereby, we recommend the following: to investigate the advantages and disadvantages of interaction styles and interface types that best support the activities and styles of learning of users the system is aimed at; to choose the type of interface and interaction styles that best supports the system goals; to choose the interaction styles that are compatible to user attributes and that support the users needs, which means to choose the styles that are more advantageous for aimed users (for example, in a system for learning and practicing programming, direct manipulation style is more advantageous which are stressed in more detail in section 3.1); and to define the user class (experts, immediates or novices) that the system is designed for, where the human factors must be taken in consideration.

Incorporating HCI design principles, we can ensure better design guidance for screen layout, menu organization, or color usage according to users attributes.

We recommend similar human-computer interaction design to similar solutions.

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