Mika Laakkonen

Learnability Makes Things Click

A grounded theory approach to the software product evaluation

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Abstract

The aim of this doctoral dissertation is to investigate the phenomenon of learnability more deeply in order to better understand the learnability process. Grounded theory was used to determine the ground concepts based on fifteen users' (N=15) actions (N=1836) in the WebCT Campus Edition's virtual environment. Based on this study, the phenomenon of learnability and the learnability process is understood in greater detail and defined from the human centric of view, where the human being is the key actor.

This doctoral dissertation answers the following research problem:

1. How learnable is the WebCT Campus Edition's virtual environment?
2. How can the phenomenon of learnability be defined in a new way?

The WebCT Campus Edition virtual environment's learnability was measured with performance time and directions of action. In addition, the traditional learnability metrics of performance time and direction of users' actions was used to verify the theoretical model of learnability and its nonlinearity. The result of this study showed that the variety of the WebCT Campus Edition's learnability was higher between the individual users than it was between the different tasks. Therefore, the variety of task difficulty, i.e. the complexity or easiness of the different part of the user interface, have less influence on learnability in the WebCT Campus Edition than do the individual users' characteristics. Thus, the research results confirm the results found in earlier studies, where two important issues for usability evaluation and therefore evaluation on learnability, are the tasks and users individual characteristics.

The theoretical model of learnability with following phases of information search, data collection, knowledge management, knowledge form, knowledge build and the result of action were determined from data. The theoretical model of learnability and its main patterns of a) data collection-information search, b) knowledge build-knowledge form and c) information search-

knowledge management proves that learnability is a non-linear process. Therefore, the phenomenon of learnability cannot purely be defined by the separate properties of learnability, i.e. the properties of a user interface and a progressively enhanced linear process illustrated with learning curves.

The theoretical model of learnability is one of the rare models of learnability that is based on empirical data. The use of grounded theory methodology means that the phenomenon of learnability is studied through tacit knowledge, i.e. through users' real actions and though explicit knowledge, the users cognitive processes during interaction i.e. the phenomenon of learnability is approached from the holistic point of view, where the phenomenon of learnability is seen as one holistic process. Thus triangulation, where the phenomenon is interpreted through several split case studies are therefore unnecessary in this research setting.

In conclusion, too many studies are still conducted in a laboratory situation using traditional methodological paradigms. More learnability studies with new methodological approaches in the natural environments are needed were the human, learning and non-linear process of learnability are in focus. It is important to understand more deeply the process of learnability and investigate more in greater detail the key elements that enhance learnability and on the other hand, cause learnability problems for users. Finally, based on the theoretical models of learnability, we can develop tools for the commercial user interface world in order to measure and test the learnability process more precisely and better understand how skills are actually learnt and how "to click" learnability.

Keywords: usability, learnability, measurements, grounded theory

Acknowledgements

I graduated from the Faculty of Education at the University of Lapland in 1995. Besides studying for my master's degree, I took psychology as a minor subject at the Faculty of Social Sciences. Professor Raimo Rajala's rave review of my thesis encouraged me to continue my post-graduate studies in the Department of Education at the University of Oulu. From 1995-1998, I studied full time for my post-graduate studies with the neuropsychological laboratory's research group headed by Professor Timo Järvilehto, and I joined in his seminars. Based on his theory of "systemic psychology," the research group investigated the interaction between organism-environment systems. A profound understanding of the theory of "systemic psychology" led me to form a more holistic picture of the interaction between humans and computers.

I was appointed as a Senior Lecturer at the University of Applied Sciences in Rovaniemi. For three years, I taught foundation courses in education and computer science to first year students. From 2001-2003, I worked as the Virtual Polytechnic's project manager. Those years provided me with the opportunity to attend several international conferences and seminars such as PROMETEUS (Promoting Multimedia access to Education and Training in European Society) in Brussels, TeleCon West in California, TeleLearning in Montreal, EREN (European Region Education Network) in Aalborg, SIGGRAPH (Special Interest Group for Graphics) in New Orleans and Cebit 2002 and 2004 in Hanover. Attending these international conferences and seminars encouraged me to deliberate on the ideas presented by the keynote speakers and lectures. My personal discussions with several well-known virtual environment and information technology specialists abroad gave me some highly valuable feedback. Moreover, my close co-operation with the Virtual Polytechnic and Virtual University in Finland gave me the opportunity to consider several e-learning specialists' opinions concerning the technical and pedagogical usability issues related to educational platforms, the learning objects and the pedagogical models of online learning. The e-learning experts' opinions have been the most helpful and have made it easier for me to understand both the theoretical and practical levels of the context of my dissertation.

Usability and user interface design have been my key interest and part of my everyday of life for years. At the beginning of 2000, I decided to apply to the Faculty of Art and Design at the University of Lapland to continue my studies in the field of human-computer-interaction, with special focus on usability and user interface design. That summer, I received delightful news from the University of Lapland; at its meeting on 29 June 2000, the Council of the Faculty of Art and Design had accepted me as a post-graduate student. Since 2000, I have energetically studied for my Doctor of Arts (Art and Design) degree under the supervision of Professor Mauri Ylä-Kotola, Dean of the Faculty of Art and Design at the University of Lapland. Two years later, a meeting of the Council of the Faculty of Art and Design on 6 June 2002 approved all my required post-graduate studies. Two people were appointed from the University of Lapland to supervise my dissertation: Professor Ylä-Kotola on 18 April 2002 and Professor Isomäki on 9 September 2004. Later, Professor Ylä-Kotola moved to Helsinki to take up his position there as Rector of Fine Arts, and Professor Isomäki took on full responsibility for the writing process of my dissertation.

Moreover, I would like to thank my colleagues Dr Veli-Pekka Räty from VTT Technical Research Centre of Finland, Juha Keinänen and Mehdi Arai from the University of Art and Design Helsinki and Director Marja Rautajoki from Virtual Polytechnic for their encouragement, support and friendship. I particularly wish to acknowledge Mr Risto Lustila, my friend for deep, profound and innovative discussions about user interface design and perspectives in the future. Besides his genuine support and companionship during my doctoral studies, one example of his good fellowship and co-operation has been through the new "SmartUs" design concept that Lappset Group Ltd and the Finnish Funding Agency for Technology and Innovation asked us to design. The result of our preliminary study is available on the SmartUs web pages at www.smartus.fi.

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I would also like to thank the Rovaniemi University of Applied Sciences, which allocated me a one-month (October-November 2005) scholarship from its personnel development found for the final phase in completing this thesis. Finally, I would like to thank the University of Lapland for giving me a grant to have this dissertation proofread by Mr Robert Kinghorn. Mr Kinghorn has been most helpful, and I have learnt lot from his comments and advice on how to improve written English scientific text. Especially, I owe my deepest gratitude to my supervisor, Professor Isomäki, who has given me the fullest support whilst exhaustively training me as a researcher. In addition, I wish to express my warmest thanks to reviewers of this thesis Professor Seppo Väyrynen and Dr. Dave Randall the most accurate comments and improvement suggestions on my doctoral dissertation.

Furthermore, I owe my gratitude to the Rovaniemi University of Applied Sciences for providing me with an enthusiastic working community devoted to further developing my expertise. In recent years, the University of Applied Sciences in Rovaniemi has nominated me for several confidential posts and research-oriented boards such as the Barents Specialist Researchers' Network and Community Learning Networks in Northern Periphery Area, and I have been appointed as Vice Chairman of the Let's Play research project, coordinator of Ubiquitous Services in Northern Finland and Secretary of the Standing Committee on Research at the Rovaniemi University of Applied Sciences.

It took me six years to complete the required post-graduate studies and write this doctoral dissertation. During my studies, I explored various areas of user interface design through literature on virtual reality, human-computer interaction, ICT, e-learning and behavioural science. My colleagues forced me out from my

lonely research in order to discuss my work and the papers written both for seminars and for other academic gatherings.

My first fully reviewed paper entitled “The future relationship between virtual reality and the human body” was published in 2003 at the international conference on User and the Future of Information and Communication Technologies at the University of Art and Design in Helsinki. In 2004, I presented the preliminary results of my doctoral dissertation at the 1st International Summer School of Applied Information Technology that was arranged by the University of Lapland. The summer school provided new ideas and helped me to develop further the theoretical model of my dissertation and to achieve a more holistic understanding of the concept of learnability and its relationship to learning. In 2005, another full paper entitled “Rovaniemi Polytechnic’s first year students’ technical readiness for online learning and the learnability of the WebCT platform” was reviewed and nominated as one of the best papers at the research meeting held at the ITK’05 conference in Hämeenlinna. The annual ITK conference in Hämeenlinna is the most renowned and distinguished online learning conference in Finland. In 2005, I had the privilege of working with my supervisor Professor Isomäki to draft an article called “On the Concept of Learnability,” which was published in Integrated Media Machine (Volumes 3-4): Aspects of Future Interfaces and Cross-Media Culture edited by Mauri Ylä-Kotola, Sam Inkinen & Hannakaisa Isomäki. I would like to thank the anonymous reviewers of the steering committee for my abstract on “The Theoretical Model of Learnability.” It was a privilege to receive most enlightening guidance during the Online Educa Berlin Conference 2005 from Dr Ulf-Daniel Ehlers from the University of Duisburg-Essen, the chairperson of Quality Measurement and Evaluation of E-Learning, and from speakers Dr Tim Linsey of Kingston University, Researcher Song-Hee Kim from Tokyo Institute of Technology and Dr Ambjörn Naeve from Uppsala University.

Sport and exercise have played an important role in my life since my days at the senior comprehensive school in Oulainen. Good physical health has helped me remain diligent with my work. My warm thanks go to my friends Mr Heikki Hannola and Mr Pekka Parkkinen, who reminded me of the importance of

sleep, healthy food and physical exercise and were there when I wanted to share my feelings as a researcher. I also wish to express my warmest gratitude to Irma and Teuvo Peltoniemi, my parents-in-law, who devoted their time as substitute parents for Katariina and Petteri, my children and their grandchildren. Irma and Teuvo gave them many wonderful experiences that will last their lifetime. They took them on trips into the city and countryside, played summer games and went on visits to the theatre, cinema and sports events and took them to swimming school when I was busy working on my dissertation. A word of thanks must also go to my closest family members: to my twin brother Juha and to my little sister Kati as well as to my caring mother Hilkka and my father Paavo who took care of me when life seemed black.

Finally, working with my doctoral dissertation has made my life more interesting. Everyday, I see great examples of how still too many user interfaces are hard to learn; the organism-environment system, i.e. human-computer interaction, is not functioning. In addition, common citizens daily discuss and make statements about learnability. Although my research has opened up my mind and thoughts in the field of science, I have often felt guilty for not spending enough time with my wife and children and our dearest friends and relatives. I would like to stress that without the total support of my loving wife Maria and my two children Katariina and Petteri, who accepted that their father was not always there for them, I would not be here writing this acknowledgement for my doctoral dissertation.

Rovaniemi, December 2006

Mika Laakkonen

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1 INTRODUCTION AND INTEREST AREA

1.1 Introduction

Many industrial companies, such as Nokia and TeliaSonera, have used the slogan “be clicked” for years, and they have developed it further for their marketing. Despite the message from marketing, “be clicked” has not come closer to the average consumer; due to the variety and expanse of different digital facilities, properties and services, the slogan is still as far distant from the average consumer as it was ten or more years ago, i.e. the learnability of modern devices is still very immature. For this reason, it is easy to understand that modern technology is not taken in use. Moreover, new technological devices very often cause human beings to feel frustration, anger, panic, chaos and fatigue and consequently, their resistance to using technological devices is understandable. Harmfully, people often experience unpleasant emotions when they interact with a technological device for the first time. As a result, they may never purchase the same product again or they may never return to using anything from the same product family.

Why it is important to study the phenomenon of learnability? First, by gaining a deeper understanding of the phenomenon and process of learnability, we can design products and services that are more learnable. Second, the present definition of learnability is unclear and there is no clear differentiation between the concepts of easy to use and easy to learn, i.e. there has been no provision for learnability. Furthermore, we do not know when learnability ends and usability begins in relation to time. Neither do we have detailed information on how the attributes of learnability, which are actually the same as the attributes of a user interface, affect learnability. Third, although several definitions for learnability do exist, there are no detailed analyses of the concept. Consequently, learnability and usability have similar attributes. Fourth, there is a need for new methodological approaches to learnability, theoretical models of learnability and tools for learnability. The same methodological approaches as those used by usability researchers have been applied to earlier learnability studies since 1990, which means that learnability researchers have in the main measured learnability with performance time, number or rates of errors and subjective ratings. Thus, no subjective means has yet been created for the exclusive measurement of learnability. However, most subjective usability questionnaires developed so far include learnability as one criterion for usability. Finally, earlier studies have focused on measuring learnability from the point of view of the product and user interface. Accordingly, there is a desperate need for studies that begin to examine the phenomenon of learnability from the human centric point of view, were the human as a learner is a key actor and were the phenomenon of learnability is investiaged in realtime from the learnability process perspective. Above-mentioned perspectives have to be taken account in order to, form more detailed picture of the phenomenon of learnability at the beginning of learning process.

My personal interest in studying the phenomenon of learnability deeply lies in the general unchangeable observation I have made over the years that people have difficulties in taking in use and learning to use household appliances such as microwave ovens, dishwashers, coffee makers, television sets, video recorders etc. in their daily lives. In fact, the learnability of digital devices is even more difficult. Often, the language of user interfaces and manuals for digital devices is very much technically oriented and the use of common language is the exception. In fact, a person has to be technologically oriented before s/he is able to learn and effectively use digital devices. In order to illustrate the importance of studying the phenomenon of learnability in detail, I would like to provide a couple of examples from daily life that we all occasionally face in our natural living environment.

My first example deals with the air-conditioning device in a typical single family home. The orange indicator light on our air-conditioner began to glow so I opened up the manual to discover what the light meant. The manual was full of technical figures, numbers, statistics, test results and the specific vocabulary used by air-conditioning engineers and other experts. However, I managed to find the part in the manual that explained the error messages and the meaning of the orange indicator. But there were two possible problems associated with the orange light: one possible solution was that the filters needed to be changed and the other was associated with the minimum and maximum values for internal and external temperatures. To solve the problem, I first decided to try to change the filters. How should I change the filters? I once more was forced to look at the manual because I had never before changed the filters on any machine whatsoever. However, the manual did not state where the filters were located, how they should be changed or even which filters were suitable for that particular air-conditioner. In the end, with trial and error I managed to open the air-conditioner with a screwdriver and pull out the old filters. But I still did not have slightest idea about the kinds of filters needed to replace the old ones, or even were I could find new ones. I drove to several air-conditioning companies with the technical manual in hand, but none of them had the right filters. Ultimately, I was able to find the air-conditioning company on the Internet. I had to order the new filters from the city of Vaasa. It took me a week to replace the old filters. Fortunately, the bridge indicator light stopped glowing after I had replaced the filters. And I did not need to search for the optimal internal and external temperatures. The above is just one typical example of the kind of learnability problems the average citizen faces because of inappropriate error messages and poor technical manuals.

My second example comes from the Homerun mobile service provided by TeliaSonera, the company that is supposed to “make thinks click”. I had a business meeting in Tampere. My friend, a specialist in information technology and network security, had produced web pages for a company. He wanted to present the graphical user interface to me, so he had placed the web pages on the Internet in order to provide as real an example as possible of how they function on the Internet. All the hotel's Internet connections were in use and so he had to purchase a so-called Homerun Internet connection card provided by TeliaSonera. The Homerun card was covered with plastic foil. He tried to remove the foil but it was so tight around the card that it was impossible to remove it using his fingers. Luckily, he found a pair of scissors in his computer bag. After he had cut off the foil, he had to find a sharp implement to scratch off the covering over the password on the Internet connection card. But when the password was revealed, the scratching had made the letters and numbers in the password very difficult to make out. Despite this, my friend decided to continue and started to follow the installation instructions on the back of the card. The instructions were printed in very small letters and the language was full of technical terminology such as WiFi, IEEE, TCP/IP, PCI/CIA etc. After half an hour of trial and error, my friend asked the hotel receptionist, the one who had sold the Homerun card, to help him. However, the only thing the receptionist was able to offer was the telephone number to the TeliaSonera help desk. My friend called the TeliaSonera help desk and after listening to music for half on hour, he was able to get through. But after the two minutes, the phone call was suddenly disconnected. He decided not to wait another half an hour for the help desk. The learnability of the Homerun card was so poor that even an information technology expert could not use it!

The above two practical examples of learnability illustrate how important it is to understand the phenomenon of learnability and learnability processes more deeply in order to make products and services more learnable and user friendly for the average citizen.

As Laakkonen & Isomäki (2005:207-232) have earlier concluded, contemporary information society user interfaces provide citizens with informational, linguistic, audiovisual, and functional channels to various services implemented as networked information systems. The role of a user interface is crucial in making electronic services part of everyday life because for users, the interface is essentially the product (e.g. Hix & Hartson 1993:1, Elliott, Barker & Jones 2002:550). The acceptability and diffusion of different electronic services as well as intelligent products depends on the learnability and quality of their user interfaces. It is commonly agreed – and explicitly stated in EU and Finnish legislation concerning public electronic services – that usability is an undisputed requirement for high quality user interfaces. Learnability is often seen as the most essential feature inherent in usability. Nielsen (1993:27-28), for example, discloses that learnability is the most fundamental attribute of usability since most products need to be easy to learn and since the first experience most people have with a new product is that of learning to use it, i.e. learnability is followed by usability. Therefore, learnability is the most vital attribute of usability, especially when new technological devices and services are taken in use. Similarly, Butler (1996:59-75) contends that learnability is a critical aspect of usability because a design that causes protracted or repeated learning easily undermines its benefit in various ways, including a loss of users. Jeng (2004:407) considers learnability particularly important when evaluating the usability of digital libraries. It can be assumed that particularly in digital libraries, understanding the learnability process and different detailed theoretical models of learnability are vital in order to locate information more easily and effortlessly.

The focal point of learnability is the user interface of a technological device (most often a graphical interface), and how users can expend the minimum effort to learn to use it. As Dix, Finlay, Abowd & Beale (1998:162) state, essential in learnability is the ease with which usually new users can begin effective interaction and achieve optimal performance. During the past decades, this issue has been the focus of extensive research and development. Common to these efforts is the problem of how to connect the features related to human learning into the attributes of a user interface. Regarding this problem, the most dominant aspect within the field of human-computer interaction (HCI) is the context-oriented viewpoint. Primarily, this view distinguishes learnability in terms of interaction between user, task, product, and environment. Shackel (1986:44-45) and Shackel (1991:21-38), for example, states that a good design depends upon solving the dynamic interacting needs of the four principal components of any use situation in system of: user, task, product and environment.

In conclusion, despite the vast growth of usability studies and evaluations, learnability seems to be a concept whose content is difficult to define, particularly with respect to human learning. In general, most of the current usability studies rely on concept definitions that have were developed during the early 1990s. Regarding research on learnability, a common problem with learnability definitions as well as studies is that they do not specify what learnability is in measurable terms (Shackel 1991:21-38). Recent literature on usability reflects a lack of learnability studies and definitions. For example, a recent and otherwise comprehensive publication, *The Human-Computer Interaction Handbook* edited by Jacko and Sears (2003), omits the viewpoint of learnability. In addition, the four-volume extensive publications of the proceedings of the International HCI '03 conference held in Crete, Greece, in June 2003, consisting of approximately 6000 pages of HCI research, does not address the issue of learnability as an essential object of research. It seems evident that the increasingly essential enigma of learnability requires further examination. In particular, learnability requires further investigation in order to clarify the content of the concept and the kinds of features of human learning the learnability phenomenon might involve. In this doctoral dissertation, I first present the earlier studies on learnability in the traditional context and more recent studies conducted in mobile, multimedia and virtual environments. Second, I examine the prevailing views of learnability and the way the phenomenon of learnability has been related to learning and the theoretical models of learnability. Third, I present the measures for learnability with respect to their constituents. The summary draws conclusions on the attributes of learnability. Forth, I present my own human centric point view of learnability. Fifth, I present the research problems, in addition to the grounded theory methodology used in this study and the grounded theory data analysis process. Sixth, I introduce the main result of this doctoral dissertation: the new model of learnability and non-linear patterns of process of learnability. Finally, I discuss the validity of the model of learnability and compare the results found in this doctoral dissertation with the earlier learnability studies and theories. In conclusion, I point out the key issues that need to be investigated in more detail in future learnability studies and I propose the way in which the perspective of learnability studies needs to be broadened.

Ultimately, the ideal goal of this study is to smooth the path to learning to use devices and to take advantage of them in such a way that will enhance the wellbeing of human beings. At the moment, especially technological devices and applications are too hard for novices and occasional users to learn and assumingly, this is one of the reasons for anxiety and strong resistance among people. It is time to stop developing useless technological products and services that are never used by consumers. Instead, we should focus on further developing such devices that support peoples' welfare and wellbeing. In the near future, using and benefiting from existing modern technology that the majority of human beings can learn to use is vital for our society's wellbeing due to the lack of social and welfare services in the rural sector – learnability makes things click - but how to click learnability.

2 ON THE CONCEPT OF LEARNABILITY

In Section 2, I present the current literature and empirical studies on learnability and I define the concept of learnability from the traditional point of view. The empirical literature on learnability supports and verifies the theoretical definitions of learnability and vice versa. However, as I pointed out earlier there have been an astonishingly small number of empirical studies on learnability. Even though learnability is recognized as one of the most important dimension on usability, it has been almost neglected in empirical usability studies. The learnability of computer programs was mostly studied in the 1990s. However, literature does not appear to present a generally accepted model of learnability. There is also an enormous amount of research on human learning, but its relationship to learnability is almost totally lacking. In the following section, I introduce the most recent literature on learnability studies into databases such as ACM, IEEE/IEE, Ebsco and Elsevier. These databases consist of the world highest quality human-computer interaction and technological literature.

2.1 Earlier studies on learnability

As presented in the following sections, the concepts of easy-of-use and easy-of-learning are strongly related. However, the phenomenon of learnability refers more to the beginning of the learning process whereas learnability is very often defined as being the time required learning to perform a specific set of tasks. Learnability is also very often illustrated with linearly progressive learning curves, where the performance time is located on the X-axis and user proficiency and efficiency is presented on the vertical Y-axis. Therefore, it is easy to understand that most of the earlier studies related the concept of learnability directly to efficiency. Faulkner (2000) points out that in the concept of efficiency sense of time is implemented in ISO DIS

9241 (1996) standard but not to the concept of effectiveness, which purely considers whether or no users is able to carry out the intended task. However, this is in contrast to Shackel's (1986:53) concept of effectiveness as being a measurement of time as well as performance. In addition, the phenomenon of learnability is studied with novice or occasional users and their ability to reach a reasonable level of performance rapidly; i.e., ease of learning refers to the experience of a novice or occasional user on the initial part of a particular learning curve.

In this doctoral dissertation, the theoretical framework of earlier learnability studies is divided into two main parts. In Section 2.1, I present learnability studies from the traditional perspective, where the phenomenon of learnability is studied in the computer software context. I then move on to describe learnability studies within the context of mobile devices and multimedia environments such as Internet services, interactive multimedia applications, smart products and virtual environments. It must be pointed out that in the 2000s mobile device manufacturers have started to pay more attention to the learnability of a new device, i.e. how easy it is to start using a new device.

In Section 2.2, I provide a cross-section of views on learnability and present the close concepts and attributes associated with the phenomenon of learnability. One interesting concept close to the definition of learnability is called the out-of-box experience, which is introduced by mobile device usability researchers. However, the out-of-box experience refers to the practical problems that users encounter when they start using a new device, product or service for the first time. In other words, out-of-box experience studies are very much problem oriented and they purely focus on the practical problems users face during interaction. In addition, the problems are not necessarily encountered at the beginning of the learning process, which can be seen in the study of severe learning barriers by Ko, Mayers & Aung (2004:199-206).

Nevertheless, the out-of-box experience focuses on the practical problems that need to be solved; nobody has yet related it to the theory of problem-based learning, even though the problem-based learning theory has the same kind of problem areas as out-of-box experience research. Due to the lack of cooperation between educationalists and mobile device user interface designers, it is easy to understand that out-of-box experience studies approach learnability in the traditional way, i.e. from the user interface and product point of view. Therefore, out-of-box experience researchers investigate the problem from a very narrow angle through user interface problems and errors.

Section 2.2.1 exposes the relationship between learnability and learning. The most recent studies have tried to link the phenomenon of learnability to users' emotions and learning, and not purely to efficiency. These studies define learnability as the effort that users need to expend in order to learn to use a new interface and thus accomplish particular tasks. In other words, learnability also means the degree to which users feel they are able to start using a device without a preliminary training period or orientation, and whether they feel confident enough about a product in order to be able to explore its features that are not immediately obvious.

Section 2.2.2 introduces the theoretical models of learnability. Due to profound performance orientation studies on learnability, i.e. studies that have measured learnability purely with performance time, number or rates of errors and subjective ratings, there are only a few theoretical models of learnability. The following five theories are presented in detail: 1) the causal model of learnability, 2) the skill acquisition theory by Fitts and Postner, 3) Gagne's phases of learning, 4) COTS (Commercial Off-The-Shelf) Acquisition Process (CAP) and 5) Rasmussen's qualitative model of human behaviour.

2.1.1 Traditional learnability studies within the software context

The traditional point of view considers performance time and number and rates of errors as the main metrics to measure learnability. Therefore, this doctoral dissertation presents the studies from the perspective of performance time, errors, error handing and complexity of product, where the key actor is the product or user interface itself.

The first traditional learnability study within the software context was conducted by Chapanis (1991a:364), who discussed an evaluation made by Software Digest. He compared thirty word-processing programs against the following criteria: ease of start up, ease of learning, ease of use rating, error handling, performance, and versatility. Chapanis (1991a:364-365) presented a correlation of the functions, and found that versatility, which allows a computer or program to perform different operations, is the only function that correlated negatively with the other functions. All others positively correlated with high values towards overall evaluation. Ease of use ratings and ease of learning had the highest correlations towards overall evaluation. Ease of learning was the most positively correlated with ease of use ratings, error handling and ease of start up. The result of Chapanis' study verifies the fact that the concept of learnability is strongly related to the beginning of learning process, i.e. to ease of start up, and it is strongest when associated with the concept of ease of learning. On the other hand, performance seems to have minor impact on learnability at the beginning of the learning process, i.e. ease of start up. Thus, it is hard to understand why performance time and efficiency are so strongly associated to definition and measurements of learnability, even though the performance time and efficiency should be related to the concept of easy-to-use. Nevertheless, it must be pointed out that ease of use ratings, error recovery and performance highly correlate with the ease of learning variable. Conversely, the versatility of computer programs impairs learnability. Nevertheless, when we look the result in more detail (see Table 1), we notice that versatility has the greatest negative impact at the beginning of the learning process and the negative affection diminishes when a user actually performs and uses a word-processing application. Therefore, it can be assumed that versatility becomes a more valuable property of software when the user has become familiar with it and used it for a certain period of time. Moreover, if we want do understand more deeply the beginning of the learning process, i.e. ease of start up, we must investigate the learning processes from the human point of view, which actions and elements during the learning process are the most vital in relation to learnability. In addition, ease of use ratings should be open because of its strong association to learnability (see Table 1).

TABLE 1. Rank order correlations between the measures used to evaluate 30 word processing programs (Chapanis 1991a:364).

	Easy of learning	Easy of use ratings	Error handling	Performance	Versatility	Overall evaluation
Ease of start up	+.65	+.51	+.50	+24	-39	+.62
Ease of learning		+.87	+.72	+.67	-.38	+.93
Ease of use ratings			+.79	+.84	-.29	+.95
Error handling				+.64	-.34	+.82
Performance					-.15	+.81
Versatility						-.25

In his article, Chapanis (1991a:365-367) relates learnability directly to efficiency, where performance time and errors indicates learning. Chapanis states the conventional wisdom among designers is the fact that there is a trade off between products that are easy for novices to learn and products that are efficient for experts to use. Based on his statement, we note that he uses the concepts of easy-to-learn and easy-to-use as synonyms, even though his own data indicates that the versatility criteria for software, which supposedly makes software more complex, has a different effect at the beginning of the learning process than when the user is actual using and working with the software. In other words, it can be stated that the versatility of software supposedly causes more trouble for a novice user than it does for an expert user at the beginning of learning process but during its use, the versatility of software can enhance performance and make the use of software more efficient for both the novice and expert user. In addition, Chapanis measures learnability with traditional metrics: time and errors. His study indicated that the learning scores showed high correlation of r=.078 with the time scores for both expert and novice users. Therefore, learnable systems are also efficient for expert users. In addition, procedural complexity underlies both expert and novice performance. Thus, learning longer methods takes longer to execute. This is also confirmed in a study conducted by Kline, Seffah, Javahery, Donayee & Rilling (2002:34-36). It was found that the learnability of software (IDE=integrated development environment) was difficult for both experienced and inexperienced users. Thus, the conventional wisdom of trade off between systems that are easy for a novice to learn and systems that are efficient to use needs more verification in future learnability studies.

In his article, Chapanis (1991a:365-367) introduces another study conducted by Roberts & Moran (1983). The traditional learnability measures of performance time and errors were used to study learning and the number and rates of errors within the context of nine text editors. In addition, the functionality of text editors was measured. The following four evaluation measures were formed: 1) the average time it took a novice user to learn how to perform a core set of tasks, i.e. learning time, 2) an expert's error free-task time to complete a set of tasks, 3) the average time experts spent correcting errors and 4) the software functionality, a measure of the number of different tasks that could be performed with the program. Besides the high correlation between learning, performance time and errors, the result indicates that functionality, which is very close to software versatility, has a negative effect on learning and performance time (see Table 2). In conclusion, Chapanis points out that Roberts and Moran actually reported the average times experts spent making and correcting errors as percentages of their error-free performance time. Therefore, the average times spent making and correcting errors in relation of error-free performance time can be considered as one of the quantitative measures of learnability.

TABLE 2. Rank order correlations between evaluation scores for nine text editors (Chapanis 1991a:366).

	Errors	Learning	Functionality
Time	+.64	.+78	-.12
Errors		+.71	+.08
Learning			-.08

Another paper by Chapanis (1991b:21-37) introduces a study conducted by Mosteller & Rooney. They studied 3000 logged error messages received by programmers at a mainframe facility. According to their data, nine common error messages accounted for approximately 85% of the events. The error messages were studied in more detail. One particularly poorly worded error message

(“Symbol not defined in procedure”) accounted for 9.8% of the error messages and it was often encountered repeatedly by the same programmer because the underlying error was difficult to correct without any additional information. After improving the wording of this one error message, if was later found that it only accounted for 1.7% of the error messages, indicating that programmers were able to avoid repeating the error.

One of the arguments by Green & Eklundh (2003:644) has been that learning is not required if user interfaces use natural language. But in real life, learning is always required. Chapanis’ (1991a:359-398) results showed that the use of common language in computer software enhances learnability and reduces errors among expert and novice users. His study compared two editors: a Control Data Corporation editor supplied by NOS and a version of an editor that they remodelled with identical power but with its syntax altered so that all commands were based on legitimate English phrases composed of common descriptive words. The results showed that with the remodelled set of commands, both experienced and novice users were able to do more work in a given time with fewer errors and with greater efficiency that they could with the original language. Even though the research result demonstrates the benefit of using natural language, it still is quite common for computer programs and help manuals to have their own specific vocabulary with which common users are unfamiliar.

Moreover, Hollnagel (1991:1-32) assumes that the number of erroneous actions (rather than types of erroneous actions) increases along with the complexity of the product. Hollnagel’s (1991:1-32) assumption is supported by a study by Senay & Staber (1987:244). They investigated in detail the use of online help and logged 52,576 help sessions. They found that 10% of the help screens accessed accounted for 92% of the requests. In addition, Bradford (1990:399-407) analysed 6,112 erroneous commands issued by users on a line-oriented products. Thirty percent of the errors were simple spelling errors, indicating the potential for a spelling corrector to help system users. A full 48% of the errors were mode errors, where users issued commands that were inappropriate for the current state of product.

Besides product complexity, the users' response times affect the number of errors. Shneiderman (1998:356) discusses system response times. He noticed that longer response times for some functions caused people to make fewer errors. According to this measure, slower software products should be more usable. Similar results were found by Hart & Steveland (1988:139-183), who evaluated performance by percent correct and reaction time (RT). The typical finding was that accuracy decreased and RT increased as the difficulty of information processing requirements increased. Shackel (1991:21-38) points out that in a conferencing tool, 1/10 time is spent in overall movement between product parts and the worst value was set at 1/3 of overall time. Therefore, the learnability process needs to be open and the pace, i.e. intensity and delay times between human and computer interaction, needs to be studied in more detail with different task difficulty, novice and expert users, environment and products.

Erroneous actions are also very expensive. Nielsen (1993:3) gives an example of an Australian insurance company that accomplished annual savings of $536,023 by redesigning its application forms to make customer errors less likely. The old forms were so difficult to fill in that they contained an average of 7.8 errors per form, making it necessary for company staff to spend more than one hour per form correcting the errors. Finally, Chapanis (1991a:382-398) states that corrected and uncorrected errors, hesitations, help requests, complaints, and long response times are all symptoms of difficulties that needed serious consideration.

Chapanis (1991a:382-398) introduces a study by Reisner (1977), which evaluates the basic features of the SEQUEL an SQUARE programming languages based on a final examination at the end of a training course. As expected, programmers earned higher scores than did non-programmers (see Table 3).

TABLE 3. Mean percentages of “Essentially Correct” scores by programmers and non-programmers on a final examination covering the basic features of two programming languages (Chapanis 1991a:373).

Programming language	Programmers	Non-Programmers
SEQUEL	78	65
SQUARE	78	55
Mean	78	60

Chapanis (1991a:382-398) states that the results in Reisner’s (1977) study are such as one might expect. However, a more important methodological standpoint is the interactions that occur between a user’s level of sophistication and various aspects of user performance. For example, in Reisner’s data (see Table 3), programmers, i.e. expert users, had exactly the same percentage of correct answers in the examinations for the SEQUEL and SQUARE programs but non-programmers earned significantly lower scores on the SQUARE program. In other words, the results indicate that the SQUARE programming language was easier for programmers than it was for non-programmers to perform, and vice versa. The results also demonstrate that it is vital to consider the type of user being evaluated when drawing up conclusions on the learnability of software. The data proves that individual user abilities, i.e. novice vs. expert users, have the major effect on learnability. Moreover, it is interesting to note that the final examination was used as an indicator to compare the basic features of programming languages.

Chapanis (1991a:373-375) presents another study by Pagerey (1981), which measures the time taken by programmers and non-programmers to read ten chapters and to program six sets of problems at the end of certain chapters dealing with the BASIC program. The results showed that the programmers took 3.5-5.5 hours to go through the training exercise, where non-programmers took from 5.9-9.4 hours to go through the same exercise (see Table

4).

TABLE 4. Average time (min.) taken by six programmers and six non-programmers to program six problems in the BASIC programming language (C). (Chapanis 1991a:375)

Programming language	Programmers	Non-Programmers
4	12.3	12.5
6	13.7	26.7
7	24.3	46.0
8	9.7	31.8
9	52.0	73.7
10	51.7	73.9

Chapanis (1991a:374-398) states that in Pagerey's study of the BASIC language, it was noted that when the average times taken by the programmers and non-programmers to complete the assignments were compared, assignment 4 was completed in about the same time by both the programmers and non-programmers but problem 8 took non-programmers over three times as long to complete. In addition to individual users' skills, task difficulty also had a major effect on learnability. However, in order to discover details on the difference between expert user performance and novice user performance, we have to develop other learnability methods, tools and indicators than simply the performance time needed to answer questions. Why was task 8 more difficult for novice users? Why was task 4 equally easy for expert and novice users?

When the number of graphical user interfaces became dominant and overtook the standard command line system, there was an acute need for companies to study and compare the learnability of two different interfaces. A study conducted by Chin, Diehl & Norman (1988:213-218) found out that graphical user interfaces are more learnable than a standard command line products. Schneiderman (1998) listed five advantages of MDA (menu driven application), and one of them shortened learning time. As I presented earlier in this section, ease of use ratings were very strongly associated with ease of start up and ease of learning, i.e. the use of listings and ratings can be assumed to enhance learnability. In the study by Chin et al. (1988:213-218), 150 PC user group members rated familiar software products in two groups, comparing the following software categories: a standard command line system (CLS) and a menu driven application (MDA). The overall reaction ratings yielded significantly higher ratings for a menu driven application (MDA). Eight of the 21 main component items were significantly different, $p<.001$, for one learning item. In addition, the differences followed the same course, at $p<.05$, on “learning to operate the system”, “exploring new features by trial and error” and “task can be done in a straight-forward manner”, it seems evident that graphical user interfaces are more learnable than command line systems within the computer software context. Same kind of interface shift from menu driven applications toward graphical interfaces can be notice within the modern mobile devices. Nevertheless, mobile devices still often use menu driven application interfaces as an alternative option for a graphical user interface. For instance, the most modern devices, such as the Nokia 9300 mobile phone, include both the menu driven application and graphical user interfaces.

The relevance of usability engineering is recognized in the health care sector. However, most studies continue to evaluate usability by using questionnaires, and the number of actual user tests is few and even fewer studies concentrate on testing the learnability of health care applications. Rodriguez, Borges & Sands (2002:357) present a study of nineteen internal medicine resident physicians’ interaction with a text and graphical-based electronic patient record system. All nineteen users were experienced computer users and had used text-based patient records an average of two hours per day i.e. usability evaluation involved occasional users. The following usability attributes were evaluated: learnability, efficiency and satisfaction within the context of typical tasks such as viewing a patient’s record, documenting and ordering. A subjective user satisfaction questionnaire was used after the task was performed. The dependent variables of the t-test were the time taken to complete the tasks, number of tasks completed and the subjective user satisfaction questionnaire. The results indicated that a graphical-based interface could reduce 35.1% of the time to complete a typical task in comparison with a text-based interface. In addition, the physicians were more satisfied with the graphical-based application. The number of tasks completed is the easiest indicator of learnability i.e. the results of actions are right if they lead to the right solution for a task. The practical thinking pattern is that if the user is able to solve a task then that task must be easy enough. In addition, performance time and subjective satisfaction questionnaires seem to be constant measurement of learnability. However, the result does not show why the learnability of a graphical user interface is more learnable than a text-based user interface, i.e. the learnability process remains the open question.

The most vital elements in a graphical user interfaces are the icons. The meaning of icons should be intuitively recognized without additional text information. However, very often the association between text and icon is not found. Bewley, Roberts, Schroit & Verplank (1983:72-77) present an evaluation of the classic study of icon ease of learning, where four different sets of 17 icons were designed for a graphical user interface. Ease of learning was assessed by several means. First, the intuitiveness of the individual icons was tested by showing them one at a time to the users and asking them to describe, “What do you think it is?” Second, since icons are normally not seen in isolation, the understandability of sets of icons was tested by showing the user entire sets of icons (one out of the four sets that had been designed). The users were then given the name of an icon and a short description of what it was supposed to do, and they were asked to point to the icon that best matched the description. The users were also given the complete set of names and asked to match all the icons with their name. The score for all these learning tests was the proportion of the icons that were correctly described or named. The meanings of icons were not recognized separately one-by-one, which indicates the importance of context in learnability studies. In Bewley et al. (1983:72-77), evaluation setting is rare even though the learnability evaluation setting is very traditional. Why? Because the human and his/her cognitive processes seem to be the key factors in the evaluation of learnability instead of the user interface. In addition, performance time and number of errors are not considered an important measure of learnability.

Bewley et al. (1983:72-77) also conducted two efficiency tests. In the first test, users who had already learnt the meaning of the icons through participation in the learning tests were given the name of an icon and told that it might appear on the computer display. A random icon then appeared, and the users pressed a "yes" button if it was what they were looking for and a "no" button if it was some other icon. In the second test, the users were shown a randomised display of icons and asked to click on a specific icon. Both of the tests were timed, and the score for an icon was the users' reaction time in seconds. It must be emphasized that Bewley et al. (1983:72 - 77) associated intuitiveness with the concept of ease of learning and efficiency with the performance of learnt skills. In other words, performance times could only be measured when the skills have been already learnt. Thus, performance time and efficiency should be associated stronger with the concept ease-of-use and they should be only measured with expert users, i.e. those who have already learnt the skills that are measured. In contrast, we should begin to use the concept of learning time instead of performance time when measuring learnability with novice users.

What are the most important software characteristics for human beings? Learnability is one dimension of usability – but how important a dimension really is learnability. Calisir[a] & Calisir[b] (2004:505-515) studied various usability dimensions of enterprise resource planning (ERP) products with 51 users in 24 companies.

They found that both learnability and perceived usefulness were the most important characteristics for user satisfaction with ERP systems. In addition, perceived usefulness was found to have a stronger influence on user satisfaction with ERP products. Moreover, perceived ease of use and product capability was found to influence ($p<0.01$) perceived usefulness, whereas user guidance was found to influence both learnability ($p<0.01$) and perceived usefulness ($p<0.01$). According to them, a good user guidance scheme would improve the learnability of a system as well as reduce the mental effort of its users. Based on their data it can be interpreted that perceived usefulness is even more important than learnability for user satisfaction, even though the learnability dimension was the amount of the most important characteristics of user satisfaction. Nevertheless, it was interesting to note that product capability, i.e. versatility, was related to perceived usefulness instead of to learnability. However, product capability could also be easily associated with the learnability of a product because it is often the case that the more capable the product is of performing a variety of tasks, it is obvious the more complicated it is to learn and affect learnability. In addition, user guidance influences learnability and perceived usefulness just as strongly.

Based on his studies and personal experience, Chapanis (1991a:359-398) states that in general, computers, computer programs, and well-designed manuals will be easier for people to learn to use, easier to use, allow users to do more work with fewer errors and will be better liked than those that are not well designed. Thus, if he were to nominate one single performance measure to be used when evaluating learnability, it would be errors. Errors can be easily observed and counted. Therefore, if one could design a computer and program that a novice could learn to use without a single error, we would indeed have a genuinely easy-to-use computer.

In conclusion, usability researchers share the traditional perspective and product oriented view, which shows very poignantly in their measurements, writings and statements. For instance, “Chapanis (1991a:359-398) presents a correlation of the measures and finds that versatility, which allows the computer or program to do different kinds of things”. However, as we all know a computer or program does not do anything without a human being. In other words, the human being is not considered an important element when studying learnability of software from the traditional point of view. In addition, it must be stated that all studies purely lack information of human learning. Therefore, the use of the learning concept, such as in Chapanis’ studies, is inappropriate because the widely recognized definition of learning means a permanent behavioural change in the human being which cannot be measured with one evaluation set. For this reason, learnability should be more proper concept instead of learning, because in the traditional view, the concept of learnability indicates contemporary performance improvement at the beginning of the learning process. Finally, it would be wise to design software that is easy for both novice and expert users at the beginning of the learning process, and versatility, i.e. the complexity of software, could increase over a specific period of time that the software is used, i.e. the properties of the software are taken into use step-by-step. This might also reduce unnecessarily erroneous actions.

Finally, it must be stated that the studies by Reisner (1977) & Pagerey (1981) as introduced by Chapanis (1991a:359-398) concentrate more on measuring the difference in the performance level of novice and expert users than on the learnability of programming languages. However, based on the Chapanis’ (1991a:359-398) examples, it can be noted that users’ experiences and personal abilities as well as task difficulty have a major effect on performance and therefore it can be assumed to influence learnability. Boloix & Robillard (1998:185-193) suggest there are three complex features effecting learnability: problem-domain complexity, i.e. the difficulty of a task, method or technique complexity, i.e. the complexity of the user interface itself, and the

HCI process and software complexity, i.e. the number of functions the software includes and the number of new features that need to be learnt before completing an assignment. However, they also address the fact that further research is required on other sources of complexity that affect the learnability of users and user performance. In addition, they point out that future studies must clarify the steps of user performance, especially when documentation for the necessary functions is not available.

In Sections 2.1.2 and 2.1.3, I present the more recent learnability studies within the context of mobile devices and multimedia environments. Nevertheless, the traditional system-oriented view and use of traditional metrics seems to be very dominant and profound in the field of learnability research.

2.1.2 Learnability in mobile devices

In recent years, the mobile phone industry has become increasingly interested in the phenomenon of learnability. Here, I introduce the learnability studies conducted during the 21st century within the context of mobile devices. Ziefle (2002:303-311) presents a learnability study into mobile phones (Nokia 3210, Siemens C35i and Motorola P7389) with 30 novice and 30 expert users who solved six tasks. The actions of the users were recorded in order to accurately reconstruct the navigation route for each user, i.e. the point of hierarchy where the users were distracted and had to reorient themselves by going back in the hierarchy they recognized. The improvement in performance time and number of actions used for solving the task was used as the measure of learnability. In addition, after the tasks the users filled in a questionnaire on the perceived ease of use. As a result, it was found that tasks for all mobile phones could be solved significantly better the second time, and the novice user showed significantly higher improvement of skills i.e. re-learnability than expert users did, i.e. performance times and the number of misleading actions (keystrokes) diminished, which indicates the benefit of training with all mobile phone brands. The ease of use questionnaire reflected the result found in performance measures. Detailed action analyses did reveal a few semantic and several navigation key problems. For instance, the buttons "#" and "*" were frequently wrongly used. The tests revealed that the Nokia 3210 mobile phone was the best. According to Ziefle (2002:303-311), the learnability of mobile phones can only be measured if the tasks are performed twice. Actually, in that case we are measuring the relearnability of mobile phones. The concept of re-learnability is closer to the concept of learning than it is to learnability. Ziefle's (2002:303-311) viewpoint is interesting because of the way the prior skills the users might have had are not purely assessed; instead of the achievement of performance, the focus is on skills. Ziefle's (2002:303-311) approach is especially important when analysing learnability with expert users. However, if we wanted to proceed further and measure learning for mobile phones, we ought to perform a third trial after a certain amount of time and analyse whether the users' behaviour and achievement of performance skills, which could be noted between the first and second runs, have become permanent. Future learnability studies also ought to pay attention to the training and pedagogical methods the users' use between trials because training by different methods has an enormous effect on re-learnability and learning.

Moreover, in a study by Bay (2003:662-663) the users were asked to solve four different tasks twice on a simulated Nokia 3210 mobile phone. The result of her study showed that the use of the spatial maps in the mobile phone manuals might benefit the majority of users. However, the manuals for technical devices are still poor and not very helpful. Therefore, there is a need for more learnability research within the context of different kinds of help desk.

Longitudinal learnability studies are still very rare. A paper by Lyons, Starner, Plaisted, Fusia, Lyons, Drew & Looney (2004:671-678) presents a longitudinal learnability study, where the 10 novice users used the one-hand chording text entry for mobile phones.

Based on their longitudinal data, it is possible to deliberate on the isolation between the two concepts of easy-to-learn and easy-to-use. The novice users typed for 20 sessions using two different methods: Twiddler's 3 x 4 button design and multi-tap, both of which are commonly used mobile phone text entry methods. Lyons et al. (2004:671-678) found that users were intuitively faster at multi-tap typing, i.e. at the beginning of learning process, the Twiddler's 3 x 4 button design was more complex for novice users and therefore the achievement of performance skills were lower. However, after the fourth session, the differences were minimal and after the eighth session, the users typed faster with the Twiddler. Moreover, after 20 sessions the typing rates for the Twiddler were still on the rise. The result indicates that the learnability of multi-tap was better than Twiddler's 3 x 4 button design. However, Twiddler's 3 x 4 button design was more effective. In fact, this result indicates that efficiency is more related to the concept of easy-to-use, to usability rather than easy-to-learn – i.e. learnability. Here, I have to reiterate that most usability experts still relate the concept of learnability directly to efficiency and even use the concepts as synonyms. Moreover, after users have had the opportunity to familiarize themselves with a device, measuring involves more the usability than the learnability of a device. In that sense, Bruijn, Spence & Chong (2002:245-252) use the term Skilled User Performance (SUP). SUP is an indicator of the efficiency of a device in terms of its economy of use. In addition, a study by Lyons et al. (2004:671-678) presented the learning curves for individual users. The steeper a curve climbs for Twiddler illustrates more rapid learning for all users, even though the multi-tap was more intuitive, i.e. at the beginning of learning process the result with multi-tap were higher than it was for Twiddler's 3 x 4 button.

It seems that the importance of intuitiveness diminished with an enhanced learning process. Moreover, the users' prior knowledge and experience of a familiar device might support learnability only at the beginning of the learning process. The curves also showed a large variance in multi-tap entry rates, i.e. there were a high number of individual user differences, and only a minority of the tested users found multi-tap easy-to-use. Despite this result, the learnability of multi-tap was quite high for most of the users. In addition, the learning rates and learning curves for multi-tap and Twiddler's 3 x 4 buttons in the 20 sessions provided an estimate of when the learnability process changes to a process of usability. It can therefore be understood that when the steep learning curves become linear, a devices is mostly learnt and taken effectively into use. However, because all 20 sessions were performed one after another with only a half-hour brake between sessions, the relationship between the concepts of learnability, usability and learning remains an open question.

WAP browsing on small devices requires a lot of scrolling, and hierarchical menus make browsing troublesome. Bruijn et al. (2002:245-252) claim that displaying recently visited pages provides users with an essential navigation aid, especially during their first navigation interaction. This might also reduce unnecessary navigation. Bruijn et al. (2002:245-252) studied an RSVP (Rapid Serial Visual Presentation) browser as an alternative means for web browsing on small screen devices to limit an unacceptable amount of scrolling and navigation. The core idea in RSVP is the rapid serial presentation of new and previously visited pages at the rate between 0.1 and 1.0 second each, probably in order to support human short time memory and therefore enhance the memorability of the user interface. Their empirical study compared the effectiveness of web browsing using RSVP against WAP. The time needed to find the answers to eight questions and the number of extra steps taken to find the right answer in relation to the minimum was used as the objective measure. A questionnaire was also used as a subjective measure. No significant difference was found between the RSVP and WAP browsing in the performance time to complete the tasks. Nevertheless, users took significantly more extra steps than necessary using RSVP to find the answer to Question 1 than those who were using the WAP browser. Accordingly, the use of lists and hierarchical menus is still an effective form of visual feedback in relation to performance time, i.e. visualization and multimedia feedback do not necessarily enhance the performance of users; conversely, extra steps are required in order to find the solution. It also seems that the questions played a significant role in determining the speed taken by a user in finding the right answer to a task. The subjective questionnaire found that the RSVP browser had poor learnability but its functions were easy to control when they were first learnt. On the other hand, the WAP browser was found laborious to operate due to the lack the controls but the users rated most highly the statements related to knowing where to go. In fact, the use of lists and hierarchical menus leads the user to finding the right solution step by step. Therefore, the visual feedback and learnability of the RSVP needs improvement in order to beat WAP browsing. How could this be done? According to Calisir[a] & Calisir[b] (2004:505-515), the learnability of the system could be enhanced by providing users with navigation aids that prevent their disorientation. Second, broad and shallow menu structures should be preferred instead of narrow and deep ones in order to help users understand the logic of the system. In addition, Wren & Reynolds (2004:370-373) have found that problem solving can be improved by adding of minimal visual feedback within the appropriate context.

Bruijn et al. (2002:245-252) have recently developed a linear navigation framework that includes four activities: browsing, content modelling, model interpretation and strategy formulation. Together, these activities constitute the navigation process, i.e. all four activities must be performed before the navigation process. They state that in order to process these activities effectively, it is essential to find the most appropriate method for the visualization of links. Nevertheless, they state that research into the use of applications such as RSVP (Rapid Serial Visual Presentation) browsing needs further expansion.

2.1.3 Learnability in modern devices and environments

This Section introduces learnability studies within the context of modern technology, Virtual Reality environments, innovative input devices and adaptive and modern interfaces.

In the future, many service robots can be voice-controlled. It is therefore vital to avoid cognitive overload when users are faced with many different products. Green & Eklundh (2003:644-650) studied the learnability of the CERO service robot that operates with a speech interface. The CERO robot was developed to perform everyday tasks in an office environment, such as fetching and delivering objects. A general assumption in their paper is that careful dialogue design may enhance the learnability of a product to be handled. In their study, learnability is seen as an effort that users need to expend in order to learn a new interface. The aim of their study was to improve the learnability of the CERO service robot, i.e. to reduce the effort spend on learning and transfer between the interfaces by using natural human behaviour. The starting point of their study is human centric because they raise a general question: how can models of human-human conversation be used to enhance the learnability of the speech interface used for the CERO service robot. A common view is that the human body, especially the human face, plays a special role during language perception and understanding. In addition, feedback is one important element in achieving common grounds in human dialogue. Feedback can be either linguistic or nonverbal human gestures. According to the authors, there are many principles that particularly affect the learnability of human-computer-interaction. One way to facilitate learnability is to adopt design functions and features that are commonly used in other speech interfaces. Consequently, this means that the humanistic starting point of the authors underlines the traditional product and user interface oriented view of the human being as a passive learner. Thus, the most vital attributes of learnability in human-robot communications are predictability, consistency and familiarity. However, they point out that the most important thing in user interface design is to provide the user with intuitive hints for understanding the functions the product can offer, which refers more to the humanistic view of the human being as an active learner. Nevertheless, the fundamental hypothesis is that learning speech is improved for new applications that use the same interface model.

However, as proven in the study by Lyons et al. (2004:671-678) into Twiddler's 3 x 4 button design and multi-tap, even though the learnability of multi-tap was higher at the beginning of the learning process than it was for Twiddler's 3 x 4, Twiddler's was more efficient to use after 20 text entry sessions. Therefore, the product and user interface point of view, i.e. the use of the same kinds of interface models and design principals, might result in ineffective devices. In conclusion, it can be noted that speech interfaces are becoming part of our everyday life as the cost of hardware falls. For instance, nowadays devices such as navigator and audiovisual systems in modern cars have a speech function that needs to be intuitively learnt. However, command-based speech interaction is still quite far from natural speech and dialog, and further research efforts should be spend on gaining knowledge about the principles that affect learnability in speech interfaces.

According to Guzman, Ho-Ching, Matthews, Rattenbury, Back & Harrison (2003:806-807), tangible interfaces for 3D navigation have the potential of supporting learning for novice users. The authors studied the learnability of the 3D virtual environment with 40 middle school science students. The aim was to design 3D input devices that provide middle and upper school pupils with more intuition and learnability to navigate a 3D virtual model of the human body. Two physical 3D input devices (an adjustable arm and a fork) were designed and then compared with a standard monitor and mouse interface. Learnability was measured by using a subjective questionnaire that evaluated the best aid to learning the devices. Their study found that both of the tangible interfaces improved intuitiveness and learnability for novice users. However, the standard keyboard and mouse interface was preferred to the adjustable arm due to its familiarity and additional capabilities. In conclusion, it can be noted that for pupils even the new kind of 3D input devices can be more intuitive and learnable than the traditional standard keyboard and mouse interface. It would be also interesting to conduct the same kind of study with older users to see if the results are the same because it seems that besides novice vs. expert users, the users' age has an effect on the result of learnability. However, no learnability studies currently take this background knowledge into account.

A paper by Pilgrim, Bouchlaghem, Loveday & Holmes (2000:126-134) presented a learnability study of data visualization in a Virtual Reality environment. The aim was to design the display for a three dimensional object to help spatial recognition and data navigation. The purpose of their paper was to point out the possibilities of different Virtual Reality environments in the design world, such as in the sketch design stage, architecture, urban planning, detailed airflow etc. The study was based on observation at the workplace. In addition, the performance times of common key work tasks were recorded. There was also a usability questionnaire, and the rate of correct and incorrect solution to the tasks was counted. The test involved three groups of users. Group 1 was used at the control group in testing Microsoft Excel spreadsheets. Group 2 tested the spreadsheets with macros and Group 3 tested the Virtual Reality environment prototype. The groups performed 44 tasks that all users were familiar with, such as: How many translucent surfaces are there in the room? Which room has the highest maximum air temperature, etc? Since Group 3 had not used a Virtual Reality environment before, they were given a ten-minute training session before they were asked to perform a task. As a result, Pilgrim et al. (2000:126-134) found that each user spent a significant amount of time searching, formatting and manipulating the output. Each test took approximately one and a half hours to perform. The results indicate that in Groups 2 and 3, the number of correct answers and perceived usability increased in relation to control Group 1. The performance times of Groups 2 and 3 also showed clear improvement over the control group. However, there was no significant difference between Groups 1 and 2.

How can human cognition, i.e. the learnability process, be improved? According to Pilgrim et al. (2000:126-134), there are six major ways that visualization can improve cognition and consequently the learnability of the environment. These are: 1) increasing the memory and processing resources for the user, 2) reducing the search for information, 3) enhancing the perception of patterns, 4) enabling perceptual interface operation, 5) using the perceptual attention mechanism for monitoring, and 6) encoding information in a medium. In addition, simulation can reduce the resources expended in development. In fact, the authors emphasize the importance of human memory and the human perceptual mechanism in association with the learning process. They recommend that the future development of Virtual Reality works on a tool that helps adapt knowledge and facilitates communication during the analysis process with fellow workmates. Accordingly, all six principals can help users to adapt knowledge and therefore improve learnability. However, all six design principals should be further tested in the world of designing a common user interface. Moreover, we do not know how those six principals affect communication between workmates during the analysis process.

Raisamo & Räihä (2000:483-506) present an empirical study undertaken with twenty-two university students that compares the ease of use, intuitiveness, learnability and efficiency of alignment menus, palettes and the alignment stick. The students were divided in three groups: experienced, intermediate and novice users. It must be born in mind that the age of the users was not considered important background knowledge in dividing the users into groups. The study presented the users' ages as a median (20 years) and variance (19 – 53), but which group they were involved in remained open. Moreover, in this study the users were divided into groups based on the length of time they had used the device or their familiarity with the tasks, i.e. their skills were not tested in any other way before the evaluation. Nevertheless, the subjects were given only the basics before they performed the tasks in order not to lose any indication of their relative intuitiveness for different techniques. However, the training was carried out just before each method was tested, which might have enhanced their intuitiveness of all three methods. On the other hand, it can be also thought that the training before the test increased other attributes of learnability, such as memorability, but decreased their intuitiveness of methods. The students were asked to rate methods in three ways – naturalness, ease of use and overall evaluation – according to the Likert scale of 1-5. Objective ratings were also used, i.e. performance time, errors and the use of two-handed input in the experiment were analysed from videotapes. It must be pointed out that naturalness, ease of use, ease of learning and overall evaluation were supported with same metrics when testing the usability or learnability of devices. Therefore, it can be stated that a precise difference between the attributes of usability and the way they should be evaluated was not made. Thus, new tools to accurately measure the learnability of a device are needed.

Nevertheless, Raisamo & Räihä (2000:483-506) found that novice users discovered the new direct manipulation tool, i.e. the alignment stick's basic operations, natural and easy to learn. The alignment stick outperformed the other methods in relation to performance time. In addition, the time and number of operations correlated and the intuitive way of aligning objects reduced the conceptual errors of direction, which could be noted with both the menu and the palette methods. In addition, almost 80% of the students considered two-handed interaction beneficial. However, surprisingly the novice users found the naturalness of the alignment stick poorer than the experienced and intermediate users did, but they still rated the alignment stick the easiest to use. As the authors themselves comment, the difference between the ratings for naturalness and ease of use seems strange. For this reason, they provide us with a possible explanation based on their observations during the sessions. They noticed that basic operations of the alignment stick were intuitive and easy. However, subjects might have evaluated the alignment stick as a whole because the additional functions of setting the alignment points were not considered natural. In conclusion, the authors point out that the novice users were from the very beginning of the learning process as fluent with the new alignment tool as they were with the alder tools. However, the experienced and intermediate users needed a short time to become familiar with the alignment stick, i.e. learnability was not as easy as it was with traditional tools. In other words, the experienced and intermediate users had to unlearn before they could relearn the use of the new device. Therefore, it can be stated that intuitive interfaces and natural interfaces are based on previous experiences and consequently, more advanced users take some time to “unlearn” habits and customs. Thus, experienced and intermediate users have to unlearn before they can relearn the use of a new device. The result of this study indicates that it is beneficial to design new kinds of devices especially for novice users because for them, new devices are as easy to learn as old ones are, and they learn even more effectively. However, there is demand for a longitudinal study in which a group of users can really get used to the new way of behaviour.

One of the key on-line merchandise and e-commerce challenges is to maintain an increasing amount of information update, without unnecessary learning effort and workload for the customer. Therefore, it is vital that the data management tools used for increasing the variety and amount of information update are efficient. According to Diego Rivera (2005:1749-1751), previous studies have proved that by blocking off seldom-used UI functions, novice users are able to accomplish tasks significantly faster with fewer errors. Diego Rivera (2005:1749-1751) presents a study of content customisation within the e-commerce context from the perspective of learnability and perceived workload. The learnability task was to create 20 different products using four different web prototypes that had different density and customisation capability. For instance, a computer manufacturer may need 60 different attributes to describe its products whereas a retailer may use only 10 different attributes. Performance mean time, number of errors and a subjective questionnaire were used to measure trials with 12 participants. The NASA Task Load Index (see Section 3.2.8) was used to measure perceived workload. As a result, it was found that content customisation enhances learnability, i.e. it allows a user to reach peak performance faster and to reduce task learning. In addition, content customisation diminishes perceived mental demand and frustration. It would be interesting to see future studies discuss the relationships between the concepts of mental demand, perceived workload, frustration and learnability. A resent study conducted by Jeng (2004:407), for example, states that learnability is to measure learning effort and to see if users achieve a specified level of proficiency. In conclusion, there are a limited number of studies that still considers human emotions an important issue when measuring the learnability of a device. However, we know that human motivation and emotions have a major impact on learnability and therefore they should not be neglected in learnability studies.

Paymans, Lindenberg & Neerincx (2004:301-303) studied the ease of use and learnability within the adaptive user interface context with eight participants. Users were asked to view two 30-minute video streams using a mobile device prototype. The learnability of the mobile device was measured using a mental model test with 10 short scenarios, where the users had to indicate which of the 6 features of the mobile device (battery, bandwidth, noise, light, movement and required discretion) were on or off in different environments. Scenario-based mental model tests are often used methods at the beginning of the design process. Ease of use was measured with a questionnaire and by asking a similar set of questions six times during each video stream. They found that with adequate user support, it is possible to improve ease of use but surprisingly it reduces the learnability of user interfaces. However, their study did not properly define the concepts of ease of use and learnability, and the reader is not given detailed information concerning the measurement of ease of use and learnability.

In conclusion, one major problem in the learnability studies presented in Sections 2.1.1-2.2.3 is that they do not define the concept of learnability precisely and accurately. This is understandable because the definition of learnability has been associated directly with the attributes of a user interface. In fact, no differentiation of the traditional dimensions of usability and learnability has been provided. The same traditional metrics of performance time and errors are also used to measure both ease of use and ease of learning. Actually, learnability is supposed to be the one of the important dimensions of usability. However, the attributes of learnability and usability are very similar (see Section 3). One reason for this is that usability and learnability studies have focused on user interfaces and products, i.e. the viewpoint and key player has been the product itself instead of issues such as individual human capabilities, skills and backgrounds, the complexity of tasks and the effect of longitudinal studies on pedagogy, training and frequency of use in different learning environments. In addition, there is also no singular subjective learnability questionnaire. Subjective learnability questionnaires often explicitly recognize the learnability dimension or it is implied in the questionnaires' scale items (see Section 3.2).

Finally, I provide a typical example in the learnability study conducted Pilgrim et al. (2000:126-134). The study does not define the concept of learnability even though the abstract for their paper states that the user test involved measurements of learnability, efficiency, memorability, errors and satisfaction. They present the result of the user trials at the end of their paper. The authors state that it was impossible to collate meaningful data for the analysis of memorability or learnability, i.e. they thought the data was insufficient to measure the effect of learning and remembering tasks. In fact, as I present below, performance time and errors actually are the most commonly used measures of learnability (see Section 3.1). In other words, Pilgrim et al. (2000:126-134) have measured the learnability of a Virtual Reality environment in the traditional way by using performance time and errors as a primary indicator of learnability. Nevertheless, their results are attached purely to the effective of use the Virtual Reality environment, i.e. efficiency is not included to the concept of learnability. However, the most interesting point of view is that they associated the measurement of learnability with learning and state that increased performance is largely be based on improved support for searching and locating data. Actually, searching and locating data are vital parts of the learnability process and therefore they form a part of the model of learnability developed in this doctoral dissertation.

In Section 2.2, I provide the definition of learnability from the traditional point of view, i.e. where learnability is seen as a linear process. I also present the dominant user interface and product oriented viewpoint. However, there are more recent studies where performance time and efficiency are not the only indicators of learnability. Therefore, in Section 2.2.1, I move toward human centric learnability studies where the concept of learnability is connected to studying human learning and the human being is the key actor.

Section 2.2 also presents a few theoretical models of learnability.

2.2 Views of Learnability

The concepts of ease-of-use and ease-of-learning are strongly related (Haramundanis 2001:7-11, Elliott et al. 2002:551 and Ziefle 2002:303). However, ease-of-learning refers more to the beginning of learning process. According to Nielsen (1993:27-28), learnability is the most fundamental attribute of usability because most products need to be easy to learn and because the first experience that most people have with a new product is that of learning to use it. Therefore, learnability refers to the ease with which new or occasional users may accomplish particular tasks (e.g., Kuljis 1996:687-694). Often, ease of learning refers to a novice user's experience on the initial part of a particular learning curve (e.g., Dix et al. 1998:162). Highly learnable products have a steep incline for the first part of the learning curve, allowing users to reach a reasonable level of usage proficiency within a short time. These kinds of products are easy to learn but they are often seen as less efficient for expert users. Chapanis (1991a:359-398) defines ease of learning as the time required to learn to do a specific set of tasks (see Figure 1). In this way, time is seen an essential feature of learnability in addition to the ease of learning.

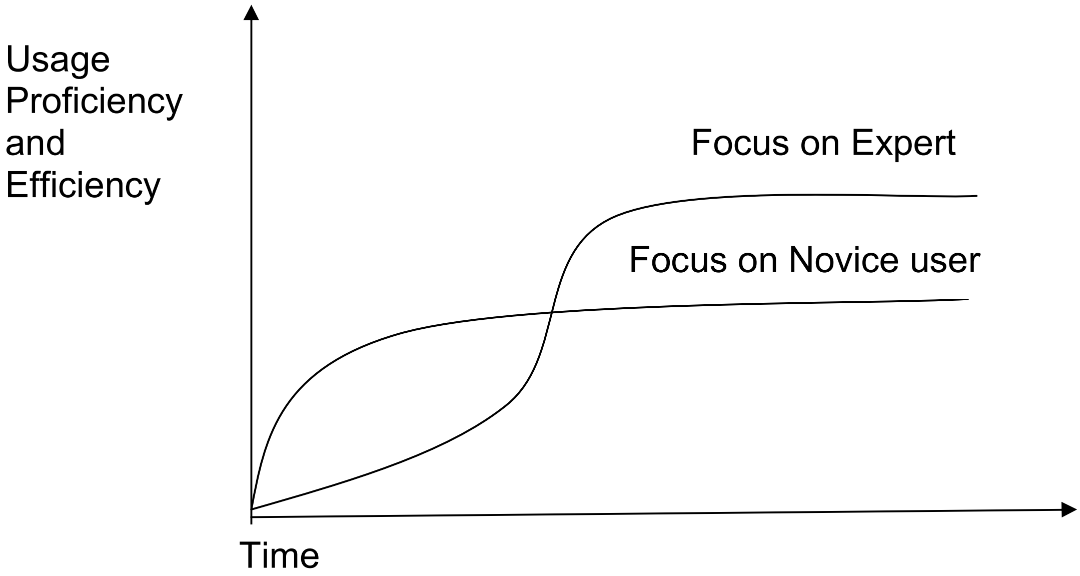

FIGURE 1. Learning curves for a hypothetical product that focuses on the novice user. (Nielsen 1993:28)

Nielsen (1993:28) emphasizes that practically all user interfaces have learning curves that assume the user is able to do nothing at time zero. However, Telles (1990:243-247) states that the standard learning curve does not apply to cases where the users are transferring their skills from the use of a previous product, such as when they upgrade from a previous to a new release of a word processor. Furthermore, Polson, Muncher & Elgelbeck (1986:78-83) point out that if the new product is reasonably consistent with the old one, users should be able to start a fair bit up on the learning curve for the new product. The learning curve in Figure 1 may give the impression that either one can have a product that is easy to learn or one that is eventually efficient, though initially hard to learn. In fact, often a product that provides novice users with learnability is also good for the experts (Nielsen 1993:28).

Often the definitions of learnability emphasize time in relation to some of the principal components of any use situation of system:

user, task, tool and environment (Elliott et al. 2002:551). For example, Hart & Steveland (1988:139-183) consider learnability measures as the speed and ease with which users feel that they have been able to use the product or as the ability to learn how to use new features when necessary. Moreover, Shackel (1986:53) and Shackel (1991:21-38) stresses the relationship of performance to training and frequency of use, i.e. to novice users' learning time with specific training and retention. The definition of learnability by Nielsen (1993:29), van Welie, van der Veer & Eliëns (1999:613-620), Ziefle (2002:303-311) and Holzinger (2005:71-74) refers to novices' ability to reach a reasonable level of performance rapidly, which indicates that they relate learnability directly to efficiency, i.e. the user interface should be easy to learn so that the user can rapidly get some proficient work done with the system. In this sense, learnability is also important in that users are able to reach expertise faster while using a product with high quality learnability.

Nevertheless, more recent definitions of learnability do not relate learnability directly to performance time and efficiency to use. Rodriguez et al. (2002:357) define learnability as user ability to learn to use a user interface and achieve productive work. The authors' definition of learnability emphasizes two things: user ability to learn and achieving productive work. In addition to the definitions related to time and performance, more recent definitions stress users' experience as an important feature of learnability. For example, Kirakowski & Claridge (1998) state that learnability within the web context is the degree to which users feel able to manage the product's basic functions during its first use. On the other hand, users have to be able to sense that they can also learn to use other, more advanced product features easily and when necessary, access other information sources once they have started using a web service. Similarly, in the MUMMS questionnaire (2003) learnability is defined as the degree to which users feel that they are able to start using a product without a preliminary training period or orientation and whether they feel confident enough about the product in order to explore its features that are not immediately obvious. In addition, Ziefle's (2002:303-311) definition of learnability is concerned with factors that allow users to easily understand how to handle a specific device.

According to Elliott et al. (2002:558) and Pirhonen (2005), users' experience with regard to the ease of the first use is often referred to as the intuitiveness of an interface. Intuitiveness is also one of the most important attributes of learnability, and it seems to have the strongest effect particularly at the beginning of the learning process. However, the intuitiveness of most web-authoring tools has been extremely low. Therefore, it is important that UI designers frequently take advantage of users' prior experiences and use metaphors for computer processes that correspond to the everyday world with which people are comfortable (e.g., Apple Computer Inc. 1987:3). Green & Eklundh (2003:645) moreover point out that in order to design learnable interfaces, devices also have to support commonly known physical features such as shape, colour and size. Ravden & Johnson (1989:32) and Norman (1990:54-55) also emphasize that the way a product looks and works should be compatible with users' conventions and expectations. Norman (1990:55) and Green & Eklundh (2003:645), especially point out that natural mapping, which means taking advantage of physical analogies and cultural standards, leads to immediate understanding, i.e. intuitiveness, and is easily learnt and always remembered.

Quite recent studies by Elliott et al. (2002:551) and Green & Eklundh (2003:645) confirmed that consistency is one factor that affects learnability. Moreover, consistency makes learning easier because new things have to be learnt only once. According to Apple Computer Inc. (1987:6), Ravden & Johnson (1989:49), Norman (1990:189), Holcomb & Tharp (1991:49-78), Nielsen (1993:132-134), ISO 9241 (1996), Shneiderman (1998:13) and Green & Eklundh (2003:645) design should recognize consistency, which refers to interface solutions holding to the same principles over a set of individual cases or situations. Norman (1989:189), Ravden &

Johnson (1989:49) and Thagard (1996) contend that consistency is concerned with creating and reinforcing user expectations by maintaining predictability across the interface. Ziefle (2002:303-311) states that users should be able to predict the effect of their actions based on their past experience, i.e. a user should be able to reuse the knowledge s/he acquired during the learning process. In a same vein, Apple Computer Inc. (1987:6), Haramundanis (2001:7-11) and Ziefle (2002:303-311) have noted that effective applications are consistent both within themselves and with one another. In other words, they are internally and externally consistent. In fact, the standard elements of an interface ensure ease of learning but they are not necessarily more efficient to use (Raisamo & Räihä 2000:483-506). Despite this, Norman (1989:189) and Ravden & Johnson (1989:49) are convinced that consistency can also greatly increase the speed of learning. In addition, Zhu, Gonçalves & Fox (2003:385) emphasize the consistency of the semantic constrains context of digital libraries. That is to say, learnability improves the efficiency and effectiveness of human-computer interaction and significantly reduces the likelihood of errors.

Errors, however, are seen as a normal part of users' learning (Norman 1990:200 and Isomäki & Häkkinen 2001:157-188). All users make errors, but Ravden & Johnson (1989:68-71) point out that it can be frustrating for the user to have to spend large amounts of time correcting trivial errors, or having to be extremely careful in order to avoid them. Therefore, a product should be designed to minimize the possibility of user error, with inbuilt facilities for detecting and handling those errors that do occur. Users should be also able to check their input and correct errors or potential error situations before the input is processed (Ravden & Johnson 1989:68-71, Norman 1990:200 and Polson & Lewis 1990:191-220). In addition to error minimization, the principle of task match is of utmost importance with respect to learnability. In particular, designers should provide exactly the information that the user needs in order to accomplish and complete his or her tasks with the product (Ravden & Johnson 1989, 56-59, Norman 1990:191-193, Polson & Lewis 1990:191-220, Holcomb & Tharp 1991:49-78, Nielsen 1993, 134-135, ISO 9241 1996, Elliott et al. 2002:553). Therefore, Ravden & Johnson (1989:56-59), Norman (1990:192) and Green & Eklundh (2003:645), for instance, emphasize that user control and informative feedback is extremely important for users when learning a product and understanding what they can do at any particular stage of a task. In addition, feedback is a common ground of human natural dialogue with an interface. People learn best when they are actively engaged in a task (Apple Computer Inc. 1987:7).

Moreover, memory load reduction is a rule that addresses a fundamental principle of human cognition. This principle shows that people do not remember unrelated pieces of information exactly. Many errors can be expected when precise recollection is required, which is why interaction should rely more on user recognition than on recall. Recall is prone to error, while people are very good at recognizing objects (Apple Computer Inc. 1987:4, Norman 1990:58, Holcomb & Tharp 1991:49-78, Nielsen 1993:129, Shneiderman 1998:355-357 and Haramundanis 2001:7-11). The allocation of work between humans and computers should therefore be such that computers present alternatives and patterns whereas people select and edit.

Nielsen (1993:26) defines memorability in very concrete terms. The casual user should be able to return to a product after a period of absence without having to learn everything all over again. Having an interface that is easy to remember is also important for users who return after a vacation or who for some other reason have temporarily stopped using a product. Largely, improvements in learnability often make an interface easy to remember but in principle when returning to a product, its usability is different from what it was when the user faced the product for the first time (Nielsen 1993:31, Bevan & Macleod 1994:132–145 and Thagard 1996). In other words, memorability increases relearnability to a great extent, but it does not replace it.

Besides the specific learnability attributes during task interaction, in order to understand the product users should be provided with informative, easy-to-use and relevant guidance and support, both on the computer (via an on-line-help facility) and in hard-copy documentation (Ravden & Johnson 1989:71-74, Halcomb & Tharp 1991 and Nielsen 1993:148). Users should be able to request help for any point of the product exploitation particularly within the context of the task. It is extremely important for a help facility to explain the options available to users at their current point in the task. Ravden & Johnson (1989:71) claim that on-line guidance also provides a very effective learning tool, if structured well.

Haramundanis' (2001:7-11) theoretical paper gives a very different approach to the concept of learnability than the studies presented earlier. In her paper, the concept learnability is merged with the characteristics of the human being and learning. According to her, the following characteristics of the human being are related to the learnability concept and they should be studied in order to create more learnable user interfaces: humans learn quickly, remember well, behave resourcefully, exhibit extraordinary patience when they believe they are being treated fairly and are problem solving. This doctoral dissertation shares her views concerning the human being. However, the key elements of learnability interfaces in Harmamundanis' (2002) paper as memorable, logical, reconstructive, consistent and visual are quite traditional and contrast with way she perceived the human being i.e. for instance the element of consistency strongly supports the "keep it simple principal", where the human seems to be perceived as a passive learner. Nevertheless, Paymans et al. (2004:301-303) emphasize the important visual feature of a user interface in order to build adequate mental models. Bruijn et al. (2002:245-252) also state that visual features do not always enhance the learnability of devices.

2.2.1 Learnability vs. learning

As I have previously concluded, earlier studies have investigated learnability purely from the product and user interface point of view.

In addition, definitions of learnability have not taken account in human and environmental issues; instead, learnability has been related to the performance and efficiency of a product or user interface. Thus, the definitions of learnability and the concepts associated with learnability have remained very traditional and even unchangeable at the beginning of learnability studies. In fact, the concept of learnability has rarely been related to learning, learning theories, pedagogy, teaching or motivation.

Pilgrim et al. (2002:126-134) and Ko et al. (2004:199-206) emphasize that in the future, learnability studies should concentrate on investigating how to support learning with severe learning barriers from human point of view. Moreover, Kellogg, Lewis & Polson (2000:69-74) point out that HCI studies need to focus on training users to use productive learning strategies and not only support for learning by exploration. Ko et al. (2004:199-206) state that the use of many design heuristics is in itself a challenge for any human-interface designer. Instead of creating a list of design heuristics, a more learner-centric design metaphor should be presented. Nevertheless, most of the current so-called learner-centric design metaphors lack even the slightest mention of human involvement. Despite their arguments, we can see that pedagogical studies with respect to learnability are still rare. This section presents the most modern and human centric learnability studies.

One of most modern peer tutoring approaches to learnability, i.e. the pedagogical approach, is presented by Höysniemi, Hämäläinen & Turkki (2003:203-225). They investigate teachability and learnability by using peer tutoring with children in the environment of a physically interactive computer game. They built a research environment, i.e. a physically and vocally interactive computer game, for children with web cameras installed to detect the position and movement of the children's bodies and microphones to detect their voices. The main idea of the peer tutoring was that classmates taught each other how to use the computer game, i.e. the idea of peer tutoring enabled the evaluation of teachability and thus provided knowledge on how children used the system and how they communicated about the computer game. According to the researchers, children only taught the things they liked, understood and felt are important. This kind of information is vital in the sense of user interface design because users select the parts of an interface that are the most attractive and learnable. The evaluation task involved two different versions of the flying game task. An interesting point of view in their study was to benefit from the contextual movements of the children, i.e. the researchers observed the most intuitive movements of children and adapted them to the story of context. As a result, the learning of movements relevant to the story became easier and faster, which is important because children tend control their world as quickly as possible. In addition, the use of the intuitive movement of children made them more attached to the computer game. In conclusion, they state that peer tutoring has proved to be effective in detecting usability flaws, promotes natural communication and improves the design of computer games. However, the challenge for further research is to approach the peer tutoring method from the point of learning theories in order to better understand how teaching patterns emerge and how children actually learn from each other.

In more recent studies Höysniemi & Hämäläinen (2004:131-134), Höysniemi and Hämäläinen & Turkki (2004:27-33), continue to emphasise the importance of intuitiveness, physical appropriateness of the movements used to control the game and narrative context in order to provide a children a pleasant play experience in physical interactive games (PIGs). In their opinion, the best user interface solutions can be found via observing children movement during the game. In addition, Hyösniemi et al. (2004:27-33) state that using the contextual movements in relation to narrative makes the learning phase shorter, which reminds us the importance of contextuality when studying the learnability.

Pirhonen (2005) analyses learnability in terms of different views of learning. According to him, learnability is a key attribute in the out-of-box experience. The out-of-box experience focuses on users' problems when they first interact with the new a device. The phenomenon of learnability was studied within the context of a portable music player with sixteen participants who all had a technological background. The tasks were performed in laboratory conditions, where each user action, which ranged from 80-160, was captured by a video camera. The learnability of the portable music player was measured with performance times, direction of user actions in relation to task goal and errors, which were separated into logical and technical errors. In addition, the proportion of successful actions amounted to the five latest actions before the succeeding action was measured in order to predict the probability of success. As a result, it was found that the result for the play/stop and volume functions had a very high percentage of success. However, the "next track" and "previous track" actions were first relatively well performed but a clear drop in the success percentage was seen after a couple of attempts. The result for "next track" and "previous track" seems very strange because usually, the success percentage increased and errors decreased during the learning process. For instance, in a study conducted by Lyons et al. (2004:675), error rates using the Twiddler mobile input device quickly decreased from 10.4% to less than 5% after the second session. However, the result of Pirhonen's (2005) study first proves that performance does not steadily enhance between sessions. Second, his study relates learning theories to the concept of learnability. His paper divides learning strategies into three parts: behavioural, cognitive and constructivist strategies. Different cognitive processes are needed, depending on task difficulty. More detailed constructivist learning strategies are important when the level of task difficulty is high, but behavioural and cognitive strategies can be used when the task difficulty is lower. Nevertheless, Pirhonen (2005) states that even in the design of simple and trivial tasks, cognitive strategies have more to offer for the designer.

However, his use of the traditional measurement of learnability (see Section 3) diminishes the value of his paper and the way he presents the results of his study. The users' actions were purely illustrated with percentage values instead of a deeper analysis of the content of their actions, i.e. which actions produced a successful result in relation to the goal. In addition, the paper fails to have a deeper discussion on the relationship between traditional usability studies and learnability, which is very important in order to merge the learning concept with learnability. The relationship between learning theories and learnability also needs further study.

Bhavnani & John (2000:205-261) present an empirical study of a CAD user in order to understand learning strategies. The task was to edit a CAD drawing of ceiling panels that overlapped air-conditioning vents. The task is very common drawing task performed by architects during detailed drawing. User performance was measured with time and errors. Performing the drawing task took over 30 minutes. Of total performance time, 16.1% was spent on correcting errors and splits, 0.4% was unexplained actions and 83.5% of the time was spent on handling the actual task. Their study concluded that many of these errors could have been avoided if an accurate aggregate-modify learning strategy had been used, i.e. the use the CAD drawing application's properties to complete the repetitious task of cutting and cleaning many lines. In addition, using the aggregate-modify learning strategy would have reduced to ideal case time to complete the task to 71%. Therefore, in the sense of learnability, most of the time it is beneficial to exploit the specific capabilities provided by a computer application before performing the actual task.

Kashif & Daniels (2000:309) moreover emphasize the importance of pedagogical effectiveness in on-line learning courses and environments. In their opinion, it is not enough that on-line learning courses and environments are usable; they also have to account for pedagogical objectives. Instead of talking about user-centred design, we ought to focus on learner-centred design, i.e. the learnability of the learning environment, where the pedagogical dimension is added. Boloix & Robillard (1998:185-193) also relate the concept of learnability to pedagogy. The purpose of their study was to evaluate, how pedagogical settings affect learnability on an engineering course. The learnability of five different software applications that are needed during the different stages in the software lifecycle was measured with performance time and the number of functions the user requires during a task, i.e. the degree of complexity in using the product. The times taken to complete the tutorials, learn the software and complete the exercise were measured separately. First, the time taken to complete the tutorials was measured as suggested by the software vendor or if the information was lacking, it was estimated by the instructor. Second, the time taken by the user to learn some of the software functions in order to perform a task was measured. Third, the actual time taken by the user to complete the task was measured, which included the time to learn the task. Boloix & Robillard (1998:185–193) found that COSTAR software was the most learnable followed by Microsoft Project, Schemacode and StP. SUIT (Simple User Interface Toolkit) was found to be the most complex to use and required the largest amount of time to complete tasks. The authors also state that there is widespread recognition that the learning curve is steep when both theory and practice are taught during a one-semester (see Table 5).

TABLE 5. Average time taken to perform lab activities. (Boloix & Robillard, 1998:189)

	Time to complete tutorials (hours)	Time to learn tool (hours)	Time to complete exercise (hours)
COSTAR	0.6	1.5	5
Microsoft Project	1.5	3	6
StP	1	1.8	7
SCHEMACODE	0.5	1.7	6
SUIT	0.5	4	16

Boloix & Robillard (1998:185-193) present very interesting results in comparing the software’s tutorial pages, documentation required (pages) and user manual. The first column in the table below presents the number of pages in the tutorial provided by the software vendor. The second column shows the number of documentation pages available to solve a proposed task. The last column shows the number of pages in the user manual. StP software has the most help desk features, followed by Microsoft Project and SUIT. The help desk features for the SUIT software seems to fail even though a substantial amount of help included the time to learn the software and the exercises with the software were very demanding for users. COSTAR, which included adequate help features, was considered the most learnable software. In conclusion, it must be stated that help desk dimension seems to be one of the important elements in learnability, especially when the complexity of tasks and software increases. Thus, it can be partly understood why Kline et al. (2002:34-36) relate the concept of learnability directly to the usefulness of error and help messages (see Tables 6 and 7).

TABLE 6. Pages of documentation per tool. (Boloix & Robillard, 1998:190)

	Tutorial (pages)	Documentation Required (pages)	User Manual (pages)
COSTAR	37	37	(120) + 37
Microsoft Project	~50 on-line	~50 on-line	600 +~210 on-line
StP	47	37 + 47	723 + 47
SCHEMACODE	18	18	36 + 18
SUIT	16	~60 + 16	162 + 16

In their paper on minimalism in ubiquitous interface design, Wren & Reynolds (2004:370-373) found that parsimony, transparency and ability to explore the features of devices are an effective learnability design principal. The term minimalism in their paper means transparent design, where cognitive demands on the user are minimized. They implemented a system called *go board*, where they used the two design philosophies of transparency and parsimony. Their empirical study compared the learnability of the traditional GUI system to *go board*. They found that users preferred the minimalist tangible interface, i.e. *go board*, and performed tasks significantly more rapidly with this interface. In other words, transparency and parsimony as a design principal enhance the learnability of devices. They also point out that in the sense of learnability, it is important for a user to explore a new device in a familiar way. Furthermore, a survey by Nielsen (1989a:66-75) found that 4 of the 6 highest-rated usability characteristics out of 21 characteristics all related to exploratory learning: easy-to-understand error messages, the possibility to do useful work with a program before having learnt all the program's features, the availability of undo, and confirmatory questions before the execution of risky commands. Lin, Choong & Salvendy (1997:267-278) and Calisir[a] & Calisir[b] (2004:505-515) confirm the results in Nielsen's (1989a:66-75) survey and they associate exploratory learning with learnability and perceived usefulness. However, Nielsen (1989a:66-75) associates exploratory learning quite strongly with error recovery, which can be associated with behaviourist learning, i.e. a trial-and-error way of learning.

Khatwa (2004:1-11) presents a study of a flight simulator (RASS) from the human point of view, which evaluated the factors as pilot spatial awareness, decision-making, workload, overall pilot acceptability and the ease of learning the flight simulator's functions. The purpose of flight simulator was to enhance the pilots' awareness during aircraft surface operations and final approach by adding visual information to oral announcements. For instance, visual information was provided to support the announcement "on runway". The announcement meant that the aircraft was lining up on the runway to within 20 degrees of the runway heading. The study involved two groups: one group used the fight simulator system and the so-called non-RASS group was used as the control group. The study objectively measured the pilots' performance and operational safety with the flight simulator (RASS). In addition, a Boeing 737-400 flight simulator was used in a between-subject experiment design. The pilots' tasks involved normal and abnormal situations associated with runway incursions. It took the each crew an average of two hours to complete the evaluation. The study by the researchers found that RASS improved pilots' awareness, i.e. the pilots recognized potential accidents earlier. The detailed results of spatial awareness showed that the distance to detect an incorrect runway in the RASS group was significantly lower than in the non-RASS control group, i.e. the RASS application improved the spatial awareness of pilots to detect the incorrect runway earlier than in the control group. In addition, RASS enhanced the pilots' decision-making and did not increase their workload. The Bedford Rating Scale was used to identify the pilots' mental capacity during completing a task. The workload ratings were significantly higher for the non-RASS control group than for RASS group in all scenarios.

Khatwa (2004:1-11) states that the main goal in the sense of learnability was to minimize flight crew training requirements. The pilots were given a short training period for RASS, which was enough for the pilots to complete all tasks without the further explanation of RASS functionality. In addition, no extra concentration was required to use the RASS application. Furthermore, none of the errors that took place during the interactions was noticed during the learnability task. Performance time per task did not increase with the use of RASS; on the contrary, a reduction in task time with RASS was noted in three out of eight tasks. Furthermore, the pilots' were able to satisfactorily complete all flight tasks and the ratings for overall pilot acceptability and learnability were very high.

Khatwa's (2004:1-11) study raises two interesting points. First, collaboration between the pilots' is necessary in order to control aircraft. Although collaboration makes the learnability of the RASS application more demanding, no learnability problems were found. However, the paper does not include any data on collaboration between the pilots; rather, the paper focuses on presenting the visual information of the RASS application. Another interesting point is that the pilots' task performance was associated with their mental capacity. In addition, it states that learnability and training problems would lead to higher task performance times. In conclusion, Khatwa's (2004:1-11) study emphasizes the investigation of human cognitive processes, i.e. learning processes, as a valuable resource and the design of applications to improve people's security.

According to Bhavnani & John (2000:205-261), a profound goal of learnability studies has been to create a simplified user interface that reduces the time to take a device into use. This approach is based on the assumption that users acquire better skills thorough experience. However, several studies have proved that basic command knowledge does not progress to the efficient use of a device. In other words, knowledge of tasks and tools is in itself insufficient to make users more efficient; rather, learning strategies are the most vital to the efficient use of device. Thus, Bhavnani & John (2000:205-261) connect the concept of learnability directly to pedagogy. They present several learning strategies within the context of applications such UNIX, CAD, word processors, and spreadsheets. According to them, learning strategies can be taught to users to aid them in seeking out the more efficient use of a device. Learning strategies involve three principals: 1) they exploit the specific capabilities provided by computer applications, such as iteration, propagation, organization and visualization, 2) knowledge is difficult to acquire from product and task knowledge alone and, 3) they are widely general in nature.

Nevertheless, Bhavnani & John (2000:205-261) present the question of why even experienced users do not learn and use learning strategies. The first possible explanation is that learning strategies are not explicitly provided in manuals nor explicitly taught during training. The second possible explanation is that the causal relationship between method and quality product is not clear enough for a user. For example: in a CAD drawing application, the user have to start drawing from the upper left corner and finish in the lower right corner of the sheet in order to avoid lines being smudged or drawings getting dirty. The third and simplest explanation is that office culture does not encourage learning. Despite many years of computer experience, users have not acquired the knowledge to efficiently use an application or even more ineffective, experienced users use the totally wrong tool to perform a task. Bhavnani & John (2000:205-261) raise another question of why learning strategies are not used even when they are known. One reason for this might be that prior habits have so strong an effect that their impact seems unchangeable.

The main idea of all learning strategies introduced by Bhavnani & John (2000:205-261) is that users should have deeper knowledge of tasks and tools and especially of the intermediate layers located between task and tool that have to be learnt in order to accomplish a task and where hidden critical knowledge usually exits. In conclusion, the authors state that if so-called hidden critical knowledge could be implemented directly for task and tool, we would have more learnable and effective devices and the amount of training could be minimized. Thus, it can be thought that a better understanding of learning strategies, i.e. pedagogical models, and the theoretical models of learnability (see Section 2.2.2) could together solve some learnability problems.

As stated earlier, the intuitiveness and guessability of devices seems to have the most significant influence on learnability. Thus, it is easy to agree with Chromsky's theory, which was used in a study by Irani & Ware (2004:308-314), that language is based on deep cognitive structures and is learnt intuitively. There have also been theories that the same kind of deep structure also exists in vision and for this reason, this link between visual and language structure may explain why certain kinds of diagrams are easy to learn. If these theories could be applied and better understood in practice, we could map the semantics of diagrams into structural objects and thus accelerate learning.

Irani & Ware (2004:308-314) have tried to adapt these theories to practice. They present an empirical study where they compare average error rates between Geon diagrams and commonly used UML class diagrams. The visual theories of deep human cognitive structures were adapted to the Geon diagrams. The subjects were divided in two groups: novice and expert users. All the subjects, both novice and expert users, had an hour-long training for object oriented modelling during which the Geon diagrams and UML class diagrams were introduced. A week after the training the subjects completed the tasks, when they were asked to present a particular problem with the right diagrams. The study found that the performance of even UML experts was better by using Geon diagrams, even though they had studied the UML language on a software engineering course. In conclusion, perception-based diagrams are more learnable and thus the use of linguistic rules and visual theories of deep human cognitive structures improves the learnability of diagrams.

Goh, Chang, & Lai (2004:564-571) present a novel approach to learnability. The active learning process was analysed based on the complexity of subjective query concepts for image retrieval. The main purpose of the authors was to find the best mathematical algorithms for information searching. First, the authors define the concept complexity with three different measures: hit-rate (scarcity), isolation and diversity. Each of the concepts affects the learnability of a concept in a different way. The hit rate indicates the instances of matching the target concept, i.e. the percentage of right search results; if the hit rate is low, it is difficult for the active learning algorithm to find enough relevant cases to achieve an accurate search result. It can also be assumed that efficient training, i.e. pedagogical tools, is lacking if the hit rates are relative low. Isolation is the degree of separation from other concepts; in their study they provide the empirical evidence that if isolation between different concepts is too low the use can be expected to display an amount of confusion and on the contrary, a good isolation of concepts results in more accurate information search results. Diversity is defined as the way relevant images are located in input space. According to the authors, the more diverse the concept is the more explorative the algorithm needs to be, i.e. it can be thought that the more complex a device or product is the more explorative it needs to be with respect to learnability. In addition, they present three active learning algorithms: speculative, simple and angle-diversity. The speculative algorithm and simple algorithm create samples by investigating the user's feedback. However, the angle-diversity algorithm performed the best out of all active-learning algorithms. This was especially the case when some interaction was involved. However, the researchers also noted the limitations of active learning. The first limitation was related to scarcity. The problem with scarcity was the lack of available images relevant to the concept to be learnt and, the other was the lack of isolation between the concepts. Thus, the active learning strategies were insufficient and ineffective to locate the relevant information. In conclusion, they point out that their content search method is more effective because they sample the concept in different clusters based on their complexity and enhance learnability by the concept-dependent active learning (CDAL) process, i.e. they adapt the sampling strategy to the concept's diversity. In brief, concept-dependent learning is highly effective.

The results from the empirical studies by Goh et al. (2004:564-571) indicate that the more complex the task or device is then the more search and explorer functions a user interface should provide. This means that in the optimal case, a user interface should be adaptive in relation to the task: for instance, based on user actions and the suggested percentage of hit rates, a user interface should be adapted to human behaviour and the interface should be simplified and designed to provide adequate pedagogical hints if needed. The easier a task is the more isolative the learning environment can be. However, when the complexity of a task increases, interaction with others is vital. In fact, communication between humans is the most effective pedagogical method to enhance learnability and the possibility to find new innovative ways of algorithm to behave. Moreover, the most important task for an active learning algorithm is to find the most useful training to learn the query concepts. However, the authors have had trouble in finding training irrespective of the complexity of concept to be learnt. Thus, we could interpret that different complexity levels of task need an individual pedagogical approach in order to be effective. Finally, it was very fascinating to see that the researchers, who tried to find the best mathematical algorithms for information searches, seemed to focus on the non-linear processes of learnability as well as on pedagogical issues even though their approach was still very product oriented. Nevertheless, a dialog between humanistic and natural science researchers could be beneficial in broadening our understanding of learnability processes.

In conclusion, the authors state that all learning strategies seem to be intuitively efficient. However, they need to be rigorously further tested with different angles. Therefore, besides exploring efficient learning strategies, the authors suggest that learning strategies could systematically be used to check whether functions added by user interface designers actually help users become more efficient. A common theoretical framework is therefore needed that could help with the systematic identification of learning strategies and result in more effective ways of training and that could moreover provide user interface designers with more principled methods to design functions. This kind of learning and pedagogical oriented research approach could also prevent the insufficient use of modern technology.

Section 2.2.2 introduces the current theoretical models of learnability and gives a more detailed introduction to the six severe learning barriers as specified by Ko et al. (2004:199-206).

2.2.2 Theoretical models of learnability

As presented earlier, the learnability of devices has been studied from the user interface and product point of view but there does not seem to be any generally accepted model for the dynamics involved in learning computer software product in literature. There is also an enormous body of research into human learning, but its relationship with learning computer systems seems lacking. However, some studies have investigated the learning processes of computer programs from the human centric point of view, i.e. how the skills are actually learnt.

First, I present a paper by Elliott et al. (2002:547-574) because they used the grounded theory approach to investigate the ease-of learning of hypermedia authoring tools. The advantage of grounded theory is that it generates theory and explains the phenomenon under investigation. Therefore, by using this method it is possible to form a deeper understanding of phenomenon of learnability. To the best of my knowledge, besides this doctoral dissertation their paper is the only one that uses grounded theory methodology within the context of learnability.

Elliott et al. (2002:547-574) introduce two studies of the learnability of HAT (Hypermedia Authoring Tools). The learnability of HAT was measured in a natural environment in a real-time learning situation. During the first study, the authors' used both quantitative and qualitative data to investigate the experiences of 16 novice academic students learning to use HAT. The quantitative data involved 16 statements that were factored to ease-of-learning, ease-of-use and task matching, and the qualitative data included audiocassettes; the users were encouraged to make comments during the interactions. In the second study, IT trainers observed the users during their interaction. This approach is close to hermeneutic methodology, which is a very commonly used method of evaluating the usability of different devices. However, none of traditional usability guidelines was used during the observation because the results found from the first study were used in second study when designing the structure and question prompts.

Based on those studies, Elliott et al. (2002:547) present the key factors that affect learnability and how these factors interact, i.e. a model of the process of learning a HAT. The following key factors were discovered from the causal model of learnability:

a) transparency of operation: "The summative aspects of an HAT that allow users to find, understand and than use rapidly and easily the functions of the HAT to achieve a task or sub-task"
b) transparency of purpose: "The summative aspects of an HAT that supports a user's image of the end-product at any point during its use"

c) accommodation: “The degree to which an HAT puts a user at easy”
d) accomplishment: “The sense imbued in the learner that the HAT has enabled them to author something useful.”

Elliott et al. (2002:547-574) found that the model of the process of learning is linear with the following causalities: transparency of operations, transparency of purpose, accommodation and accomplishment. In other words, transparency of operation and transparency of purpose lead to a sense of accommodation and finally to a sense of accomplishment. In addition, the poor transparency of operations and purpose lead to increased effort and longer task completion times. In other words, transparent design minimizes cognitive demand on the users (Wren & Reynolds 2004:370-373). However, transparency of operation is directly related to the efficiency of a user interface that allows users to find, understand and then use rapidly and easily the functions of the user interface to complete a task or sub-task. In addition, transparency of operations refers to concept guessability used by Dix et al. (1998:162), Bruijn et al. (2002:245-252). They define guessability as an indication of intuitiveness, i.e. how obvious the operations are that can be performed by users who have no experience with the device and have not received any earlier instruction. Bruijn et al. (2002:245- 252) use the term guessability as a synonym for learnability. Transparency of purpose means that users should be able to imagine the end product at any point during its use. However, it would be beneficial if transparency of purpose is understood and seen before the interaction process and not during it. The third phase of causal model of learnability, accommodation, is more related to the concept of easy-to-use than it is to easy-to-learn. The fourth phase is very close to the concept of usefulness, which is a separate concept from that of learnability.

Moreover, Elliott et al. (2002:547-574) causal model of learnability is compared in relation to Gagne’s phases of learning:

the motivation (expectancy), apprentice (attention, selective perception), acquisition (coding, storage entry), retention (memory storage), recall (retrieval), generalization (transfer), performance (responding) and feedback (reinforcement) phases. In conclusion, Elliott et al. (2002:547, 569) emphasize that the grounded theory approach offered an explanatory theory, i.e. a causal model of learnability to provide information for hypermedia authoring tool (HAT) design, which is more detailed and complete than any other contemporary theory of learnability, i.e. a model that explains the dynamics of learning. Elliott et al. (2002:548) also suggest that studying learning process might encourage researchers to design educational efficacy interfaces due to the increased amount of hypermedia used in teaching.

A paper written by Pirhonen (2005) presents another theoretical model of learnability, i.e. skill acquisition theory. The skill acquisition theory was originally developed by Fitts & Posner and further developed by Anderson, where the declarative knowledge “knowing what” and procedural knowledge “knowing how” support each other in the process of skill acquisition. The theory recognizes three phases. The first phase is called cognitive, where the learner is trying to understand the task. The second phase is called associative, where the understanding of the task begins to emerge in existing skills and where inappropriate patterns of action are rejected and new patterns are generated. The third phase is called autonomous, where less cognitive control is necessary and skill becomes automatic. Pirhonen (2005) states that we should use different learning strategies based on the kind of task we are trying to solve. The cognitive view might be the most helpful when designing user interfaces in detail. On the other hand, the constructivist view is more suitable if we want to consider subjective experience and conceptualisation processes. The figure in his paper shows that the higher the learner’s task knowledge is the more constructivist strategies are in use. In other words, learning a new device is easier if we are able to utilize the users’ existing mental structures during the learning situation. Nevertheless, Ziefle (2002:303-311) has found that common learning patterns, i.e. the experienced mental models, do function in a familiar context. However, they are inefficient in the new technological situation. Thus, the demanding job for designers is to be able to recover new learning patterns that are sufficient in the new technological situation. In conclusion, it can be stated that for humans living in modern society, the abilities of unlearning and relearning are more important than the ability to learn.

The focus of the study presented by Ko et al. (2004:199-206) is on the environmental and human learnability barriers. They define the learning barrier from the human perspective; if the assumptions of humans towards a program are valid before s/he begins the learnability process s/he will make a progress but if his/her assumptions are invalid, knowledge breakdowns will probably be evident. It must be pointed out that in the study by Ko et al. (2004:199-206), transparency of purpose comes before transparency of operation. In addition, the theory by Fitts & Postner emphasizes that a user has to “know what” before “know how” when interacting with the user interface. In addition, the assumptions of humans towards a program are very close to Gagne’s motivation (expectancy) phase of learning (Elliott et al. 2002:547-574), (see Figure 2).

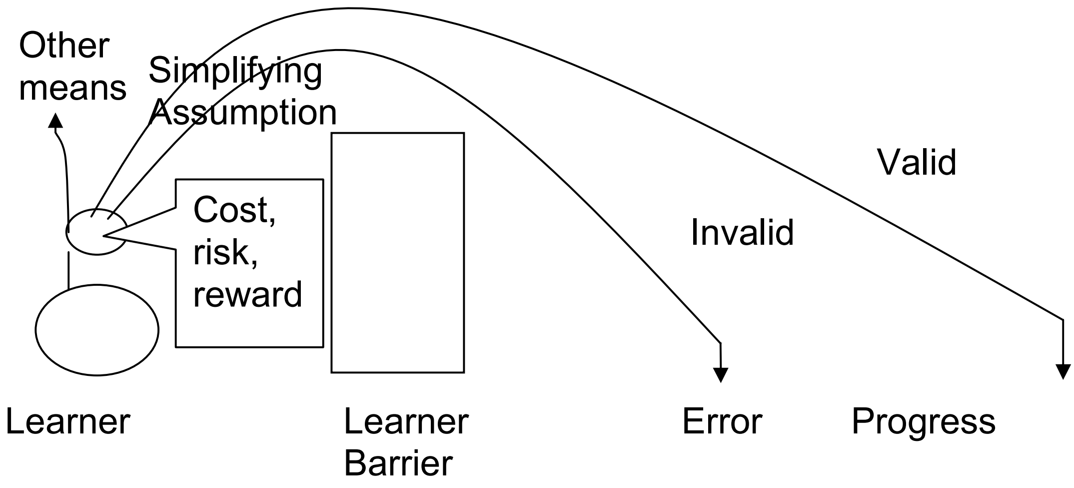

FIGURE 2. In overcoming barriers, the risk to learners in making invalid assumptions that often leads to error. (Ko et.al. 2004:199)

A study by Ko et al. (2004:199-206) with 40 novice programmers identified six learnability environmental barriers within the context of Visual Basic.NET. The definitions of the barriers rely on the activities of novice users with severe learning barriers. The concepts of following six learning barriers – design, selection, coordination, use, understanding and information – were determined from the Visual Basic.NET interface.

1) *Design barrier* included cognitive difficulties of a programming problem. "I don't know what I want the computer to do…"

2) *Selection barrier* involved attributes of an environment's functions, i.e. what programming interfaces are available and which can be used to achieve a particular task. "I think I know what I want the computer to do, but I don't know what to use…"

3) *Coordination barriers* included the limits on programming interfaces i.e. how to merge interfaces in its language and libraries to proceed with complex behaviour. "I think I know what things to use, but I don't know how to make them work together..."

4) *Use barriers* involved the attributes of programming interface usability problems. "I think I know what to use, but I don't know

how to use it…"
5) *Understanding barriers* involved properties of a program's compile or runtime errors, where the learner could not evaluate the program's behaviour relative to his/her expectations. "I thought I knew how to use this, but it didn't do what I expected…"
6) *Information barriers* involved the attributes of an environment that make it difficult to acquire information about a program's behaviour. "I think I know why it didn't do what I expected, but I don't know how to check…"

At the end of their study, the researchers describe a new metaphor of computation that facilitates a more learner-centric view of programming software products, which is very interesting. They propose that selection barriers tend to lead to use barriers, i.e. usability problems can be expected when a user has difficulties in finding the right tool or interface to perform a particular task. Furthermore, they point out that selection, coordination and use barriers often lead to the understanding and information barriers. It must be pointed out that 60% of coordination problems lead to understanding problems and 50% of design problems lead to selection problems. In brief, many severe learning barriers are due to invalid assumptions that learners have to overcome earlier barriers, i.e. errors are cumulative (see Figure 3).

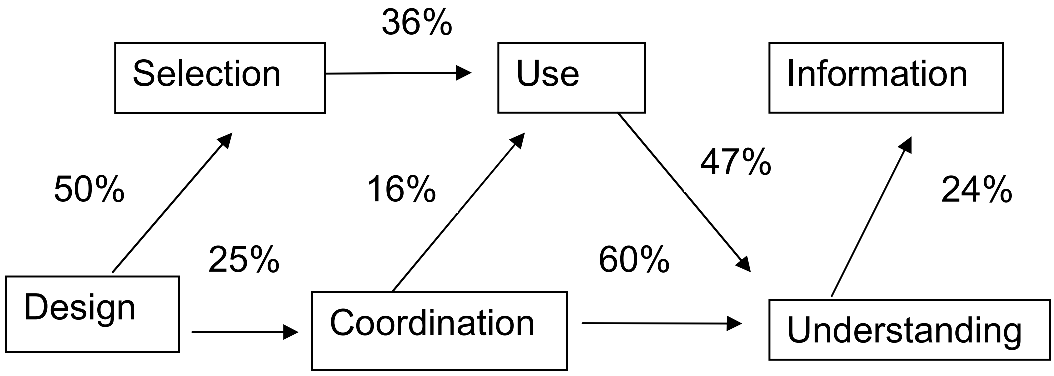

FIGURE 3. For surmountable barriers, the percent of each type overcome with invalid assumptions, and the type of barrier to which the assumption led. (Ko et. al. 2004:202)

Finally, it must be stated that Ko et al. (2004:199-206) has investigated only the severe learning barriers that occur during interaction. However, they have purposely left out the other interaction processes, which are very important if we want to understand the learnability process as a whole. In addition, as with the other theoretical models of learnability, their model of severe learning barriers is illustrated with a simplified linear process. Nevertheless, their study is one of the rare studies that broaden the understanding of the human learnability process, i.e. from the point of view of the users' individual actions. Their study brought very interesting points to our knowledge. First, severe learning barriers are not necessarily caused by understanding the data itself but by not knowing how to act with the data. Second, in their experience the presented learning barriers are general enough to capture differences between three programming software products. However, a deeper understanding of learnability interaction within other contexts and as a whole process is vital in order to draw a more profound picture of the learnability process.

Moreover, Torchiano, Jaccheri, Sørensen & Wang (2002:335) introduced two interesting concepts related to learnability called Commercial Off-The-Shelf (COTS) and COTS Acquisition Process

(CAP). The purpose of their study was to develop a structured approach to COTS exploration and learning within the educational context. A traditional way to learn about Commercial Off-The-Shelf (COTS) is to define a set of attributes and then collect information about them. However, their paper proposes a set of attributes for COTS product characterization within the context of learning and shows why ISO 9126 is insufficient for this purpose. Nevertheless, COTS involves several similarities with the generic usability evaluation attributes defined by ISO 9126 but CAP provides a more general framework where the aim is reduce the effort needed to take a new product into use through reusing the information acquired during the learning process. The general framework in CAP divides the learning process into three parts: initialisation, execution and reuse.

In addition, Helander, Landauer & Prabhu (1997:92-99) introduce Rasmussen's three-level model of skill based, rule-based and knowledge-based human behaviour in the context of supervisory control paradigm. (see Figure 4)

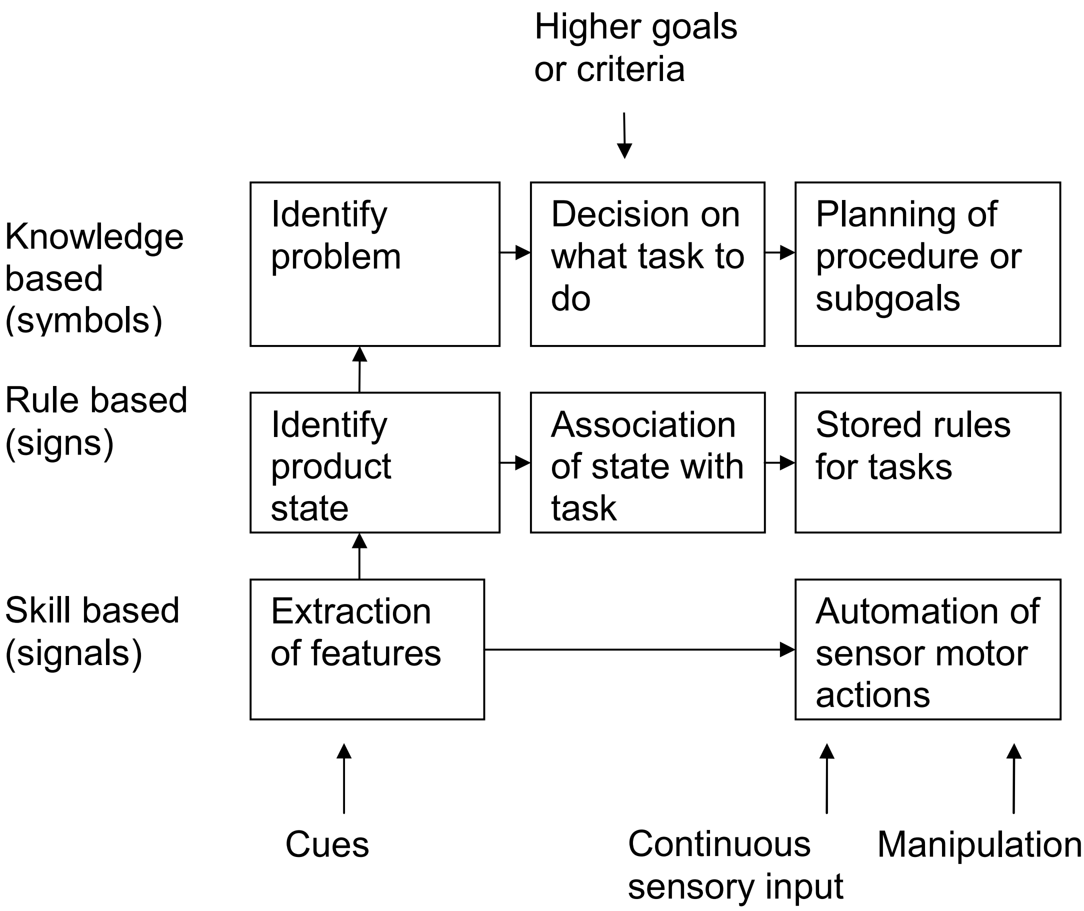

FIGURE 4. Simplification of Rasmussen's qualitative model of human behaviour. (Helander et al. 1997:100)

It is interesting to notice that Rasmussen's qualitative model of human behaviour clearly separates three levels: knowledge, rule and skill level, where human behaviour is not seen as one cognitive process, which includes different phases of learning (Elliott et al. (2002:547-574). In Rasmussen's model the problem is identified in the knowledge based level and actual learnability process begins in the rule based level, where the different learning strategies, patterns, signs and rules are created. Therefore, the rule based level in Rasmussen's qualitative model of human behaviour is the most interesting in relation to phenomenon of learnability. How the learning strategies actually are formed? The skill based level operates with signals, detailed control commands and requests for demonstrations. Rasmussen approaches the problem solving inductively, however the deductive approach to the problem solving could also be considered.

The following section 2.3 gives a brief summary of the concept of learnability, the view of learnability and earlier studies on learnability.

2.3 Summary

In brief, learnability has most often been defined in terms of its practical relevance: time-related task-specific user performance. Recently there have been attempts to define learnability in a more holistic manner by emphasizing the users' experienced confidence in learning to use a certain product.

Moreover, the latest studies have not only measured learnability within a computer software context but also within multimedia environments such as Internet services, interactive multimedia applications, smart products and virtual environments. It must also be pointed out that in the 21st century, more attention has been paid to interactive software product usability design that supports the reality of people working together (Kellogg et al. 2000:69). In addition, mobile device manufacturers have started to pay more attention to how easy it is to start using a new device, i.e. to the learnability of a new device. For instance, Sinkkonen (2001:215-233) and Ketola (2002:66) have studied the so-called out-of-box experience within a mobile phone context. Out-of-box experience refers to the practical problems that users encounter when they start using a new device, product or service for the first time. Out-of-box experience is thus close to the concept of learnability because it concentrates on the beginning of users' learning processes with a new device, which emphasizes the intuitiveness aspect of learnability. Pirhonen (2005) points out that learnability is a key factor in the out-of-box experience. The results of these recent studies contribute to the design process of mobile devices rather than to the content of the concept of learnability. The dominant attributes of learnability according to the prevailing definitions focus on time, errors, intuitiveness, consistency, task match, and memorability and user guidance.

Second, instead of performance time and efficiency oriented learnability studies, I analyse the learning process, i.e. learnability based on human actions and the cognitive process. Earlier studies have described the phenomenon of learnability with a linear learning curve in relation to time, where the user's performance progressively enhanced. However, the result of this study proves that the phenomenon of learnability is not linear; rather, it is a non-linear process.

Third, the most profound difference between this doctoral dissertation and earlier learnability studies is that in the earlier studies perceive the human being as passive in relation to the environment. Thus, it can be easily understood that usability experts and UI designers frequently advise using the users' prior experiences and the corresponding metaphors of the everyday world that people are used to and comfortable with and therefore fits users' prior conventions and expectations. In other words, the main assumption is that the human is passive and has difficulties in adopting and learning new things; rather, the human tends to follow habits learnt, absorb metaphors close to the real world and senses commonly known physical features.

As a result of the HCI views of the human being, the principle of keep it simple in usability design already seems to be profound in common speech and to be the most dominant perspective in the usability design world. Nevertheless, this study approaches the phenomenon of learnability from the human centric point of view, where the characteristics of the active human being are a key actor. In fact, the human centric view of learnability means that the human is seen as a quick learner, having an excellent memory and behaving innovatively and resourcefully, and exhibiting extraordinary patience when he s/he believes that they are being fairly treated and they are solving real problems. In other words, humans learn best when they are actively engaged with a task and have the opportunity to freely explore a device. Furthermore, the problem-based learning approach seems to enhance human persistency and commitment to solve real world tasks. However, there is a need for more learnability studies that deal with modern learning theories, human motivation and emotional issues. In conclusion, it is hard to underline profound usability design principles where the human is seen as a passive learner, especially when designing devices for children. A paper by Bhavnani & John (2000:205-261) states, “when children can choose among alternative ways of executing a given strategy, they should increasingly choose the ones that are fastest and that yield the most accurate results.” A paper by Hyösniemi et al. (2003) also points out that children invent their own problem-solving mechanisms and discover their own solutions. Moreover, the problem solving mechanism is especially effective in fostering creativity.

Finally, several studies by Bhavnani & John (2000:205- 261) have already shown how prior experience with manual tasks has a strong effect on performing computerized tasks. For instance, an expert typist encounters difficulties when learning to use a word processor. Furthermore, more easily learnt devices are not necessarily effective in long run, as shown in a study by Lyons et al. (2004:671-678) with two different mobile text entry methods. The is a need for more cognitive studies that concentrate on investigating, how previously learnt habits can be broken, i.e. in the future, unlearning and relearning will be more important than learning.

As stated earlier, there are different definitions and views on learnability. However, based on those studies it has been hard to identify and show the particular attributes of learnability. Therefore, Section 3 studies measurements for learnability in detail and deals with subjective learnability measurements in order to build a deeper understanding of the phenomenon of learnability. In other words, I proceed with the examination of the learnability concept by concentrating on the dominant ways in which learnability has been investigated and measured because the attributes of learnability are implied in the measurements for learnability, especially in scale items.

3 ON MEASURING LEARNABILITY

Although the challenge of learnability is commonly known and acknowledged among users, designers, manufacturers and research communities, there is an astonishingly small amount of published research on this topic. In order to top up the content of the concept of learnability, I shall look in the following into the common ways of measuring learnability, and thus aim to find completing or corroborating attributes for the concept with respect to the previously described definitions.

The dominant way of investigating learnability often refers to different quantifiable operations of the principal features in any use situation in system of: user, task, product and environment. Previous studies have measured learnability by using mainly three metrics: time, errors and questionnaires following the tasks. Earlier studies have considered performance as a key indicator when studying learnability. The related questionnaires, however, have only been able to measure the users' opinions after task performance. According to Shackel (1991:21-38), there are three general types of measurements available for evaluation: human dimension, performance, and attitude for learnability. Basic data about the human dimension comes from anthropometrics. The dimension, which refers to physical anthropometrics, is used to analyse the human dimension. There often is great diversity in these static measures, which reminds us that there can be no image of an average user even in terms of anthropometrics. However, these physical measures of static human dimensions are not enough. The measures of dynamic actions – such as reach distance while seated, speed of finger presses, or strength of lifting – are also necessary, when investigating learnability. Green & Eklundh (2003) state the study of the anthropometrical features of humans together with their behaviour result in more learnable interfaces.

Both performance measurements are seen as objectives –

performance time and the number of errors (Shackel 1991:21-38 and Shneiderman 1998:18–19). The last one – attitude for learnability – is referred to as a subjective measure based on answers on rating scales. Shackel (1991:21-38) and Chapanis (1991a:359-398) emphasize that these three types of measurements are not regarded as alternatives, but as complementary.

Altogether, there has been much research on controlled methods of gathering subjective data from users, and various forms of scaling techniques are now well developed and proven. Chapanis (1991a:359-398) contends that the measurement of learnability should consist of both objective and subjective measures. Objective measures of learnability are related to the observable features of users' performance, in particular to time and errors, which are both easily observable and quantifiable in any use situation (Shackel 1991:21-38 and Nielsen 1993:28-29). On the contrary, subjective measures focus usually on users' feelings about the system (Chapanis 1991a:359-398). Subjective learnability questionnaires are usually applicable to any software product that has a display, keyboard or other data entry device and a peripheral memory device such as a disk drive. Subjective learnability questionnaires often explicitly recognize the learnability dimension or it is implied in the questionnaires' scale items.

Nevertheless, the study of ergonomics widens the perspective, when studying and measuring on the phenomenon of learnability. Ergonomics promotes a holistic approach, where physical, cognitive, social, organizational, environmental and other relevant factors are under investigation. In addition, ergonomic studies emphasises the importance of human factors International Ergonomics Association (2006), when trying to understand the interaction between humans and systems. Here it must be point out that the ergonomic approaches Shackel (1986:44-64) at this human-machine level system in four separate perspectives in system of: user, product, task and environment in order to design more learnable user interfaces. However, Shackel (1986:44-45) states that during the authentic development situation these principal features are merged in a mixed, overlapping and iterative process.

The following discusses both objective and subjective measures with respect to learnability.

3.1 Objective Measurements of Learnability

Objective measurements of learnability are related to performance. Tyldesley (1988:431-436) argues that “objective measurements” such as the time required for learning a product are preferred measurements, and should be used as criteria for software evaluation. Shackel (1991:21-38), as well as Apple Computer Inc. (1987:16) and Nielsen (1993:29-33) state that objective criteria comprise the task, the time and the number or rate of errors, which are – if used in an appropriate manner – effective quantitative variables that enable the use of relative scales. Learnability might be studied, for example, by first measuring the initial performance of a novice user in terms of time and errors, repeating the measurements after a period of training, and calculating the differences in performance levels. This kind of protocol reveals learnability as consisting of a combination of criteria instead of an elementary criterion (see also Figure 1).

The performance time seems to be the most often used objective criteria, when measuring the learnability. According to Nielsen (1993:29) among all the usability attributes the initial ease of learning is perhaps the easiest to measure. One simply measures the novice users' learning time, i.e. how long it takes them to reach a specified level of proficiency in using a system. The specified level of proficiency is commonly presented as the user’s ability to complete a certain task successfully. The other way to specify the proficiency is to provide the users a set of tasks, which they have to complete within a set time before one considers them as having learnt the system. The learning curve symbols a continuous progress of user performance. Indeed, the learning curve describe quite detailed the progress of learnability instead of offering us only the two-dimensional learnt/not learnt distinction (see Figure 1). In fact, quite often a certain stage of performance is still defined, which points out that the user has passed the learning stage and is able to use the system. It is also common to measure the time it takes a user to reach that stage. Jeng (2004:407) state that learnability is to measure learning effort and if users achieve specified level of proficiency. Nielsen (1993:29-30) reminds us that when analysing learnability we should bare in mind that users normally do not take the time to learn the entire interface fully before beginning to use it. However, users often start using a system shortly they have learnt to use a part of it. In conclusion, Nielsen (1993:30) points out that we should not only measure users' performance time to achieve control over entire system but we also ought to measure the time it takes to achieve a certain level of proficiency to do useful work.

The relearnability of a system is rarely tested. For Nielsen (1993:31-32) and Holzinger (2005:71-74), the concept memorability and relearnability are very close terms. When comparing the definitions of memorability (Nielsen 1993, 31-32 and Holzinger 2005:71-74) and relearnability (ISOMetric^{S} 1998), one could conclude that Nielsen and Holzinger use the concepts as synonyms. However, the Isometrics Usability Inventory considers time between sessions using the system as a key indicator to measure relearnability, whereas Nielsen and Holzinger emphasis more the influence of the human memory. Moreover, Elliott et al. (2002:547-574) regard memorability as an overlapping concept of efficiency, and therefore an overlapping concept of learnability because efficiency has strongly been related to the concept of learnability. In addition, efficiency and learnability have been measured with the same metrics of performance time, i.e. how long time it takes a user to perform a particular task. Thus, there is only two main ways of measuring relearnability. One is to set a normal user test with casual users who have not used the system for a specified amount of time and to measure the time they need to perform the typical test. The other way is to arrange a normal memory test after the user has finished a test session. The normal memory test may include for instance questions about the effects of different commands or the other way around the users are asked to name the command that does a certain thing. Nielsen 1993 (31-32).

Another considered objective measurement of learnability is the number or rate of errors. Very often, an error is defined as any action that does not take users towards the desired goal. The software product's error rate is measured by counting the number of such actions made by users while completing a specified task. Simply defining errors as any user action away from the desired goal does not take into consideration the highly varying effect of different errors. Some errors are solved right a way by the user and have no other effect than to slow down the user's performance. Such errors need not be calculated separately because their effect is included in the learnability measurement. Instead of, the other errors, which are not discovered by the user, destroy the user's work, make them difficult to recover, and therefore lead to a faulty work product are more serious in nature. Such harmful errors should be calculated separately and special attention should be paid to minimizing their frequency. Nielsen 1993 (32–33).

When summing up references concerning the objective measurement of learnability, it can be noted that all measurements are related to performance. Similarly, Nielsen & Levy (1994:66-75) compared objective and subjective usability criteria, using 57 conference papers and journal articles as their source material. They found that the objective measures comprised errors and task time. Similar results can be found when analysing the theoretical framework of this doctoral dissertation. Therefore, at this point the performance time and the number or rate of errors is considered as the only effective quantitative variables when measuring learnability. However, operational criteria and learnability goals with numerical values have also been created. In addition, the relearning time has been measured after some specified amount of training or user support for intermittent users. Moreover, this kind of the methodological setting could provide the opportunity to evaluation the effects of different educational methods. However, relearnability of a system after different educational methods used for intermittent users is rarely tested. There clearly is a demand for new objective measurements of learnability that are not purely related to efficiency or speed of performance.

3.2 Subjective Learnability Measurements

It seems that no subjective measurement exclusively for learnability has yet been created. However, the majority of subjective usability questionnaires developed so far includes learnability as one criterion for usability. Keinonen (2004) has aggregated multiple dimensions of usability and general usability measurements on his own web site. The majority of these usability measurements regard learnability as an inherent part of usability. However, some usability measurements do not include the learnability dimension at all, or the measurement does not explicitly state learnability as a usability criterion. This section concentrates on subjective learnability measurements. It presents the learnability part of those subjective usability measurements that explicitly recognize the learnability dimension, or the learnability dimension is implied in the scale items.

The first large-scale questionnaire specifically to address the problem of devising a rigorous measure of user-perceived quality was reported by Dzida, Herda & Itzfeldt (1978:270-276). Later Dzida et al. (1978:270-276) produced a seven-factor structure (which was a precursor of the ISO 9241 draft standard, part 10) from their starting point of a sample of 100 system requirements for user-perceived quality. Their paper reports a study with several replications. Most of their seven factor scales stood up quite well to the replications. There are many aspects of Dzida et al.'s list of software quality features in the EVADIS evaluation procedure by

Opperman, Murchner, Reiterer & Kock (1992). These early measurements build the ground for subsequent subjective usability measurements.

Chapanis (1991a:359-398) states that subjective measures generally deal with our feelings about something and that they correlate with our performance in using it. For example, we feel that something is easy to learn if we do not have a lot of trouble learning it. However, the correlation is far from perfect because our feelings are also determined by other factors such as our prior experiences, our perceptions and our expectations. Chin et al. (1988:213-218) disclose that subjective satisfaction questionnaires are typically very short, though some longer versions have been developed for more detailed studies. LaLomia & Sidowski (1990:231-253), in turn, contend that typically, users are asked to rate systems on a 1–5 or 1–7 rating this is normally either a Likert or semantic difference scale. Nielsen (1993:36) states that a semantic differential scale lists two opposite terms across a dimension (for example very easy to learn vs. very hard to learn) and asks the user to place the system on the most appropriate rating along the dimension.

Based on previous studies, the following subjective measurements describe items of learnability and based on these items, it is possible to work out attributes of learnability. In addition, the attributes of Nielsen's (1993:26) usability dimensions include the learnability attribute. However, it does not describe any factors of learnability nor does it discriminate any subscales of learnability. The following sections explore subjective measures to reveal the learnability definitions they imply:

- Software Usability Measurement Inventory (SUMI)
- Questionnaire for User Interface Satisfaction (QUIS)
- Post-Study System Usability Questionnaire (PSSUQ)
- After-Scenario Questionnaire (ASQ)
- Isometrics Usability Inventory
- Purdue Usability Testing Questionnaire (PUTQ)

- Practical Heuristics for Usability Evaluation (PHUE)
- System Usability Scale (SUS)
- Measurement of Usability of Multi-Media Systems (MUMMS)
- Website Analysis and Measurement Inventory (WAMMI)
- Subjective Mental Effort Questionnaire (SMEQ)
- Nasa Task Load Index (NASA-TLX)

3.2.1 Software Usability Measurement Inventory (SUMI)

Learnability is one of the subscales in the Software Usability Measurement Inventory (SUMI) by Kirakowski & Corbett (1993:210-212), Porteous, Kirakowsky & Corbett (1993:6-7), Kirakowski (2000) and Kline et al. (2002:34-36). It is important to note that SUMI scales distinguish different levels of components of usability as follows: efficiency, affect, helpfulness, control and learnability. The learnability subscale measures the speed and facility with which the user feels that they have been able to master the product, or to learn how to use new features when necessary. Learnability refers to the early phase of becoming familiar in the use of the software. Kirakowski & Corbett (1993:210-212), Porteous et al. (1993:7) and Kirakowski (2000) state that learnability refers to the perceived effort of learning, memorability and the quality of documentation etc. Nevertheless, additional detailed analyses of the SUMI learnability statements are necessarily in order to find the other attributes of learnability within the SUMI.

The Software Usability Measurement Inventory (SUMI) has fifty statements. Based on those statements, the following seven indicators of learnability in the response scale of agree, undecided, or disagree can be determined:

(1) *Overall learnability,* which refers to the users' overall opinion of the software's learnability (e.g., "It takes too long to learn the software commands," "I will never learn to use all that is offered in this software" and "Learning how to use new functions is difficult").
(2) *Intuitiveness*, which refers to the users' opinion on how easy the

software is to take in use for the first time (e.g., "Learning to operate this software initially is full of problems," "This software seems to disrupt the way I normally like to arrange my work" and "The software has not always done what I was expecting").
(3) *Consistency, which* refers to the users' expectations by maintaining predictability across the software (e.g., "I think this software is inconsistent" and "Either the amount or quality of the help information varies across the system").
(4) *Error recovery*, which refers to the users' ability to correct errors or potential error situations before the input is processed (e.g. "Error prevention messages are not adequate").
(5) *Task match*, which refers to the users' control and informative feedback (e.g., "The way that system information is presented is clear and understandable," "There is never enough information on the screen when it's needed" and "I can understand and act on the information provided by this software").
(6) *Memorability, which* refers to the software interface and how easy it is to remember (e.g. "It is easy to forget how to do things with this software).
(7) *Help desk*, which refers to relevant guidance and support that should be provided to users (e.g., "The instructions and prompts are helpful" and "I find that the help information given by this software is not very useful")

In earlier studies, Kirakowski & Corbett (1993:210-212), Porteous et al. (1993:6-7) and Kirakowski (2000) have related the learnability to perceived effort of learning, memorability, and the quality of documentation etc. As a result, the SUMI learnability measurement analyses the following seven attributes of learnability can be determined: overall learnability, intuitiveness, consistency, error recovery, task match, and memorability and help desk. The attributes of learnability provide to us more coherent understanding of the concept of the learnability than purely the list of the SUMI statements.

3.2.2 Questionnaire for User Interface Satisfaction (QUIS)

According to Chin et al. (1988:213-218), QUIS measures the user’s subjective rating of the human-computer interface. The original questionnaire consisted of 90 questions. Five questions were overall reaction ratings of the product and the remaining 85 items were organized into 20 different groups that had a main component question followed by related subcomponent questions. The original questionnaire was modified and expanded into three sections in the QUIS 3.0. In Section 1, three questions concerned the type of system being rated and the amount of time spent on the product. In Section 2, four questions dealt with the users' past computer experience, and Section 3 was a modified version of the original questionnaire with the rating scales changed from 1-10 to 1-9. Chin et al. (1988:213-218) published an important evaluation of QUIS in 1988, when the questionnaire had been incremented up to version 5.0. The QUIS version 5.0 consists of an introductory section, disclosing an overall reaction to the software scale, and four other sections, each consisting of between 4 to 6 items. These sections are Screen, Terminology and System Information, Learning, and System Capabilities.

Chin et al. (1988:213-218), Harper & Norman (1993:224-228) and Shneiderman (1998:134-135) present in the QUIS questionnaire the dimension of the learning factor. The learning factor evaluates the suitability of the product for learning. Learning covers the experience of learning, but it also addresses topics concerning specific product characteristics, such as feedback, logic of sequences, and intuitiveness. The current version reported by Shneiderman (1998: 135) has two forms: a long one (126 items) and a short one (47 items), and a space for users to write down their comments about the product being evaluated. Slaughter, Harper & Norman (1994:224-228) state that several computer-based versions of QUIS share the same reliability as the first standard pencil and paper version. Harper, Slaughter & Norman (1997:1-4) argue that QUIS version 5.5 has proven reliable and valid when applied to many interface styles.

Chin et al. (1988:213-218) established QUIS generalization by having different user populations evaluate different products. The development of QUIS included respondents who were students, computer professionals, computer hobbyists, and novice users. The QUIS was administered in different experimental conditions: strictly controlled experiments with a small number of subjects exposed to a product for a very short period of time, less rigidly controlled manipulations with a medium number of participants who used a product for a limited time, and a field study having no control over volunteers who had used a product extensively. Chin et al. (1988:213-218) state that the factor analysis of version 3.0 and 4.0 corresponded with the data from version 5.0. The items under the Learning and System Capabilities headings matched, with the exception of "experienced and inexperienced users needs," which factored with the Learning items. This convinced our knowledge of experienced and inexperienced users needing personalized user interfaces to enhance the learnability of product.

The QUIS 5.0 has a separate learnability sub-scale with six items. The first item "Learning to operate the system" indicates overall learnability. The second item "Exploring new features by trial and error" indicates error recovery. The third item "Tasks can be performed in a straightforward manner" indicates intuitiveness. The fifth item indicates the system's memorability "Remembering names and use of commands". The fourth "Help message on the screen" and the last item "Supplemental reference material" indicates help desk. The response scale is 1 to 9, with answers ranging from difficult to learn to easy to learn. Likewise, Harper & Norman (1993:224-228) and Shneiderman (1998:134-135) present the learnability sub-scale items address topics concern specific product characteristics, such as feedback, logic of sequences and intuitiveness. In addition, the following attributes of learnability can be determined from the separate QUIS (5.0) learnability subscale: overall learnability, intuitiveness, error recovery, memorability and help desk.

The QUIS 7.0 is an updated and expanded version of the previously validated QUIS 5.5 (Harper & Slaughter & Norman 1997:1-4). This current version of QUIS is enhanced by the following scales: Technical Manuals and On-line Help, Online Tutorials, Multimedia, Teleconferencing and Software Installation. The QUIS 7.0 includes four measurements of specific interface factors, one of which is learning. The overall reliability of this version in the Cronbach's alpha is 0.95, which yielded similar results as the previous version of QUIS. However, although they could show that the questionnaire's overall reliability is good, no separate reliability measures for the five sub-scales (e.g., for learnability) were reported.

3.2.3 Post-Study System Usability Questionnaire (PSSUQ) and After-Scenario Questionnaire (ASQ)

Lewis (1995:57-78) presents two subjective usability measurements: the Post-Study System Usability Questionnaire (PSSUQ) and the After-Scenario Questionnaire (ASQ). Both questionnaires focused on evaluating the psychometric attributes designed for use in scenario-based usability evaluation. The questionnaires address evaluation at both a global overall product level and at a more detailed scenario level. The PSSUQ has excellent internal consistency, with an overall coefficient alpha of 0.97. In addition, ASQ has excellent internal consistency, with coefficient alpha across a set of scenarios rating from 0.90– 0.96.

For more global usability assessment, the PSSUQ has forty-eight statements. Based on these statements, the following five indicators of learnability can be determined. The first item "It was easy to learn to use the system" indicates overall learnability and the item "I believe I become productive quickly using the system" indicates intuitiveness. The two items "Whenever I make a mistake using the system, I recover easily and quickly" and "The system gives error messages that clearly tell me how to fix problems" indicates error recovery. The item "The information is effective in helping me complete the tasks and scenarios", indicate task match. The item "It is easy to find the information I need" indicate consistency. The two items "The information (such as online help, onscreen messages, and other documentation) provided with the system is clear" and "The information provided for the system is easy to understand" indicate help desk. The response scale was 1 to 7 with answers ranging from disagree to agree. Users were also offered opportunity not to make a statement of the system at all.

For scenario level measurement, Lewis (1995:57-78) presents the After-Scenario Questionnaire (ASQ), which has totally three items. In ASQ, the two items "Overall, I am satisfied with the easy completion of tasks in this scenario" and "Overall, I am satisfied with the amount of time it took to complete tasks in this scenario," indicate overall learnability. The last item indicates help desk "Overall, I am satisfied with the support information (online-help, messages, documentation) when completing the tasks". The response scale was similar to that of the Post-Study System Usability Questionnaire (PSSUQ). Based on the ASQ, two attributes of learnability, overall learnability and help desk, can be found. Even though both questionnaires are seen to focus on evaluating the psychometric attributes designed for use in the scenario-based usability evaluation, the PSSUQ and ASQ do not have separate learnability sub-scales. The PSSUQ and ASQ learnability measurements focus on the following seven attributes of learnability: overall learnability, intuitiveness, consistency, error recovery, task match, and memorability and help desk.

3.2.4 IsoMetrics Usability Inventory

According to Gediga, Hamborg & Duntsch (1999:151-164) the IsoMetrics usability inventory is a user-oriented, summative as well as formative approach to software evaluation on the basis of ISO 9241, Part 10, standard. The current version of IsoMetrics comprises

75 items adapted from the seven design principles of ISO 9241. The ISO 9241 (1996) principle of Suitable for Learning is clearly related also to learnability as indicated by the SUMI questionnaire. IsoMetrics Usability Inventory measures “Suitability for learning,” which indicates a system’s learnability on a 9-point Likert scale.

The IsoMetrics’ (1998) subscale category “Suitability for learning” includes eight learnability items. The first item “I needed a long time to learn how to use the software” indicates overall learnability. The second item “I was able to use the software right from the beginning by myself, without having to ask co-workers for help,” indicates intuitiveness. The subsequent items “The explanations provided help for me to understand the software so that I became more and more skilled in using it,” “So far I have not had any problems in learning the rules to communicate with the software, i.e. data entry” and “I find it easy to use the commands,” indicate task match. One item “I felt encouraged by the software to try out new system functions by trial and error,” indicates error recovery. One item “In order to use the software properly, I must remember a great many details,” indicates memorability.

Based on the IsoMetrics Usability Inventory the following attributes of learnability can be determined: overall learnability, intuitiveness, error recovery, task match, and memorability. In addition, one item “It is easy for me to relearn how to use the software after a lengthy interruption” measures relearnability. Therefore, IsoMetrics is the only subjective learnability questionnaire, which considers relearnability as one of the attributes of learnability instead of one of the design objectives.

3.2.5 Purdue Usability Testing Questionnaire (PUTQ)

Based on the human information processing theory Lin et al. (1997:267-278) derived the Purdue Usability Testing Questionnaire (PUTQ). High correlations have been shown to exist between PUTQ and the Questionnaire for User Interface Satisfaction (QUIS version

5.5). PUTQ is grouped into eight parts. One of those parts measures learnability. The questionnaire contains questions regarding the product to be evaluated and consists of the following three sequential parts. The first part consists of 100 questions by which the user is asked to assess whether they are applicable to the product under evaluation. The second part evaluates the importance of the questions, and the third part focuses on the evaluation of effectiveness of the product.

The PUTQ contains 100 statements about computer interfaces. All the questions concern graphical user-interfaces. The questionnaire includes seven learnability statements and six of those are related to consistency and task match. For example, "Does it provide clear wording? "Is the data grouping reasonable for easy learning?" "Is the command language layered?" "Is the grouping of the menu options logical?" "Is the arrangement of the menu logical?" and "Are the command names meaningful?" The last statement indicates error recovery: "Does it provide no-penalty learning?" Based on the Purdue Usability Testing Questionnaire (PUTQ), the following attributes of learnability can be found: consistency, task match, and error recovery.

3.2.6 Practical Heuristics for Usability Evaluation (PHUE)

Perlman (1997:168-169) presents the Practical Heuristics for Usability Evaluation (PHUE) based partly on Nielsen's (1993:115-155) heuristics and Norman's (1990:188-203) usability principles. PHUE includes a learning factor, and measures learnability with the 7-point Likert scale.

PHUE consists of thirteen statements. The measure includes four learnability statements. The first item is "Help and Documentation" (Design for use without documentation). It provides an easy-to-use task oriented help, which indicates the help desk. The second item is "Adopt the User's Viewpoint" (Speak the user's language. Avoid jargon. Make use of existing knowledge or familiar mental models). This one is associated with task match and memorability. The third item is "Simple and Natural Dialogue" (Avoid extraneous information, steps and actions). Information should be presented in a logical and natural order, which indicates consistency and task match. The fourth item "Design for Advancement" (Provide shortcuts: quick keys, customisation) relates to task match.

As mentioned above, Nielsen's (1993:115-155) usability heuristics and Norman's (1990:188-189) usability principles have strongly influenced PHUE. It can be seen in the attributes of learnability that PHUE emphasizes: help desk, task match, memorability and consistency. These are similar to the attributes of learnability stressed by Nielsen and Norman.

3.2.7 System Usability Scale (SUS)

Brooke's (1996:189) presents "a quick and dirty usability scale" called System Usability Scale (SUS). In his article he emphasises, that usability of any product has to be viewed in terms of the context. System Usability Scale (SUS) is design especially for industrial usability evaluation.

According to, Brooke (1996:189-192) the purpose was to develop a subjective usability measure, which is cost-effective and reliable enough to make comparisons of user performance changes. First, fifty potential questions was aggregated on Likert scale (1-5) ranging from "strongly agree" to "strongly disagree" and then the most extreme responses from the original pool were selected.

Final version of, Brooke's (1996:189-192) System Usability Scale (SUS) consists ten-item scale rating on Likert scale (1-5). Four items in ten-item scale indicates overall learnability: "I found the system unnecessarily complex", "I thought the system was easy to use", "I think that I would need the support of a technical person to be able to use this system" and "I found the system very cumbersome to use". One item "I thought there was too much inconsistency in this system" indicates consistency. The two items "I would imagine that most people would learn to use this system very quickly" and "I need to learn a lot of things before I could get going with the system" indicates intuitiveness. Therefore, the SUS learnability measurement focus on the following three attributes of learnailbity: overall learnability, consistency and intuitiveness.

At the end, Brooke (1996:194) states that SUS has proved to be robust and reliable subjective measurement. It has been found to correlate well with the other subjective measurements of usability such as SUMI Software Usability Measurement Inventory (SUMI).

3.2.8 Measurement of Usability of Multi-Media Systems (MUMMS) and Website Analysis and MeasureMent Inventory (WAMMI)

MUMMS (2003), the Measurement of Usability of Multi-Media Systems, is based on previous experiences with the Software Usability Measurement Inventory (SUMI) questionnaire. MUMMS is a 50-item questionnaire with learnability scale characteristics whose reliability has been rated at 0.786 (Cronbach's Alpha). In a same vein, Kirakowski & Cierlik (1998) and Kirakowski & Claridge (1998) state that user-based satisfaction questionnaires have not been used much in the evaluation of web sites. A 60-item questionnaire was developed following a factor model used successfully for conventional software evaluation, including attractiveness, efficiency, controllability, helpfulness, and learnability. Each of the five factors includes 12 items. The questionnaire was named WAMMI – Website Analysis and MeasureMent Inventory.

Similarly, in the MUMMS questionnaire (2003) on learnability is defined as the degree to which users feel that they can start using a product without a training period or orientation and whether they feel confident enough about the product to be able to explore features that are not immediately obvious.

The results from the questionnaire data have been compared with the results from user performance and heuristic evaluation data. The overall reliability ratings for each five factors were adequately high, from 0.697 to 0.898 according Cronbach's alpha. The total questionnaire produced a reliability of 0.959. The result of this experiment indicates that the WAMMI is not only a reliable measure but it also displays some concurrent validity.

Both MUMMS and WAMMI have been developed based on the previous experience of usability questionnaire development. However, the MUMMS (2003) and WAMMI (2004) questionnaires are in commercial use and not available for public use. Furthermore, the research papers concerning MUMMS and WAMMI measurements only deal with reliability and validity issues: they do not reveal detailed information on the content of the items used. However, it can be noted that SUMI and MUMMS involve exactly the same amount of usability statements and one of its subscales measures learnability.

3.2.9 NASA Task Load Index (NASA-TLX) and Subjective Mental Effort Questionnaire (SMEQ)

The last two subjective questionnaires the NASA Task Load Index (NASATLX) and Subjective Mental Effort Questionnaire (SMEQ) are the most human centric in nature. Both of the subjective questionnaires deal with human characteristics and recognize human characteristics as an important part when studying elements that affect performance within the workload context. The NASA-TLX divides the factors that have an impact on task performance into task-and-performance related factors and behaviour and subject-related factors. The task-and-performance related factors are external elements that influence behaviour and subject related factors, and vice versa. In addition, this section compares the factors between the two questionnaires (NASA-TLX and SWAT) and analyses them within the context of workload. The Subjective Workload Assessment Technique (SWAT) is another popular workload rating scale.

The NASA Task Load Index (NASA-TLX) subjective questionnaire was created by Hart & Steveland (1988:139-183) during their profile study on the factors associated with variations in subjective workload. The workload was defined as the cost by a human operator to achieve a particular level of performance. Achieving a particular level of performance is related to the objective measurement of learnability. However, the performance level in the NASA-TLX is measured through users' self-reflection instead of using performance time as a measurement. In their study, the following factors, which indicate the cost by a human to achieve a particular level of performance, were found from the most to the least relevant: task difficulty (TD), frustration (FR), time pressure (TP), mental effort (ME), physical effort (PE), own performance (OP), stress (ST), fatigue (FA) and activity type (AT). The Subjective Mental Effort Questionnaire (SMEQ) created by Kirakowski & Cierlik (1998) also measures cognitive effort in relation to the task performance. In SMEQ, a user is asked to draw on a horizontal line the degree of s/he felt when completing a task, with answer alternatives ranging from tremendous effort to no effort at all.

According to Hart & Steveland (1988:139-183), the importance of each workload factor in the NASA-TLX has proven to be relatively independent of other factors. Based on their data, it was found that time pressure was considered the most important variable, producing frustration, stress, mental effort and task difficulty. Physical effort was considered the least important variable. Fatigue and activity type were also found relatively unimportant. Statistical analysis showed that the six NASA-TLX subscales regressed against the overall workload (OW) rating within each category and across categories with high r-squared values from 0.78 to 0.90. In addition, the correlation among the regression coefficients was rarely significant, which provided additional evidence that these six subscales represent relatively independent sources of information about the workload in different tasks. The greatest statistical connection was found between activity type and stress (-0.50) or frustration (-0.40). The feelings of stress and frustration were not found relevant, if the type of activity performed was regarded particularly important, and vice versa. In addition, the next highest statistical connection was noted between own performance and fatigue (-0.46) or stress (-0.35). This indicates that if a user feels that his/her level of performance is sufficient enough to complete the task, the sense of fatigue or stress are not considered relevant performance related factors.

Hart & Steveland (1988:139-183) studied the three subscales of time pressure, stress and mental effort (TP, ST, ME) that were similar to another popular workload rating scale, called the Subjective Workload Assessment Technique (SWAT). The SWAT included three factors: time load, psychological stress, and mental effort. They determined whether these factors alone might provide sufficient information on workload. It was shown that these three factors alone were inadequate to represent the variety of factors that influence the workload for a broad range of tasks. As a result, one of their key assumptions of conjoint analysis, i.e. the statistical independence of the components, was not supported by the data. In many experiments, the correlations were 0.70 or higher between factors. However, despite the relative success of both measurements, neither of measures has been able to account for a substantial percentage of the workload variance.

In conclusion, Hart & Steveland (1988:139-183) point out that there may be at least two patterns of workload definition: one based on task-and-performance related factors and another based on the subjective and physiological impact of a task on performance. The task related factors alone do not provide information about the behavioural and psychological responses of individuals. In fact, behaviour-related and subject-related factors necessarily reflect task-related factors. Therefore, an evaluation of the subjects' responses to a task can provide additional and highly valuable information. The information that is needed is not only associated with their objective contribution but also with the subjective importance of the factors. According to them, the simplest way to receive information about subjective importance would be to ask the subjects to set the values for each of the six subscales.

Finally, the NASA-TLX scale shows that a lower workload is usually associated with better performance. All six of the NASA-TLX rating subscales – mental demand, physical demand, temporal demand, performance, effort, and frustration level – have an influence on learnability. Mental demand measures the amount of mental and perceptual activity required during a task whereas, physical demand measures the amount of activity required during the task. Temporal demand measures the time pressure the user feels due to the rate or pace at which the task elements occurred. Performance measures how successfully the user thinks s/he has accomplished the goals of the task. Effort measures how hard a user had to work (mentally and physically) in order to accomplish a level of performance. Lastly, frustration level measures how insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent the user was during the task.

The NASA-TXL rating scale and SMEQ's cognitive effort have a major effect on performance and therefore on learnability. However, the subjective learnability measurement and prevailing definition of learnability does not consider human characteristics as attributes of learnability, even though human characteristics, especially cognitive abilities, are unanimously agreed to influence learnability. As mentioned earlier, to achieve a particular level of performance refers to the objective measurement of learnability. In the NASA-TLX, own level of performance is evaluated using self-reflection instead of performance time. Despite this, the performance factor and part of the mental demand factor (memorability) seem to be the only indicators that relate directly to the definition of learnability.

3.3 Attributes of Learnability

The dimension of learnability is described and the selections of learnability factors are determined based on the information provided by the subjective usability measures presented above. They should represent the types of phenomena that influence subjective learnability experiences in a broad range of tasks, although the importance of individual factors might vary from one type of task to the next. Based on previous validated and reliable subjective usability measurements, seven learnability attributes are built. In addition, they represent the dominant view of attributes of learnability according to prevailing definitions of learnability: overall learnability, intuitiveness, consistency, error recovery, task match, and memorability and help desk.

The figure below also summarizes the approaches to learnability in Apple Computer Inc. (1987:16), Ravden & Johnson (1989:45-74), Norman (1990:188-209), Polson and Lewis (1990:191-220), Chapanis (1991a:359–398), Holcomb & Tharp (1991:49-78), Shackel (1991:21-38), Nielsen (1993:26-37), Bevan & Macleod (1994:132-145), ISO 9241 1996, Thagard (1996), Shneiderman (1998:135) and Sinkkonen (2001:215-233). The approaches recognize three measurements – the number of errors, performance time and answers on a rating scale or scales, two design objectives – the experienced user's performance (EUP) and retention or relearnability over time by the casual user, and seven attributes of learnability based on subjective usability measurement – overall learnability, intuitiveness, consistency, error recovery, task match, memorability and help desk. The measurements determine the value of a variable. The objectives cover the issues that learnability aims at or for which it is the purpose. The attributes are the actual analysed qualities of a product (see Figure 5).

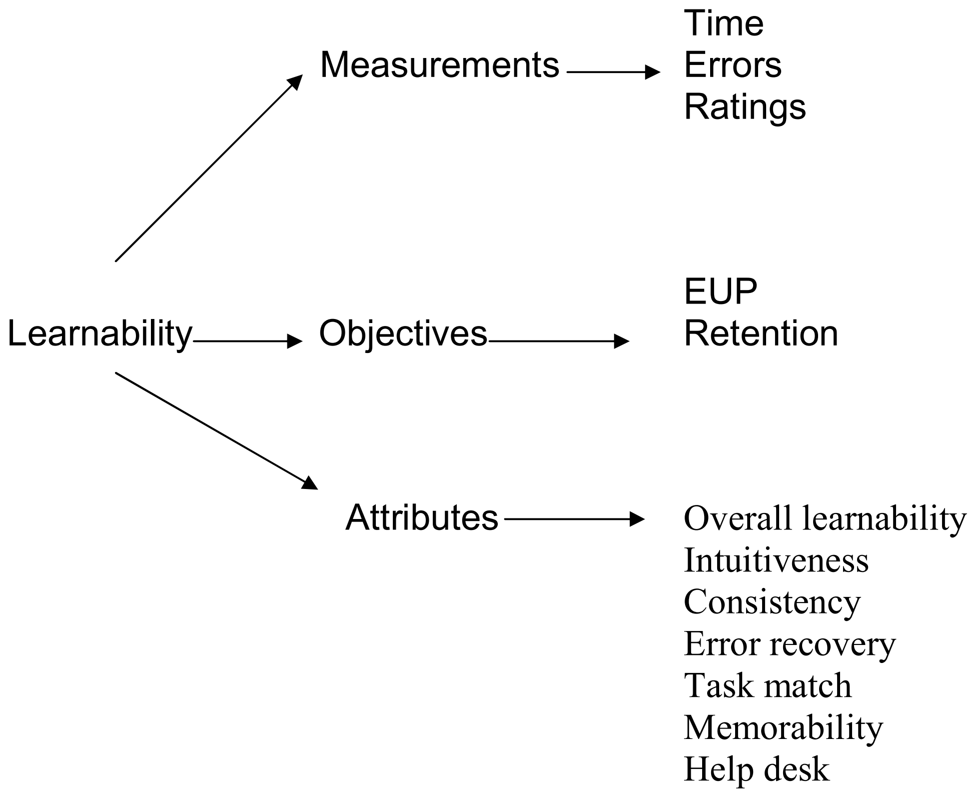

FIGURE 5. Measurements, objectives and attributes of learnability. (Apple Computer Inc. (1987:16), Ravden & Johnson (1989:45-74), Norman (1990:188-209), Polson and Lewis (1990:191-220), Chapanis (1991a:359–398), Holcomb & Tharp (1991:49-78), Shackel (1991:21-38), Nielsen (1993:26-37), Bevan & Macleod (1994:132-145), ISO 9241 1996, Thagard (1996), Shneiderman (1998:135) and Sinkkonen (2001:215-233))

Earlier studies show that intuitiveness is one of the most important attributes of learnability, and it seems to have the strongest effect particularly at the beginning of the learning process. Therefore, it is easy to understand that users' experience with regard to the ease of first use is often referred to as the intuitiveness of an interface. Another learnability attribute consistency, is concerned with creating and reinforcing user expectations by maintaining predictability across the interface i.e. users should be able to predict effect of their following actions based on their past experience. In other words, consistency refers to interface solutions holding to the same principles over a set of individual cases or situations. Third, attribute of learnability error recovery, is concerned the users' ability to recover the false action easily. It can be frustrating for the user to have to spend large amounts of time correcting trivial errors, or having to be extremely careful in order to avoid them. Fourth, attribute of task match is of utmost importance with respect to learnability. Particularly, designers should provide exactly the information that the user needs in order to accomplish and complete his/her tasks with the product. Fifth, attribute of learnability memorability is defined by concrete terms by Nielsen (1993:26). The casual users' should be able to return to the product after a period of absence, without having to learn everything all over again. Memorability of user interface can be enhanced by allocation of work between humans and computers such that computers present alternatives and patterns while people select and edit. Nielsen's (1993:26) attribute of memorability is very close to the concept of relearnability. However, he emphasizes more the users mind and memory than the environment or product needed to return after period of absence. Sixth attribute of learnability is called help desk, which include the feedback information provided to the user after his/her actions. Kline et al. (2002:34-36) relates learnability concept directly to the usefulness of error and help messages. Thus, users should be able to request help for any point of the product particularly within the context of the task. It is extremely important for a help facility to explain the options available to users at their current point in the task.

In conclusion, it can be stated that all attributes of learnability are related to each other in a non-linear timeline. The relationship is non-linear because learnability is not a progressively enhanced process. Thus, it can be assumed that importance of learnability attributes varies in different phases of the learning process, i.e. intuitiveness is most important at the beginning of the learning process whereas the attributes of task match and consistency are more vital during the learning process. The help desk is needed when practical problem occur and error recovery is not immediately possible, i.e. when the user have to quit the learning process and search for additional support or help. It must be pointed out that a good quality help desk facilitates enhanced error recovery. The attribute of memorability is important when returning to product after a period of absence. Finally, the dominant attributes of learnability definitions focus on time, errors, intuitiveness, consistency, task match, memorability and user guidance.

3.4 Summary

In the Section 3, I explored the objective and subjective measurements of learnability. The objective measurements of learnability are related to performance. Learnability, efficiency, speed of performance, and time to learn are directly related to each other. Performance time and number or rate of errors is used as objective criteria in different task settings. Subjective learnability questionnaires often explicitly recognize the learnability dimension or it is implied in the questionnaires' scale items. Based on subjective learnability questionnaires, the following attributes of learnability can be determined: overall learnability, intuitiveness, consistency, error recovery, task match, and memorability and help desk. Objective and subjective learnability measurements seem to be based on human information processing theories. In addition, existing definitions of learnability are very much product and graphical user interface oriented and do not consider human as a key actor. Overall learnability, intuitiveness, consistency, error recovery, task match, memorability and help desk are actually attributes of user interfaces, i.e. attributes that are supposed to make a user interface more learnable as such. In this way, for instance, a help desk, which is considered as a one of the attributes of learnability, has little to do with the learning related characteristics of human beings.

The user interfaces that have been created so far do not take into consideration users' individual learning styles. Neither do the definitions of learnability recognize modern learning theories. At the moment, the attributes of learnability are purely connected with knowledge transfer theories. Therefore, learnability seems to be a concept, whose content is difficult to define, particularly with respect to human learning. Modern learning theories emphasize the learner's own activity and collaborative learning. In the theory of constructivism, the learner constructs new knowledge based on his/ her earlier knowledge (see Miettinen 2000:276-292) because for the constructivist, learning is problem solving based on personal discovery (see Pirhonen 2005) and thus, constructivism has a very close connection to the theoretical model of learnability. However, constructivism does not advocate precise steps for learning (see Elliott et al. 2002:547-574). The collaborative learning concept is related to socio-constructivism, according to which thinking is developed through social interaction (Lave & Wenger 1991). Collaborative learning means educational methods that encourage learners to cooperate and solve assignments together, whereas problem-based learning anchors learning to the real problem situation. Nevertheless, neither do the theoretical models of learnability address the social context in learning. According to van Welie et al. (1999:613-620), task analysis should provide information for the requirements of a product both in the functional and in the ergonomic and cognitive senses. Instead of finding the problems, engineers in general are very good at solving functional problems and correcting errors in user interfaces. There might also be a possibility that engineers are not solving the right problems in the cognitive sense. Therefore, it is also important to identify the real user problems in the cognitive and ergonomic sense. In addition, there is a specific modern learning theory particularly created for the information and communication technology context. Computer Supported Collaborative Learning (CSCL) means learning and teaching methods where modern information and communication technology are used to support users' mutual work to enhance learning (Lehtinen 2003:1-33). How can modern learning theories for the phenomenon of learnability be adapted?

As Shackel (1991:21-38) and Elliott et al. (2002:547-574) state, a common problem with the learnability definition as well as with studies is that they do not specify what learnability is in measurable terms. Subjective measurements only provide a numeric value of the efficiency of the attributes of learnability but they do not explain which features of attributes of learnability cause the problems. In my understanding, the definitions of learnability are so general because of the traditional way of measuring them in terms of quantifiable questionnaires or objective measurements such as performance time and number of errors. Therefore, using different research methods might provide a more human centric perspective of learnability. However, if we continue to use the same metrics (time, number of errors and subjective learnability questionnaires) and the same research methods, user interface designers shall also in the future lack a more complete, dynamic and detailed learning model and the more concrete elements in measurable terms that influence learnability. Instead, concise definitions and the abstract attributes of learnability from earlier usability studies are used. Regarding particularly the social and collaborative aspects of learning, qualitative approaches could be beneficial in studying learnability because they reveal the underlying problems and possibilities of use by studying the future context of use, and they still include the automated 'tacit' knowledge inherent in users' tasks (Kujala 2003:1-16).

The recent literature on human-computer interaction does not address the issue of learnability sufficiently, which might be one reason why the definitions and measurements of learnability are quite far from human characteristics and modern learning theories. The concept of learnability needs to be studied in more detail and not merely within the user interface context where technology plays a key role. At the moment, the definition of learnability is very narrow and needs to be broadened. How do people learn? How should people's learning be supported? Studying learnability as a phenomenon cannot be separated from learning and neither can a user interface be kept apart from the learning task. Pirhonen (2005) states, when studying the phenomenon of learnability, that we should focus more how people learn a specific task in a certain kind of environment instead of purely analysing the learnability of a user interface. Since learning is a continuous process in which human interacts with the environment, it is hard to define where learning starts and when it ends. In addition, the learning process is much slower and last longer. Therefore, more longitudinal learnability studies are needed, because earlier learnability studies have concentrated to investigate the initial part of learning curve.

Learnability studies currently consider implicitly the individual as the learner and they do not discuss how a team or a collective learns to use a product in their collaborative work. Nor do they discuss the specific learnability problems of product created for the support of cooperative work. These viewpoints are important for future studies in this field. The concept of learnability should be studied more deeply, and HCI researchers should find new ways of describing the phenomenon. More attention should be paid to contextuality, modern learning theories, tasks and human characteristics. In this way, research could provide us a more holistic and thorough understanding of the phenomenon of learnability.

In conclusion, Elliott et al. (2002:547-574) point out that many measurements for learnability identify the factors that affect learnability. However, they do not pay attention to the interaction of factors and they are not further deconstructed. Hence, in the absence of a concrete model of learnability it has been necessary to consider that the elements of objective and subjective learnability measurements pertain to phenomenon of learnability.

4 HUMAN CENTRIC VIEW OF LEARNABILITY

In this section, I describe the human centric view of learnability in the context of main principle components in system of: user, task, product and environment. Second, I point out the profound differences between earlier learnability studies versus this doctoral dissertation. Third, I emphasise the importance to understanding the non-linear theoretical models of learnability. In addition, I point out the possible advantages of grounded theory comparing the traditional learnability methodologies. At the end I suggest, the issues future learnability studies should concentrate on to investigate.

Accordingly, there exists a wide range of learnability approaches with varying ways of studying the principal components mentioned above of any use situation in system. What does the human centric view of learnability means? In brief, the human centric view of learnability emphasises human being as an active learner, the characteristics of the human being and learning (Hart & Steveland (1998), Kline et al. (2002:34-36) and Haramundanis' (2001:7-11).

This doctoral dissertation shares the user interface design principals (Hart & Steveland (1998), Kline et al. (2002:34-36) and Haramundanis' (2001:7-11), where the human is perceived as an active learner. From the human centric point of view, humans are instinctively curious; they want to learn, and they learn best by active self-directed exploration of their environment. (Haramundanis 2001:7) People like to have a sense of control over what they are doing, to see and understand the results of their own actions. In addition, people are also skilled in manipulating symbolic representations; they love to communicate through gesture and verbal and visual language. Finally, people are both imaginative and artistic when they are provided with a comfortable context. This doctoral dissertation argues that human centric view of learnability adds the knowledge value i.e. knowhow to the traditional user interface and product oriented design principles. However, the “keep it simple principal” seems to be the almost profound principal in the world of user interface design, which perceives the human being as a passive learner. (e.g., Apple Computer Inc. (1987:3), Ravden & Johnson (1989:32), Norman (1990:54-55), Nielsen (1993), Thagard (1996) and Green & Eklundh (2003:645). According to “keep it simple principals” humans have difficulties in adopting and learning new things and instead tend to follow habits learnt, absorb metaphors close to the real world and sense commonly known physical features.

Ziefle’s (2002:303-311) study states that the human centric view of learnability could be the most valuable design principle in new technological situations. Ziefle (2002:303-311) confirms that common learning patterns, i.e. the experienced mental models, do function in a familiar context. However, they are inefficient in new technological situations. Thus, the demanding job for designers is to recover new learning strategies and patterns that functions when the product or service is unfamiliar for users.

In the theoretical background, I have provided an overview of earlier studies and different views on learnability (see Session 2 and 3). Those studies approached the phenomenon of learnability from quite a different perspective. First, the main aim in this study is to investigate the phenomenon of learnability without any prior assumptions of the concept through using the method of grounded theory. Second, this study approach the phenomenon of learnability from the holistic point of view, where the phenomenon of learnability is seen as one holistic process. Thus triangulation, where the phenomenon is interpreted through several split case studies, and data is collected through observation; interviews are unnecessary in this research setting.

Moreover, the grounded theory is seldom used methodology within the context of learnability. However, the advantage of grounded theory is that it generates theory and explains the phenomenon under investigation. The grounded theory approach makes possible to analyse non-linear learnability process, i.e. from the point of view of the users' individual actions. The main aim to analyse the non-linear learnability process is to reduce the effort needed to take a new product into use; through reusing the information, learning patterns and strategies acquired during the learning process. Therefore, by using new method it is possible to form a deeper understanding of phenomenon of learnability and provide alternative answers to question: How are the skills actually learnt? (see Kline et al. (2002:34-36).

One of the important contributions in this dissertation is the new methodological approach within the usability research context. As pointed out above, this study first starts to analyse the phenomenon of learnability inductively based on collective data and therefore, uses performance time and goal direction only to horizontally strengthen the model of learnability. This study concentrates on defining the phenomenon of learnability from the learnability process perspective, where the interaction between the human and user interface is in focus. Third, it combines learnability to the human cognitive and learning processes. In conclusion, using the different research methods provides a new and more holistic perspective of learnability, opens up the definition of learnability, and provides a new model of learnability. However, the model of learnability presented in this study needs to be further tested, clarified, and reformulated.

As a have stated earlier, the concepts of ease-of use and ease-of learning are strongly related. (Haramundanis (2001:7-11), Elliott et al. (2002:551) and Ziefle 2002:303). Bewley et al. (1983:72-77) associated intuitiveness with the concept of ease of learning and efficiency with the performance of learnt skills. Thus, performance time and efficiency should be associated stronger with the concept ease-of-use and efficiency should be mainly measured with expert users, i.e. those who have already learnt the skills. In addition, we should begin to use the concept of learning time instead of performance time when measuring learnability with novice users.

Raisamo & Räihä (2000:483-506) and Lyons et al. (2004:671) express that the standard elements of an interface ensure ease of learning but they are not necessarily more efficient to use. In other words, efficiency of product can not be noticed during the initial part of learning curve. Instead, it can be recognized after certain amount of use when the learning curve has stopped to rice.

In addition, definitions of learnability have not taken account in human and environmental issues; instead, learnability has been related to the performance and efficiency of a product or user interface. Thus, the definitions of learnability and the concepts associated with learnability have remained very traditional and even unchangeable at the beginning of learnability studies. In fact, the concept of learnability has rarely been related to learning, learning theories, pedagogy, teaching or motivation.

As I have pointed earlier, the knowledge of tasks and tools is in itself insufficient to make users more efficient; rather, learning strategies are the most vital to the efficient use of device. Bhavnani & John (2000:205-261) connect the concept of learnability directly to pedagogy. The main idea of all learning strategies introduced by Bhavnani & John (2000:205-261) is that users should have deeper knowledge of tasks and tools and especially of the intermediate layers located between task and tool that have to be learnt in order to accomplish a task and where hidden critical knowledge usually exits. In conclusion, the authors state that if so-called hidden critical knowledge could be implemented directly for task and tool, we would have more learnable and effective devices and the amount of training could be minimized. Thus, it can be thought that a better understanding of non-linear model of learnability and learning strategies, i.e. pedagogical models, could together solve some learnability problems.

Finally, by identifying the specific source of learnability, i.e. the elements based on users' actions that enhance learnability in a task, we can provide a basis for design decisions concerning how to modify unacceptably high levels of workload in operational environments and how to create products that are more learnable.

At the end, I must point out that the relationship between learnability studies and modern learning theories is lacking or totally neglected. Therefore, there is a desperate need for more longitudinal learnability studies that associate the concept of learnability to learning, emotions and motivation. Concept of learnability should not be considered only the initial part of learning curve but instead repetitions of same task in longer period Shackel (1991:21-38), which opens up more the non-linear process of learnability and relates it more closer to the concept of learning, which means in this case permanent behavioural change of human being.

5 RESEARCH PROBLEMS

My personal interest towards the phenomenon of learnability has grown into a state of research through observing the common everyday of problems people face after they have purchased a new product and tries to take it into use. However, it is not only my personal interest that has driven me to investigate the phenomenon of learnability in more detail. In addition, a deep understanding of the phenomenon of learnability and the theoretical models of learnability is important because before taking any product whatsoever into use, people have to learn how to use it. Therefore, it is vital to understand how these skills are actually acquired and learnt.

The research problems in this study are:

1. How learnable is the WebCT Campus Edition software?
2. How can the phenomenon of learnability be defined in a new way?

The easiest way to approach the research problem would be just to observe whether people could take a new product into use. As a result of observation, the definition of learnability would be: learnability means the users' ability to successfully to take a new product into use or fail to take a new product into use. Another way to approach the phenomenon of learnability would be to use purely traditional measures of learnability, where the phenomenon of learnability has been directly connected to performance. Thus, learning time in relation to performance has been the primary indicator of learnability and it has been considered the only adequate and so-called objective measure of learnability. As a result, the phenomenon of learnability would be purely defined by performance time and the number or rate of errors and illustrated with learning curve.

However, there is also the third possibility to approach the research problem. A number of subjective learnability measurements have been developed in order to investigate learnability. All of them include the learnability items and quite many of them are validated, and the reliable measurements have their own learnability category. Nevertheless, a subjective learnability measurement has not yet been created. The measurements of learnability are currently more diagnostic than global learnability ratings, i.e. the learnability measurements provide the numeric value of the attributes of learnability, which are the same as the attributess of a user interface. In conclusion, the number of attributes of learnability has been determined (see Section 3.3).

Usually, a user interface designer expends a lot effort trying to find the best set of objective and subjective learnability measurements. Although these measurements are useful, it remains unclear how they are related and how the results found with measurements are judged, i.e. do they give advice on what needs to be concretely done in order to improve the quality of a user interface and what part of the user interface needs to be fixed. Therefore, the abstract way of looking at learnability is not directly applicable in practice because all the different definitions and principles make learnability a problematic concept when actually designing a new user interface.

This study approaches the phenomenon of learnability differently through using grounded theory (see Section 5). In fact, grounded theory was used in order to better understand the learnability processes and patterns from the human point of view.

In this doctoral dissertation, I study the phenomenon of learnability within the context of WebCT Campus Edition software. I measure the learnability of WebCT Campus Edition software with the traditional measures of learnability, performance time and the direction of actions. Then, I use the results found with traditional metrics in order to define the phenomenon of learnability and verify the learnability model and patterns of learnability based on users' actions.

6. METHOD

As earlier presented in this study (see Section 2), the traditional definition of learnability has had the following characteristics. First, it has been related to the performance. Learnability, efficiency, speed of performance, and time to learn have been directly related to each other. Second, the existing definition of learnability has been very much oriented towards the product and graphical user interface, and the definition of learnability has been built with separate learnability attributes such as overall learnability, intuitiveness, consistency, error recovery, task match, memorability and help desk. Thus, the attributes of learnability are actually the attributes of user interfaces, i.e. attributes that are supposed to make user interfaces more learnable as such. However, more recent definitions of learnability stress users' experience and feeling as the important feature of learnability, but they are only able to measure users' opinions after task performance. Third, learnability has been described in a timeline with a progressive learning curve, where the focus has been the novice user's experience at the beginning of the learning curve, i.e. the ease of learning often refers to the novice user's experience on the initial part of a particular learning curve. Fourth, the definition of learnability has been studied mostly from the performance skill perspective. However, few studies have brought learning, pedagogy, human cognition and learning strategies to the theoretical models of learnability, i.e. how skills are actually acquired.

How does this study differ from the earlier studies that have been presented? First, this study begins openly to analyse the phenomenon of learnability based on the collected data and uses performance time and goal direction only to horizontally strengthen the model of learnability that is built. Second, this study investigates the phenomenon of learnability from not only the user interface point of view but it also emphases the role of the human and the role of the interaction between the human and the user interface, i.e. learnability is seen as the interaction between the user interface and the human being. Where does the learnability process begin and end? Third, in this study learnability is considered as a continuous process. Thus, learnability cannot be defined by separate attributes that are not associated with each other or where the connections between the attributes of learnability are not found. In addition, learnability is not a constant progressive process as the learning curve indicates. In many cases, a user has to start all over or go back to an earlier phase while learning to use a new product. Therefore, it is also important to understand the whole learnability process from the novice and expert users' point of view and not only the initial part of a particular learning curve with novice users. The process of learnability is much more complicated than the impression given by earlier studies. Thus, more relearnability studies should conducted, i.e. the demand for longitudinal learnability studies is obvious, partly because it is hard to apply a standard learning curve to users who have earlier experience of a product or they are able to transfer skills from the use of a previous product or products that are very much related to system needs to be learnt. Longitudinal studies would also bring the phenomenon of learnability closer to learning, i.e. learning can be seen as a profound change of human behaviour. This study claims that learnability cannot be separated from learning and therefore the phenomenon of learnability is also analysed from the process point of view, i.e. most earlier studies have left out the human cognitive and learning processes from the definition of learnability. Finally, literature seems to lack any generally accepted model for the dynamics of learning a product, even though there is an enormous body of research into human learning.

Moreover, previous studies have measured learnability by mainly using three metrics: performance time, errors, and subjective questionnaires after task performance (see Section 3). The phenomenon of learnability has been analysed and discussed only through the objective and subjective measurements of learnability.

First, the objective measures of learnability are related to performance. Second, performance time has been considered as a primary measure of learnability, i.e. the amount of time it takes to learn a specific set of tasks. Nevertheless, International Ergonomics Association (2006) one of the objective measures of learnability, to analyse human dimensions through physical anthropometrics and other issues of physical ergonomics such as: human anatomical, physiological and biomechanical characteristics as they relate to physical activity has often been left out when studying learnability. Third, performance time and number or rate of errors is used as objective criteria in different task settings. Fourth, the performance measures of learnability focus on first experience users, where it has been assumed that user is able to do nothing at time zero. The other way to analyse learnability has been thorough subjective measurements of learnability. Subjective learnability questionnaires often explicitly recognize the learnability dimension, or it is implied in the questionnaires' scale items. The earlier mentioned attributes of learnability have been determined based on subjective learnability questionnaires.

The aims of earlier studies have been to verify existing theories. Therefore, it has been understandable and wise to use the same logico-deductive research methods and metrics (time, number and rate of errors) and measurements (subjective learnability questionnaires). In fact, learnability has been measured the traditional way for decades in terms of quantifiable questionnaires and objective measures as performance time and number or rate of errors. In many cases, based on the earlier studies and theories, the researcher has decided which measurement to use and which learnability questions are sufficient to ask users. Therefore, the same subjective learnability measurements are used and very often, the concepts for the definitions of learnability have been described and set out before the empirical data has been collected. To the best of my understanding, this is the main reason why the definitions of learnability are so general.

What kind of research method is suitable for studying the phenomenon of learnability? Glaser & Strauss (1967:29-30) point out that grounded theory can be used as a test of a logico-deductive theory in the same research area, which is one reason why grounded theory was chosen for the research method. Another reason was the possibility to inductively approach the phenomenon of learnability without the previous assumptions or definitions of learnability. In this study, the model of learnability was derived from data and not deduced from logical assumptions. Based on the data, it was also possible to analyse the phenomenon of learnability as a continuous process in a real time learning situation. In fact, the phenomenon of learnability has not been studied inductively from the learning process point of view. Due to the human-computer interactions in a real time learning process, it has not been possible to conduct an analysis by using the traditional subjective learnability measurements. Hence, previous studies have failed to capture the important part of learnability, i.e. interaction, even though the human and system together affect learnability. Another common problem with the learnability definition as well as with studies is, as Shackel (1991:21-38) express, that they do not specify what learnability is in measurable terms. However, this is only partly true because numeric values for each attribute of learnability can be determined through quantifiable questionnaires. On the other hand, the measurable terms can only be provided by the separate attributes of learnability. For this reason, the learnability process in measurable terms has remained the open question in earlier studies.

This study approaches the phenomenon of learnability by using both the traditional objective measures of learnability through measuring the users' performance time and goal direction during a task in order to horizontally strengthen the model of learnability and through a new method of using grounded theory in order to find the basic concepts and categories that define the phenomenon of learnability. In fact, the creators of grounded theory, Glaser & Strauss (1967:16-18), do not see any fundamental disagreement between the purpose and capacities of qualitative and quantitative methods or data. The primary debate concerns the emphasis on verification or generation of theory. However, each form of data is useful for both the verification and generation of theory. In many cases both forms of data are necessary, not only quantitative used to test qualitative, but both used as supplements, as mutual verification and, most important for this study, as different forms of data on the same subject, which when compared will each generate theory.

Next, I first discuss the grounded theory in general, which originated with Barney G. Glaser and Anselm L. Strauss' work to develop a canon more suitable to the discovery of theory and their attempts to close the gap between theory and research. Second, I describe the epistemology of the grounded theory and its main principles. Third, I point out how the grounded theory is suited to studying the phenomenon of learnability. I then explain the grounded theory coding procedures, which include three phases, and how thorough the open coding, axial coding and selective coding phases, the model of learnability was built. In brief, what kind of method is grounded theory? What are the main characteristics of grounded theory? How does grounded theory suit the study of the phenomenon of learnability?

Finally, I describe the research process from an empirical point of view: subjects, software product, task development, data collection, evaluation process, and the analysis of the data.

6.1 The grounded theory

A Public Health Service Research Grant made the Discovery of Grounded Theory possible. The grounded theory has been very commonly used method in the sociology, cultural studies, anthropology and the field of ethnographical content analysis. The grounded theory was created by Barney G. Glaser and Anselm L. Strauss and the theory was first presented and published in "The Discovery of Grounded Theory. Strategies for qualitative research" in

1967. (Glaser & Strauss 1967:1-9, Glaser 1992:1, Strauss & Corbin 1998:9)

According to Moilanen (2001:162), the most significant difference between the Barney G. Glaser and Anselm L. Strauss interpretation concerning grounded theory is that Anselm Strauss' theory allows theoretical perception and applies earlier theories and models during the analysis process, whereas Barney G. Glaser has gone so far that even he would like to deny the use of the questionnaires in the fieldwork. In other words, Barney G. Glaser's interpretation of the grounded theory is more philosophy oriented whereas Anselm L. Strauss' thoughts fit more the empirical research approach with the analysis of empirical data. Finally, Järvinen & Järvinen (2000:52) conclude that grounded theory has been undergoing development. Strauss & Cobin (1998:101-143) state the current development stage of grounded theory is increasingly controlled with many new concepts for researchers to make use of the latest form of grounded theory. Nevertheless, the current development stage of grounded theory was applied in this doctoral dissertation.

6.1.1 The epistemology of grounded theory

What are the main principles of the grounded theory? First, the grounded theory of Järvinen & Järvinen (2000:46) is the theory of inductively researched phenomenon, where the induction is a method of logical reasoning that obtains or discovers general laws from particular facts or examples. Glaser & Strauss (1967:2-6; 30-32) express the same matter in other words and clarify that the basic idea in grounded theory is the discovery of theory from systematically collected data and the generation of theory from data, which means that most hypotheses and concepts are systematically built in relation to the data during the research process. Second, Glaser & Strauss (1967:32-33) point out that there are two kinds of theory grounded in data. The substantive theory is developed for the empirical area of inquiry and the formal theory is developed for the conceptual area of inquiry. However, in any study each type can at points shade into the other. In any case, the analyst should focus clearly on one lever or other. The focus in this study was on the substantive area where the model of learnability was developed from the empirical area of inquiry based on fifteen different user cases. Nevertheless, both substantive and formal theory must be grounded in data. Third, Strauss & Corbin (1998:114) emphasize that grounded theory, is not describing phenomenon in concrete terms because theoretical discussion uses the abstract concepts and relations between them. Fourth, Glaser & Strauss (1967:31) state how grounded theory can be presented and written to fend off the critique that the only true theory is the one written in numbers.

6.1.2 The grounded theory for the phenomenon of learnability

At the beginning of the analysis process, Glaser & Strauss (1967:33) the researcher has to focus a general question or problem in mind. In this study the main question and problem in mind was how to define phenomenon of learnability.

How does grounded theory suit the study of the phenomenon of learnability? First, as pointed out above, the starting point in this study was to choose the methodology that would enable the study of the phenomenon of learnability without the prior assumptions or definitions of learnability. Hence, this study examined the phenomenon of learnability without any preconceived theory that dictates prior research concepts and hypotheses. Second, grounded theory was chosen because the grounded theory by Glaser & Strauss (1967:31) emphasizes the process when generating the theory. In addition, this study sees and analyses the phenomenon of learnability as a process. In my opinion, the vital elements and parts of a user interface that enhance the learnability of products can only be found by closely and openly studying learnability processes within different contexts.

However, Glaser & Strauss (1967:31) point out grounded theory may have different forms for presenting the theory. The presentation of the theory can be independent of the process in which the theory was generated. In other words, grounded theory can be presented either as a well codified set of propositions or in a running theoretical discussion using conceptual categories and their attributes. In this study, the model of learnability was built using conceptual categories and their attributes in three theoretical phases: open coding, axial coding and selective coding.

6.2 The grounded theory coding process

The grounded theory coding procedures includes three phases: 1) open coding, 2) axial coding and 3) selective coding. (Strauss & Corbin (1998:101-161), Järvinen & Järvinen (2000:47) and Moilanen 2001:162). However, the coding process does not occur linearly from one phase to another; rather, the three phases vertically stimulate one another. The non-linear process can also be seen in the model of learnability built in this doctoral dissertation. Perhaps the grounded theory coding process itself has an effect on the results, i.e. on the theoretical model and patterns of learnability.

Moilanen (2001:159) states that grounded theory coding is created during the analysis process. Therefore, writing codes in grounded theory is a vital part of the material analysis process. The codes can be divided into two categories: substantial codes and theoretical memos. Substantive codes are the conceptual meanings given by generating categories and their attributes and the theoretical memos from material are connected to specification of theory. The purpose of codes is to combine the empirical material analysis and researchers' ideas; the result of that theory grows in memos. Moilanen (2001:162-163) states that the meaning of the substantial memos is the perceptual specification of material.

6.2.1 Open coding phase

The open coding phase identifies concepts, and their properties and dimensions are discovered from data by researching and comparing similarities and differences from concrete concept expressions. The concepts are building blocks of theory. Järvinen & Järvinen (2000:47) and Strauss & Corbin (1998:101-103) define concepts as expressions, which refers to occurrences, cases and other forms of phenomenon. A concept is a labelled phenomenon, which leads to classification. In many cases, ground codes are left purposely open and are not described in detail during the first analysis. The codes become increasingly detailed during the analysis process. Glaser & Strauss (1967:21-24) conclude that a concept may be generated from facts, i.e. from real users' interactions with a user interface.

The first ground concepts are generated from facts during the open coding phase. Then, based on the concepts found, abstract conceptual categories are formed. The concepts are built through comparative analysis and certain concepts are linked to same kind of phenomenon. The category is defined as a classification of the concepts that are found by comparing differences and similarities in the concepts. This allows fine discrimination and differentiation among categories and enables the creation of more abstract categories. By comparing the similarities or differences in the facts, the researcher can generate the attributes of the categories that increase the categories' generality and explanatory power (Järvinen & Järvinen 2000:47, Strauss & Corbin 1998:114). In other words, events, happenings, objects, and actions/interactions found from data are conceptually similar in nature or related in meaning and are grouped under more abstract concepts termed "categories". Glaser & Strauss (1967:21) point out that comparative analysis in grounded theory is used as a strategic method for generating theory.

Once the categories are identified, the researcher can begin to develop it in terms of its specific attributes and dimensions. The attributes are characteristics of a category, the delineation of which defines and gives it meaning. The dimensions are the range along which the general attributes of a category vary, giving specification to a category and variations to the theory (Strauss & Corbin 1998:116-117).

6.2.2 Axial coding phase

The second face is called axial coding, where all the other categories but one is considered as sub-categories. The sub-categories are concepts that pertained to a category, giving it further clarification and specification. (Strauss & Corbin (1998:123-142) and Järvinen & Järvinen (2000:48). The categories are bind together by researching phenomenon's relations, context, actions/interaction strategies and consequences. According to Järvinen & Järvinen (2000:48) and (Strauss & Corbin (1998:123-142) behind the axial coding definition is the following model: The other categories are related to core categories by following the axial coding model a) causal condition, b) phenomenon, c) context, d) intervening conditions, e) action/interaction and f) consequences. The causal condition means situation or occupation, which leads to phenomenon's appearance or development. The phenomenon is the central idea, occupation or case where a group of actions is focused to control and take care of it or where a group of actions are related. The context is certain amount of conditions, where action/interaction strategies are realized. The intervening conditions are structural conditions that affect the phenomenon of action/interaction and make strategies easier or difficult to conclude. The action/interaction is strategy, which are planned to control and take care of phenomenon and be responsible of it in certain conditions. The consequences are results of action/interaction.

6.2.3 Selective coding phase

Järvinen & Järvinen (2000:49) and Strauss & Corbin (1998) conclude that those researchers who develop a certain concept can finish after axial coding phase. However, those who want to create a new theory must continue to the selective coding phase. Glaser & Strauss (1967:2-6; 30-32) state that during the theoretical generation process, the researcher builds general categories and their attributes for general and specific situations and problems.

The selective coding phase means the search process of core category, where other categories are related to it and relations are validated and those categories that need refinement and development are completed (Strauss & Corbin 1998:143-161 and Järvinen & Järvinen 2000:49). According to Järvinen & Järvinen (2000:49) and Strauss & Corbin (1998:181-199), the conditional/consequential matrix has been used in an attempt to strengthen grounded theory. The conditional/consequential matrix is a coding device to help analysts bear several analytic points in mind. These are a) that macro conditions/consequences, as well as micro ones, should be part of an analysis (when these emerge form the data as being significant), b) that the macro conditions often intersect and interact with the micro ones and c) thereby, in direct or indirect ways, become part of the situational context, and d) that the paths taken by conditions as well as the subsequent actions/interactions and consequences that follow can be traced in the data (the paths of connectivity).

Järvinen & Järvinen (2000:49) and Strauss & Corbin (1998:148-153) conclude that an analytical story based on core category is theory based on material that a researcher can publish. The theory must fit with the phenomenon, clarify the phenomenon under study and be as general as possible. Before the theory is ready for publication, the researcher is advised to check at least one more thing: how the phenomenon changes in a timeline or when changes are conditional. This is done to ensure that the theory is not too vertical. In a timeline, some attributes of change are speed (slow-fast), occurrence (planned-unplanned), character (regular-occasionally/progressive/unprogressive), direction (forward-backwards/up/down), surface (large/narrow), effect (major-minor) and control (high-low).

In conclusion, Järvinen & Järvinen (2000:51) and Strauss & Corbin (1998:201-215) state that theoretical sampling has to be taken in consideration in the different phases (open, axial, selective coding) of the theory development process. The theoretical sampling is based on concepts, which has proved to be relevant in theory, which has under development process. In open coding face theoretical sample tries to be open and cover categories the most widely, axial coding face pays attention to relations variety and validity and selecting coding face maximize the verification of analytic story. When sample is completed with theoretical sampling the categories are theoretically saturated in other words all attributes, and their classes are covered. At the end, Glaser & Strauss (1967:2-6; 30-32) points out that the theory building process is seen as an ever-developing entity, not as a perfect product and the form in which theory is presented does not make it a theory because the theory always explains or predict something.

The following sections describe the research method from an empirical point of view.

7 THE GROUNDED THEORY DATA ANALYSIS PROCESS

Many researchers have been stated that analysing qualitative material is intuitive, an instantly human process taking place at the conscious level (Glaser & Strauss 1967:3 and Moilanen 2001:159). However, critical analyses first need theoretical references and concepts that are able to distinguish the new characteristics in the material and assimilate them into studying the phenomenon. In other words, the researcher needs theoretically distinguished concepts even when using grounded theory to critically analyse data. These concepts aid the researcher to observe the new features of phenomenon and assimilate the features found as part of studying the phenomenon. Barney G. Glaser (1992:25) states that it is natural that researcher is trained in the sophisticated use of one or the other concepts and s/he will be more theoretically sensitive in his/her own area. The researcher must be sensitive in order to be capable of forming conceptual sense close and integrated theory. In grounded theory, there are no preconceptions; rather, the grounded theory process steers the path to bounded focus.

According to Glaser & Strauss (1967:33), the researcher has to focus a general question or problem in mind. In this study, the general question in mind was to define phenomenon of learnability. The phenomenon of learnability was studied without any preconceived theory that dictates prior research concepts and hypotheses. The grounded theory data analysis process is presented in Figure 6.

Polytech-nic students (N=15)	WebCT Campus Edition software	Pre-test Six tasks	Office PC 110 Sony video camera Observer	Video film Performan-ce times User action (N=1836)	Open coding Axial coding Selective coding
Subjects →	Software Product →	Task development →	Evaluation process →	Data collection →	Data analyses

FIGURE 6. Data collection and analysis process.

7.1 The subjects

Subjects were Rovaniemi Polytechnic's first year students (N=15). From the chosen subjects sixty percent (60%) were male and forty percent (40%) female. The subjects' age range was 18 – 24 years (93%) and 35 – 45 years (7%).

The selecting criteria were that subjects did not have any previous knowledge or use of any educational platforms. The random sample was taken from different degree programs (see Figure 7).

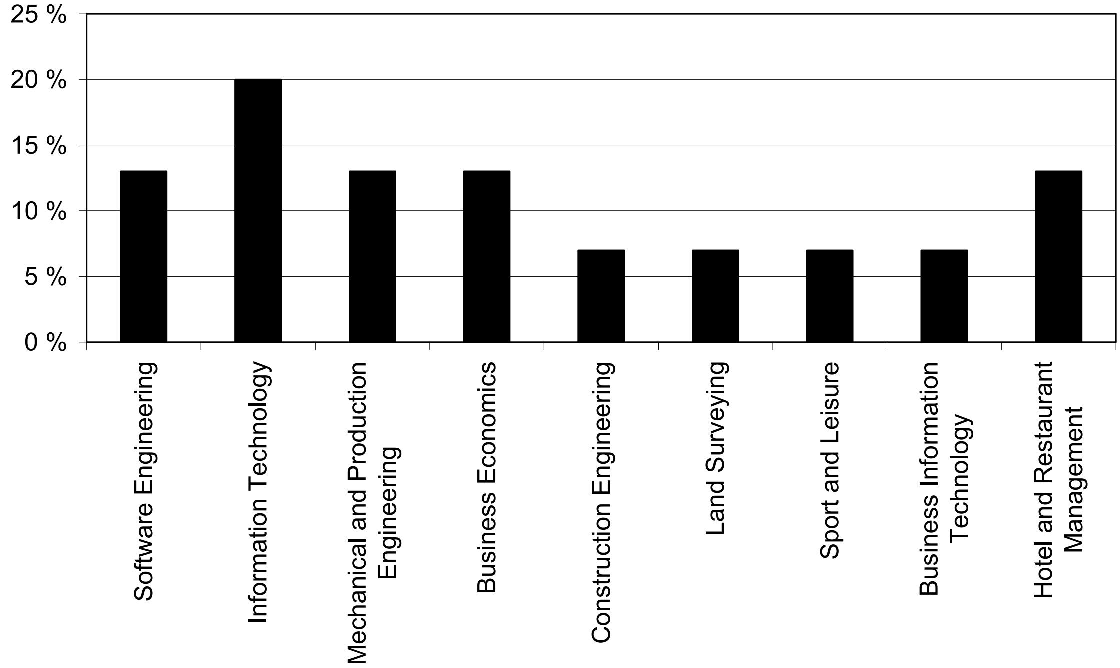

FIGURE 7. The subjects' degree programs.

7.2 Software product

The evaluation environment was arranged so that it was possible to control the unwanted variables that might affect the result. The learnability tasks were performed in the same conditions with the same computer and physical and social evaluate environment.

The learnability task was performed with the same Pentium III laptop computer. Logitech's coreless keyboards and mouse were used as input devices. The tasks were performed in as natural an on-line learning situation as possible with Ethernet 10/100 Mbit Internet connections. The WebCT Campus Edition was used on the Microsoft Explorer version 6.0 browser.

The WebCT Campus Edition software product is commonly used in on-line studies in different types of organizations. The WebCT Campus Edition, i.e. the educational platform, provided a Virtual Course Environment with a complete set of tools for on-line learning. The WebCT Campus Edition includes a separate interface for instructors, where users can easily prepare, deliver and manage the online courses. In addition, it offers a wide range of assessment and assignment tools for an on-line course. Therefore, instructors can easily prepare their course materials and efficiently manage day-to-day tasks. The WebCT Campus Edition also includes a separate interface for students and offers a set of tools to help them efficiently manage their workload and monitor their own progress. In addition, the WebCT Campus Edition provides course interaction tools as announcements, calendar, chat & whiteboard, discussion board, e-mail and who is online. The course interaction interface has tools for group work, which enables instructors and students to communicate and collaborate effectively. Figure 8 presents WebCT's key course instruction tools for instructors and students.

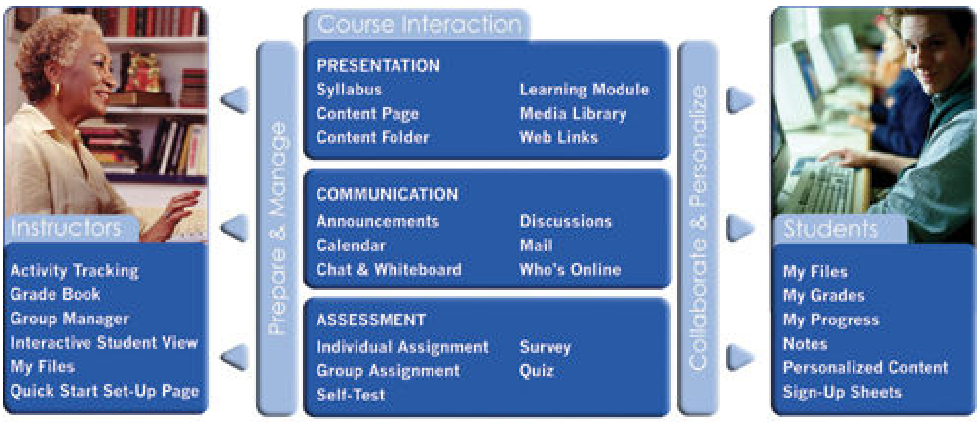

FIGURE 8. WebCT Campus Edition's Virtual Course Environment. (webct.com)

The graphical user interface view was evaluated from the students' point of view in order to investigate the learnability at the beginning of the on-line course for novice users. The WebCT Campus Edition's presentation and communication graphical user interface were evaluated. The presentation graphical user interface included the information search course content and its architecture and navigation structure. In the communication graphical user interface, the following communication tools were tested: calendar, discussion board and e-mail. In addition, the learnability of the log in and log out features in the WebCT Campus Edition were evaluated. The graphical user interface views tested in the WebCT's Campus Edition can be seen from the users' point of view in Figures 9-14.

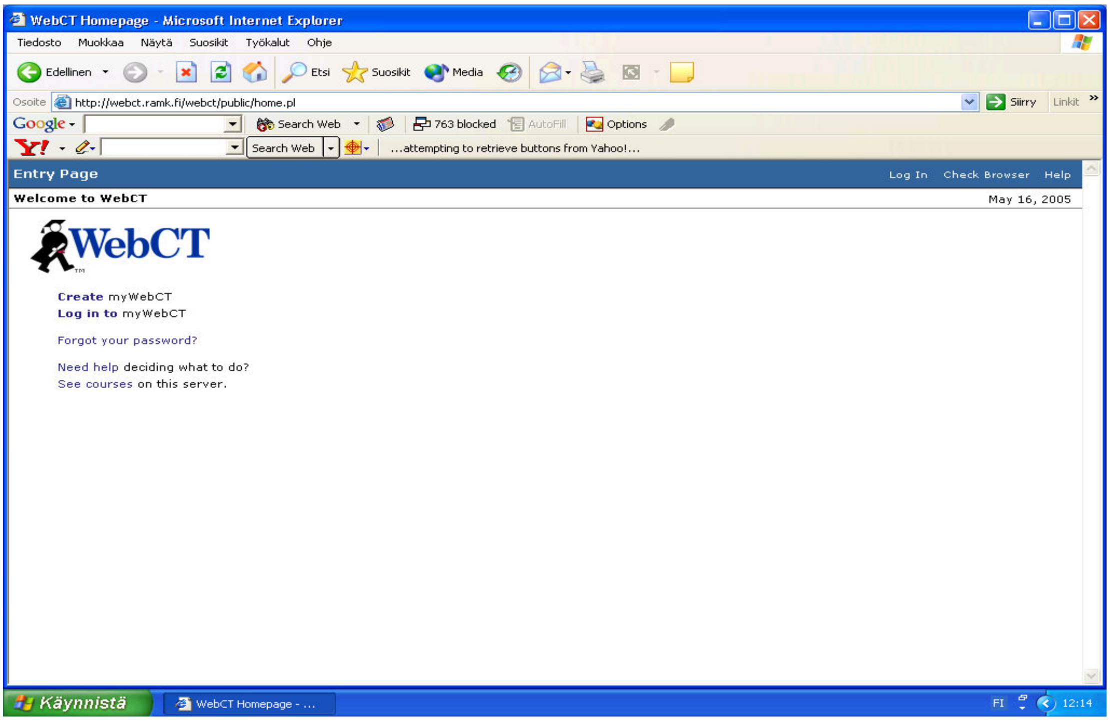

FIGURE 9. WebCT's Campus Edition graphical user interface view for log in.

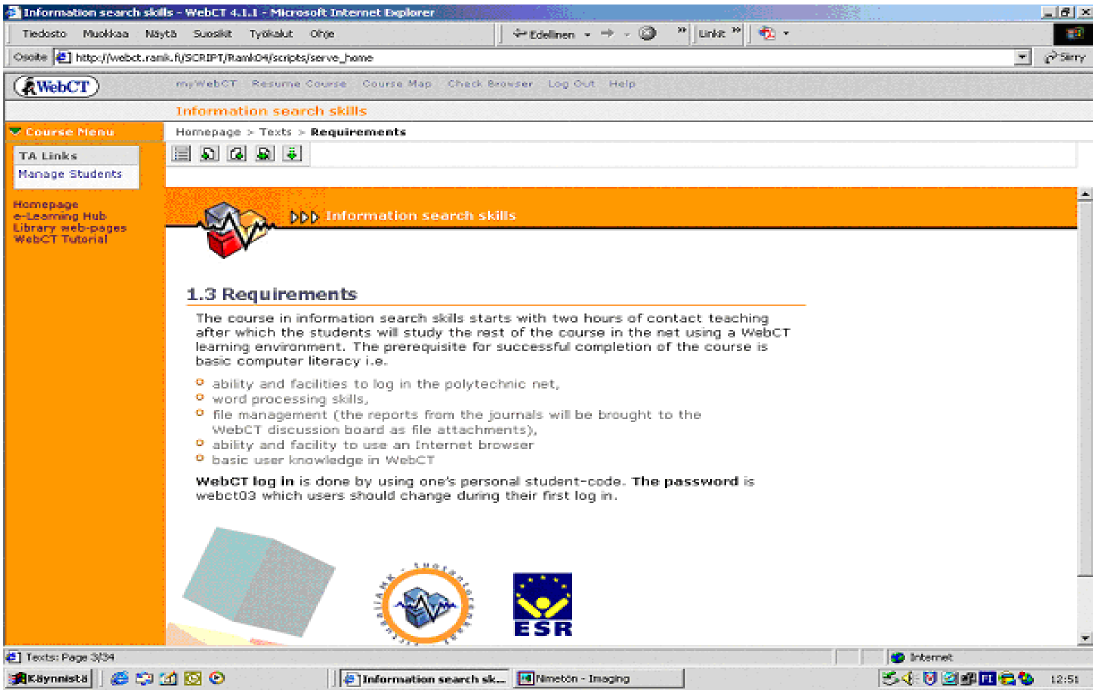

FIGURE 10. WebCT's Campus Edition graphical user interface view for information search course requirements.

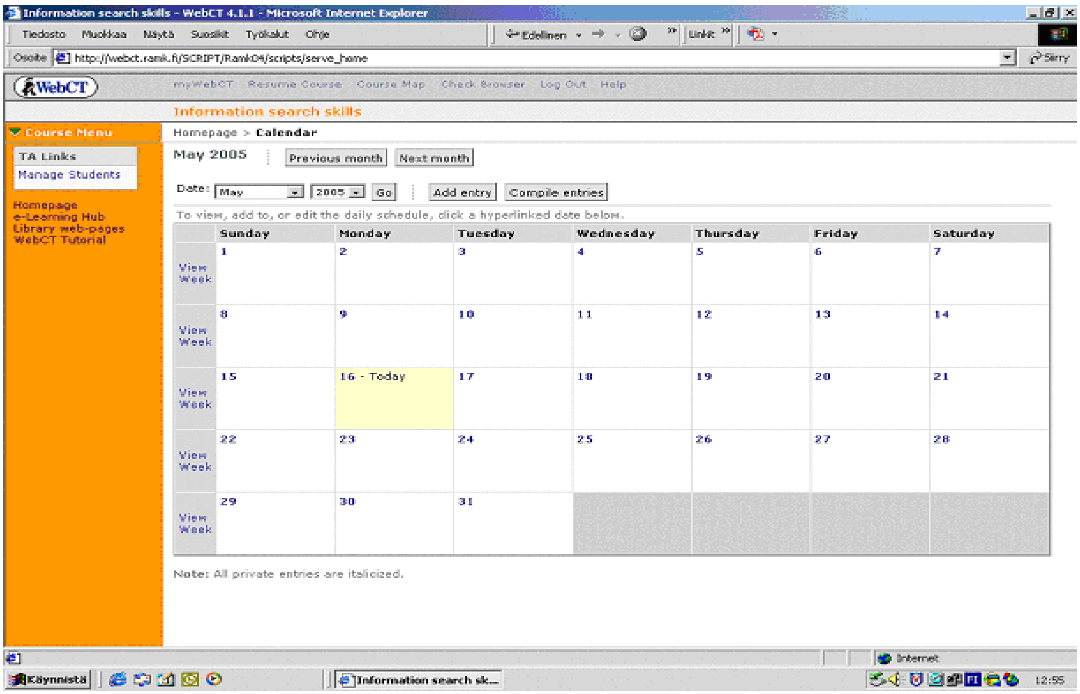

FIGURE 11. WebCT's Campus Edition graphical user interface view for the calendar.

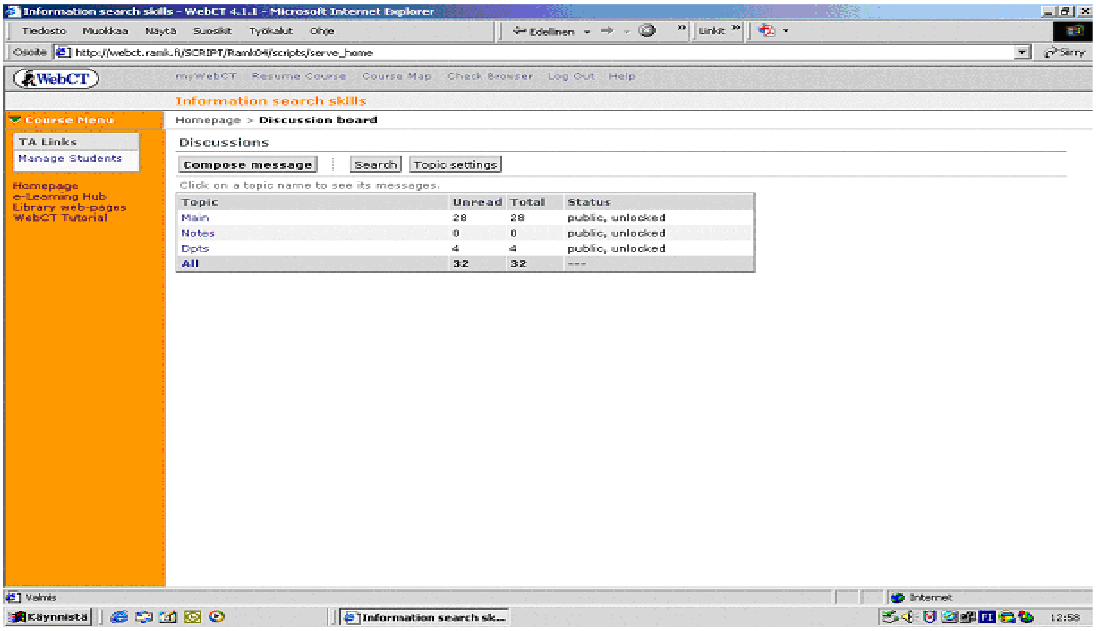

FIGURE 12. WebCT's Campus Edition graphical user interface view for the discussion board.

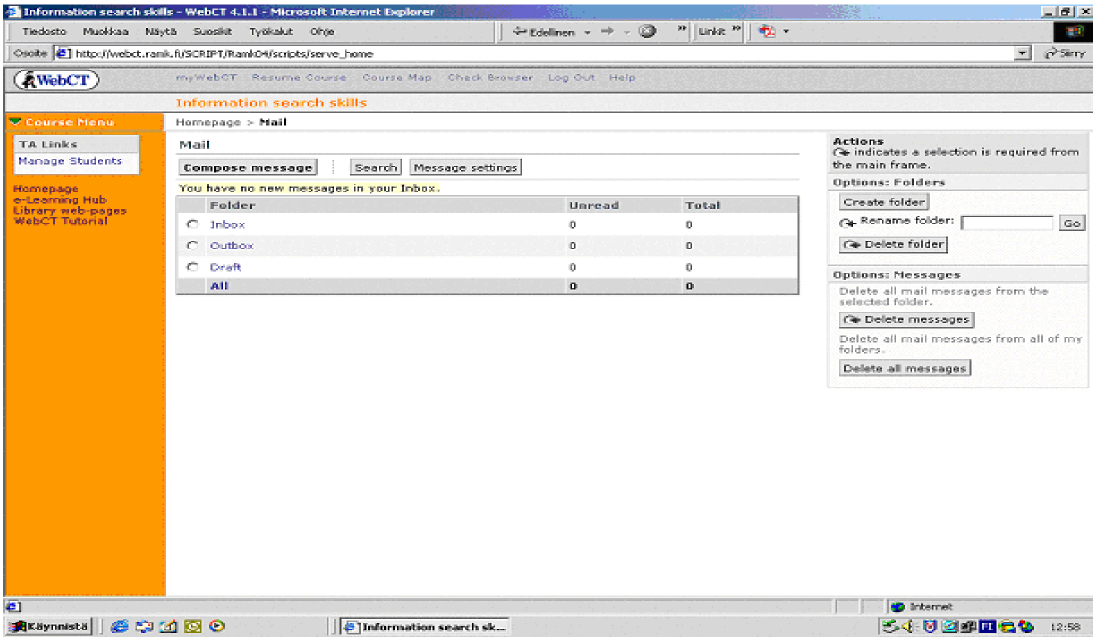

FIGURE 13. WebCT's Campus Edition graphical user interface view for e-mail.

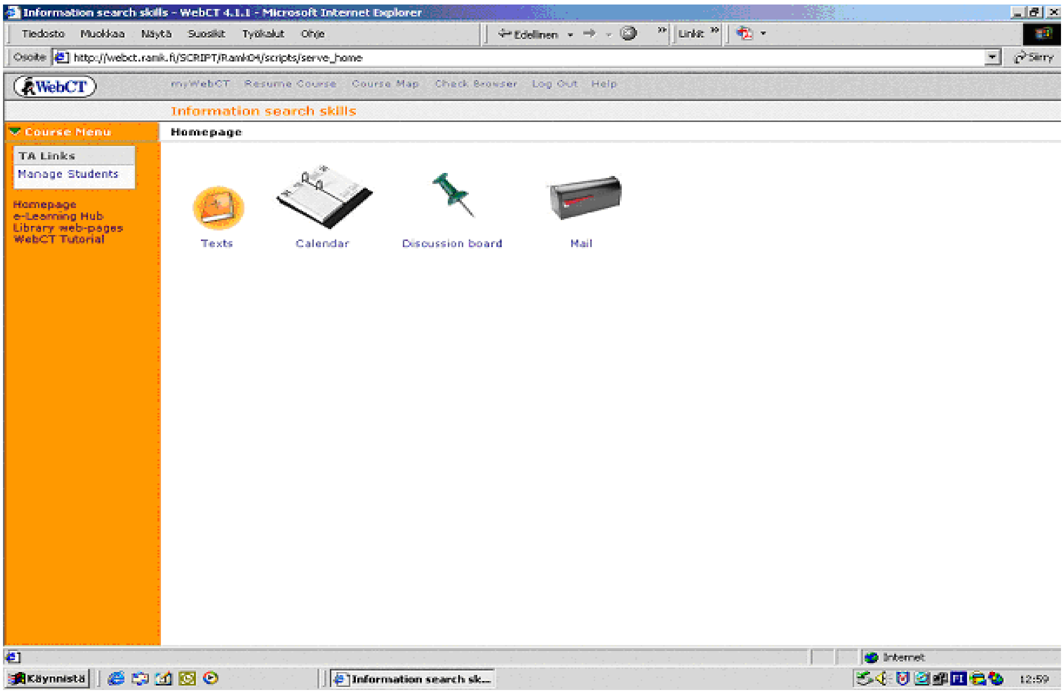

FIGURE 14. WebCT’s Campus Edition graphical user interface view for log out.

7.3 Learnability task development

A short pilot study was carried out during the spring 2003 to check the adequacy of the task developed for the learnability evaluation. This enabled an assessment of whether the task to be used in the evaluation met the general criteria. The pilot study involved carrying out the learnability task using the WebCT Campus Edition in different kinds of on-line-courses with 1 to 2 Rovaniemi Polytechnic students in order to check whether alterations were necessary. It appeared that task had to be simplified and assignments had to be modified to focus more at the beginning of learning process, i.e. the indention in this study was to measure the early stages of the learning process. In other words, how easily the novice polytechnic students begin to study on-line courses by using the WebCT Campus Edition software.

There was one main point involved in constructing the task developed for the learnability evaluation. How could the evaluation task to measure the learnability process at the beginning of an on-line course be developed? First, it was considered whether it was possible to create one general task that included the relevant functions of the WebCT Campus Edition software that the students need at the beginning of their on-line studies or whether several tasks that "test" different aspects of the WebCT Campus Edition software should be employed. The second consideration was whether it was possible to combine all the relevant WebCT functions and the on-line course interface into one large task, i.e. whether such a combination would be realistic. In a real on-line study situation, the WebCT educational platform and on-line study course are not two separate units that have to be learnt separately; rather, they form a unified interface. Therefore, it was decided to develop one large task that evaluate both the WebCT Campus Edition software and the on-line course interface because one large task better demonstrates the real on-line study situation and better indicates the learnability process at the beginning of the on-line course.

The development of evaluating one large task involved deciding on the number of assignments, appraising the chosen evaluation task, how well they can be performed, and the extent to which they explore the functionality of the WebCT Campus Edition software and on-line course interface under evaluation. Consequently, one large learnability task was developed with six separate assignments. The learnability assignments covered the key WebCT platform's functions, which are normally used at the beginning of on-line study process, from the student point of view. The task was reasonably broad in that the required functions of both the WebCT Campus Edition software and the on-line course interface were explored to as great an extent as possible at the beginning of the on-line study process. The tasks described the realistic problems to be solved using the WebCT educational platform. In addition, the learnability assignments were created so that they could be successfully completed by the majority of polytechnic students.

The six assignments measured learnability in a real study situation where the WebCT educational software was used to conduct an information search on-line study course. In the timeline, learnability focused at the beginning of learning process. Fifteen first year students from the polytechnic conducted six assignments within the WebCT Campus Edition software. As stated earlier, the assignments were developed to cover the major parts of the educational platform features needed at the beginning of the on-line study. The large task involved the following six assignments: 1) Log on to the information search course, 2) Print the information search course instructions, 3) Find the first information search course contact day on the calendar, 4) Set a new discussion topic for everyone on the discussion forum, 5) Send an e-mail to the information search course teacher and 6) Log out from the course

7.4 Learnability evaluation process

Rovaniemi Polytechnic first year students (N=15) were given a detailed explanation of each step of the learnability evaluation process, before the actual learnability task. The students were told what the WebCT educational platform was and why it was being evaluated. They were also told why and how their particular background was relevant, i.e. why the evaluator was chosen for the students, who had not have any prior experience of educational platforms, and how their contribution would benefit the evaluation. In addition, the students were told that their identity would remain anonymous and this study would have no untoward ramifications for them personally.

The task was given to the students in writing. Not only did this ensure that the task was described in the same way to all students, but having a written task also allowed the students to refer to the task description during the experiment instead of having to remember all the details. After the students had been given the task and had a chance to read it, the evaluator allowed the students to ask question about the task description in order to minimize the risk that a user had misinterpreted the task. In addition, they were told the estimation on the time for the evaluation process.

Before the actual learnability task, the students were first asked permission to video record the interaction and then they were told why it was being carried out. If the students were unsure about any aspect of the evaluation, they were told they could ask questions at any time.

The learnability task was recorded on video using a Sony PC110 video camera. The video camera was set up in a place that it was as unobtrusive as possible for students. The social environment was also controlled so that only two people were in the same room when the learnability task was taken. One person was the evaluator of the learnability task, and the same instructions were given to each subject in each step of the evaluation. The steps in the evaluation were undertaken in the same order.

The fact that the students were not being evaluated was also stressed; rather, the aim was to assess the WebCT educational platform and not the students because they could become highly stressed, particularly when carrying out a learnability task, if they felt they were under examination. Finally, the students were told that the results of the evaluation would be kept confidential and they were asked not to discuss the evaluation with fellow students who might participate in a future evaluation.

7.5 Data collection

The video recording should do such as research studies where absolute certainty is needed. Having the videotapes of user evaluation is essential for many research purposes where one needs to study the interaction in minute detail. Why relay on video data? I like my theorizing to be responding to the phenomenon of learnability itself rather than to the characteristics of the representational system that reconstruct it and thereby force the direction of theoretical model of learnability. (see Jordan & Henderson 1995:12-14). Henderson (1989:105) continues that the video is powerful new methodology for studying human activity without preconceived notions of what issues or even perspectives will be important. In addition, Henderson (1989:104) video can be helpful, when investigating the process of learning. Nielsen (1993:203). Hyösniemi et al. (2003) verify that videotaping is a key element in storing the physical action in evaluation situation. However, interaction-analytic studies (Jordan & Henderson 1995:4) perceive learning as social process, where people do learn collaboratively. Therefore, based on video data used in this dissertation, which consist individual users action is not able investigate the collaborative aspect of learning.

The model of learnability built in this study is based on data. Therefore, all the actions must be possible in detailed collected from data. The data collection involved measuring the users' (N=15) performance times; compile all the user actions and goal directions in relation to the task. Individual user's actions were saved in separate video cassettes. The data collection process was time consuming. The totally amount of video data was 3 h 46 min (226 min). It took total of three months for two researches, Licentiate of Education Mika Laakkonen from humanistic background and software engineer Stefan Brandt from the technical background, to collect the data from fifteen video films.

The video data (Jordan & Henderson (1995:1-7) can be re-viewed repeatedly and make observation not possible on a single viewing. Also, errors in a paper-and pencil record can be invisible because there is no opportunity to go back and re-examine the situation. During the data collection process researchers had to confirm and recheck users' actions from the video films several times. The first observational phase involved measures of total performance times of assignment from each student (N=15). Times per assignments were calculated from the point, where the students started the assignment and when s/he gave the last input to finish the assignment. Jordan & Henderson (1995:24) state that things often have to happen at particular period of time and rhythm. Therefore, interaction analyses observe repetitive aspect sequences and their variability. The second observation involved collecting every single action (N=1836) from the video material and simultaneously the actions were synchronized with time. In addition, the actions were defined weather they were towards or away from the task solutions. Therefore, based on video data it was possible investigate more detailed ground concept appearance in timeline, which horizontally strengthen the theoretical model of learnability. Furthermore, data allowed to examine intensity and delay values of individual users and learnability process in relation to task complexity.

In this study, the unit for analysis was the single user action. Grounded theory does not give precise instructions concerning the unit size to been analysed (Glaser & Strauss (1967:21) and Moilanen (1992:162). In addition, the central idea of collecting data is the level of saturation. In other words, the data have to be collected as long as no new material for the phenomenon being studied appears. The study involved fifteen users (N=15).

7.6 Data analysis

The grounded theory coding process includes three phases: 1) open coding, 2) axial coding and 3) selective coding. In open coding phase, ground concepts close to user real actions were collected from data and synchronised with time. Than similarities and differences from concrete concept were compared and more conceptual abstract categories were formed. In axial coding phase sub-categories were formed and in selective coding phase the theoretical model of learnability was build.

The following figure 15 illustrates the data analyses process in different phases of grounded theory. (see Figure 15)

1) Open coding phase	**2) Axial coding phase**	**3) Selective coding phase**
Ground concepts were created from real users' actions Similarities and differences from concrete concepts were compared More abstract conceptual categories were formed	Sub-categories were formed	Core category was searched Refinement of categories was done Theoretical model of learnability was build

FIGURE 15. Data analysis process in different phases of grounded theory. (Strauss & Corbin 1988:101-161)

As a previously mentioned, in this doctoral dissertation the data was observed twice. The first observation formed the general idea of the phenomenon learnability. Simultaneously, the performance times per tasks and total users' performance times were measured. First, the performance times were captured in order to verify the result discovered by using grounded theory and to validate the results that were found. The second reason was to measure the performance times to horizontally strengthen the model of learnability and the third reason was to be able to evaluate the learnability of WebCT Campus Edition Software (see Table 7 and Table 8).

TABLE 7. Users' 1 - 8 total performance times (sec.) and times per tasks.

Tasks	User 1	User 2	User 3	User 4	User 5	User 6	User 7	User 8
1	52	64	76	85	71	70	60	187
2	639	191	550	164	95	156	170	117
3	122	34	114	74	32	111	65	132
4	86	184	111	355	219	319	73	71
5	498	226	266	432	258	315	146	82
6	132	130	39	55	92	37	25	110
Total	**1529**	**829**	**1156**	**1165**	**767**	**1008**	**539**	**699**

TABLE 8. Users' 9 - 15 total performance times (sec.) and times per tasks.

Tasks	User 9	User 10	User 11	User 12	User 13	User 14	User 15
1	60	50	46	89	62	74	56
2	202	63	107	148	196	198	275
3	90	51	115	500	70	65	68
4	103	64	187	109	126	61	69
5	307	105	434	452	346	310	198
6	52	33	30	171	51	31	41
Total	**814**	**366**	**919**	**1469**	**851**	**739**	**707**

Furthermore, the intensity and delay values were calculated from the total performance times. The intensity value was formulated as frequencies/time (sec.) and delay value as time (sec.)/frequencies. Then the maximum and minimum values of intensity and delay times were selected and they were next subtracted. The subtracted value was divided by five and the grading range values were formed to the scale: excellent (5), good (4), fair (3), satisfy (2) and poor (1). In brief, the intensity means the number of the user actions per second. The delay indicates the time between the user actions. The scale in both the intensity and delay indicators was 1 to 5, where 1 meant slow intensity and long delay times, and the value 5 meant fast intensity and short delay times (see Tables 9 – 12).

TABLE 9. Intensity values. (N/sec.)

Min	0.08
Max	0.26
Max-Min	0.18
(Max-Min) / 5	0.036

TABLE 10. Intensity scale.

Excellent (5)	0.08-0.11
Good (4)	0.11-0.15
Fair (3)	0.15-0.18
Satisfy (2)	0.18-0.22
Poor (1)	0.22-0.26

TABLE 11. Delay values. (sec./N)

Min	3.90
Max	13.09
Max-Min	9.20
(Max-Min) / 5	1.84

TABLE 12. Delay scale.

Excellent (5)	3.90-5.73
Good (4)	5.73-7.57
Fair (3)	7.57-9.41
Satisfy (2)	9.41-11.25
Poor (1)	11.25-13.09

7.6.1 Data analysis in the open coding phase

The open coding phase includes gathering in detail all the users' actions (N=1836). In order to horizontally strengthen the model of learnability that is built, Järvinen & Järvinen (2000:49) and Strauss & Corbin (1998:148–153) emphasize the importance of understanding how the phenomenon changes in a timeline. The phenomenon of learnability and its concepts were checked by showing a connection to performance times and goal direction, i.e. the users' action towards and away from the solution. The User 7 learnability process, i.e. the user's actions in relation to goal direction in a timeline, can be seen in detail in Table 13.

TABLE 13. Users' 7 actions and goal direction in timeline.

Concepts (concrete)	minutes	seconds	tenth	The goal direction
click on the log on hyperlink	0	4	18	towards the solution
written user name	0	11	14	towards the solution
press on the backspace key on the keyboard	0	11	15	away from the solution
written user name	0	14	2	towards the solution
press on the tab key on the keyboard	0	17	13	towards the solution
written password	0	21	6	towards the solution
press on the enter key on the keyboard	0	22	0	towards the solution
vertical scroll down with the mouse scroll button	0	49	7	away from the solution
click on the information search course hyperlink	0	59	11	towards the solution

Concepts (concrete)	minutes	seconds	tenth	The goal direction
click on the WebCT instructions hyperlink	1	31	21	away from the solution
maximize window (click on title bar)	1	37	9	away from the solution
vertical scroll down with scroll bar	1	39	17	away from the solution
vertical scroll up with scroll bar	1	51	0	towards the solution
vertical scroll down with scroll bar	1	54	13	away from the solution
close the window	1	58	24	towards the solution
click on the information search course hyperlink	2	5	9	towards the solution
click on the study material content hyperlink	2	13	22	towards the solution
vertical scroll down with the mouse scroll button	2	19	4	away from the solution
vertical scroll up with the mouse scroll button	2	19	17	towards the solution
click on the introduction hyperlink	2	23	0	away from the solution
vertical scroll down with the mouse scroll button	2	28	0	away from the solution
vertical scroll up with the mouse scroll button	2	30	6	towards the solution
navigation back	2	32	9	towards the solution
click on the information search course instructions hyperlink	2	34	21	towards the solution
vertical scroll down with the mouse scroll button	2	46	3	away from the solution
vertical scroll down with scroll bar	2	49	13	away from the solution

Concepts (concrete)	minutes	seconds	tenth	The goal direction
vertical scroll up with scroll bar	2	50	20	towards the solution
vertical scroll down with the mouse scroll button	2	59	13	away from the solution
vertical scroll up with the mouse scroll button	3	0	7	towards the solution
starts to paint the information search course instructions	3	2	21	towards the solution
finish to paint the information search course instructions	3	11	8	towards the solution
press on the ctrl-c keys on the keyboard	3	11	10	towards the solution
click on the start menu	3	14	12	towards the solution
click on the Microsoft Word application shortcut icon	3	18	11	towards the solution
press on the ctrl-c keys on the keyboard	3	23	0	towards the solution
vertical scroll up with scroll bar	3	29	6	towards the solution
close the Microsoft Word side menu	3	34	19	away from the solution
click on the menu bar file option	3	37	18	towards the solution
click on the menu bar print option	3	38	17	towards the solution
click on the ok button	3	49	4	towards the solution
minimize the window	4	6	24	towards the solution
navigation back	4	9	4	away from the solution
navigation back	4	14	13	away from the solution

Concepts (concrete)	minutes	seconds	tenth	The goal direction
navigation back	4	16	12	away from the solution
navigation back	4	21	14	towards the solution
click on the calendar hyperlink	4	26	4	towards the solution
click on the month dropdown menu	4	40	13	towards the solution
click on the September option on the dropdown menu	4	43	1	towards the solution
click on the go button	4	45	2	towards the solution
navigation back	5	3	2	away from the solution
navigation back	5	4	19	towards the solution
click on the discussion forum hyperlink	5	7	4	towards the solution
click on the compose discussion message hyperlink	5	19	7	towards the solution
click on the topic dropdown menu	5	25	23	away from the solution
close the topic dropdown menu	5	28	4	towards the solution
click on the subject text box	5	29	0	towards the solution
written subject	5	33	1	towards the solution
click on the message text area	5	36	22	towards the solution
written message	5	53	16	towards the solution
click on the attach file button	5	59	5	away from the solution

Concepts (concrete)	minutes	seconds	tenth	The goal direction
alert window (Please, browse to find the file to attach)	6	1	0	away from the solution
click on the ok button	6	4	18	towards the solution
click on the post button	6	8	3	towards the solution
navigation back	6	17	24	towards the solution
click on the tutors contact information hyperlink	6	28	5	towards the solution
vertical scroll down with the mouse scroll button	6	31	1	away from the solution
vertical scroll up with the mouse scroll button	6	31	14	towards the solution
vertical scroll down with the mouse scroll button	6	34	20	away from the solution
vertical scroll up with the mouse scroll button	6	34	33	towards the solution
paints the e-mail address	6	48	17	towards the solution
press on the ctrl-c keys on the keyboard	6	48	18	towards the solution
click on the e-mail hyperlink	6	53	14	towards the solution
minimize the window	7	14	4	away from the solution
click on the explorer shortcut icon	7	15	19	towards the solution
click on the URL dropdown menu	7	20	10	towards the solution
close the URL dropdown menu	7	24	8	towards the solution
click on the URL text box	7	24	15	towards the solution

Concepts (concrete)	minutes	seconds	tenth	The goal direction
press on the backspace key on the keyboard	7	26	8	away from the solution
written the URL (tlmail.ramk.fi)	7	32	22	towards the solution
click on the web mail hyperlink	7	34	8	towards the solution
alert window (Security alert)	7	34	24	towards the solution
click on the ok button	7	35	0	towards the solution
click on the web mail hyperlink	7	37	5	towards the solution
alert window (Security alert)	7	37	6	towards the solution
click on the ok button	7	38	6	towards the solution
written user name	7	42	1	towards the solution
press on the tab key on the keyboard	7	42	20	towards the solution
written password	7	45	5	towards the solution
press on the enter key on the keyboard	7	45	6	towards the solution
alert window (Auto complete)	7	45	17	towards the solution
click on the yes button	7	46	14	towards the solution
click on the inbox hyperlink	7	48	20	towards the solution
click on the send icon	7	52	0	towards the solution
press on the ctrl-v keys on the keyboard	7	55	11	towards the solution
paste the send to text box	7	55	12	towards the solution

Concepts (concrete)	minutes	seconds	tenth	The goal direction
click on the subject text box	7	57	19	towards the solution
written subject	8	11	20	towards the solution
click on the message text area	8	14	21	towards the solution
written message	8	31	1	towards the solution
paints the signature	8	31	18	away from the solution
press on the delete key on the keyboard	8	32	10	away from the solution
click on the send button	8	33	23	towards the solution
close the window	8	38	2	towards the solution
click on the e-mail task bar	8	40	19	towards the solution
close the window	8	59	8	towards the solution

Furthermore, the most important part in theory building in grounded theory is conceptualising because the main feature of this method is grounding concepts in data. In other words, the concepts are used as the building blocks of the model of learnability. The concepts were generated from facts by analysing and comparing similarities and differences from concrete concept expressions (see Table 13 and 14).

TABLE 14. Users' 7 concept similarities and differences.

Concepts (concrete)	Similarities	Differences
click on the log on hyperlink	click (hyperlink)	name (log on)
written user name	write (text)	name (subject)
press on the backspace key onthe keyboard	press (keyboard)	key (backspace)
written user name	write (text)	name (subject)
press on the tab key on the keyboard	press (keyboard)	key (tab)
written password	write (text)	name (password)
press on the enter key on the keyboard	press (keyboard)	key (enter)
vertical scroll down with the mouse scroll button	move (mouse button)	direction (down)
click on the information search course hyperlink	click (hyperlink)	name (information search course)
click on the WebCT instructions hyperlink	click (hyperlink)	name (WebCT instructions)
maximize window (click on title bar)	click (title bar)	resize (maximize)
vertical scroll down with scroll bar	move (scroll bar)	direction (down)
vertical scroll up with scroll bar	move (scroll bar)	direction (up)
vertical scroll down with scroll bar	move (scroll bar)	direction (down)
close the window	click (icon)	name (close)
click on the information search course hyperlink	click (hyperlink)	name (information search course)

Concepts (concrete)	Similarities	Differences
click on the study material content hyperlink	click (hyperlink)	name (study material content)
vertical scroll down with the mouse scroll button	move (mouse button)	direction (down)
vertical scroll up with the mouse scroll button	move (mouse button)	direction (up)
click on the introduction hyperlink	click (hyperlink)	name (introduction)
vertical scroll down with the mouse scroll button	move (mouse button)	direction (down)
vertical scroll up with the mouse scroll button	move (mouse button)	direction (up)
navigation back	click (icon)	name (navigation back standard buttons)
click on the information search course instructions hyperlink	click (hyperlink)	name (information search course instructions)
vertical scroll down with the mouse scroll button	move (mouse button)	direction (down)
vertical scroll down with scroll bar	move (scroll bar)	direction (down)
vertical scroll up with scroll bar	move (scroll bar)	direction (up)
vertical scroll down with the mouse scroll button	move (mouse button)	direction (down)
vertical scroll up with the mouse scroll button	move (mouse button)	direction (up)

Concepts (concrete)	Similarities	Differences
starts to paint the information search course instructions	paint (text)	name (information search course instructions)
finish to paint the information search course instructions	paint (text)	name (information search course instructions)
press on the ctrl-c keys on the keyboard	press (keyboard)	key (ctrl-c)
click on the start menu	click (start menu)	
click on the Microsoft Word application shortcut icon	click (icon)	name (Microsoft Word application)
press on the ctrl-c keys on the keyboard	press (keyboard)	key (ctrl-c)
vertical scroll up with scroll bar	move (scroll bar)	direction (up)
close the Microsoft Word side menu	click (side menu)	name (Microsoft Word)
click on the menu bar file option	click (menu bar)	name (file menu)
click on the menu bar print option	click (menu bar)	name (print option)
click on the ok button	click (button)	name (ok)
minimize the window	click (icon)	resize (minimize)
navigation back	click (icon)	name (navigation back standard buttons)

Concepts (concrete)	Similarities	Differences
navigation back	click (icon)	name (navigation back standard buttons)
navigation back	click (icon)	name (navigation back standard buttons)
navigation back	click (icon)	name (navigation back standard buttons)
click on the calendar hyperlink	click (hyperlink)	name (calendar)
click on the month dropdown menu	click (dropdown menu)	name (month)
click on the September option on the dropdown menu	click (dropdown menu)	name (September option)
click on the go button	click (button)	name (go)
navigation back	click (icon)	name (navigation back standard buttons)
navigation back	click (icon)	name (navigation back standard buttons)
click on the discussion forum hyperlink	click (hyperlink)	name (discussion forum)

Concepts (concrete)	Similarities	Differences
click on the compose discussion message hyperlink	click (hyperlink)	name (compose discussion message)
click on the topic dropdown menu	click (dropdown menu)	name (topic)
close the topic dropdown menu	click (dropdown menu)	name (topic)
click on the subject text box	click (text box)	name (subject)
written subject	write (text)	name (subject)
click on the message text area	click (text area)	name (message)
written message	write (text)	name (message)
click on the attach file button	click (button)	name (attach file)
alert window (Please, browse to find the file to attach)	alert (window)	Message (Please, browse to find the file to attach)
click on the ok button	click (button)	name (ok)
click on the post button	click (button)	name (post)
navigation back	click (icon)	name (navigation back standard buttons)
click on the tutors contact information hyperlink	click (hyperlink)	name (tutors contact information)
vertical scroll down with the mouse scroll button	move (mouse button)	direction (down)
vertical scroll up with the mouse scroll button	move (mouse button)	direction (up)

Concepts (concrete)	Similarities	Differences
vertical scroll down with the mouse scroll button	move (mouse button)	direction (down)
vertical scroll up with the mouse scroll button	move (mouse button)	direction (up)
paints the e-mail address	paint (text)	name (e-mail address)
press on the ctrl-c keys on the keyboard	press (keyboard)	key (ctrl-c)
click on the e-mail hyperlink	click (hyperlink)	name (e-mail)
minimize the window	click (icon)	resize (minimize)
click on the explorer shortcut icon	click (icon)	name (explorer)
click on the URL dropdown menu	click (dropdown menu)	name (URL)
close the URL dropdown menu	click (dropdown menu)	name (URL)
click on the URL text box	click (text box)	name (URL)
press on the backspace key on the keyboard	press (keyboard)	key (backspace)
written the URL (tlmail.ramk.fi)	write (text)	name (URL)
click on the web mail hyperlink	click (hyperlink)	name (web mail)
alert window (Security alert)	alert (window)	Message (Security alert)
click on the ok button	click (button)	name (ok)
click on the web mail hyperlink	click (hyperlink)	name (web mail)
alert window (Security alert)	alert (window)	Message (Security alert)
click on the ok button	click (button)	name (ok)

Concepts (concrete)	Similarities	Differences
press on the tab key on the keyboard	press (keyboard)	key (tab)
written password	write (text)	name (password)
press on the enter key on the keyboard	press (keyboard)	key (enter)
alert window (Auto complete)	alert (window)	Message (Auto complete)
click on the yes button	click (button)	name (yes)
click on the inbox hyperlink	click (hyperlink)	name (inbox)
click on the send icon	click (icon)	name (send)
press on the ctrl-v keys on the keyboard	press (keyboard)	key (ctrl-v)
paste the send to text box	press (keyboard)	key (ctrl-v)
click on the subject text box	click (text box)	name (subject)
written subject	write (text)	name (subject)
click on the message text area	click (text area)	name (message)
written message	write (text)	name (message)
paints the signature	paint (text)	name (signature)
press on the delete key on the keyboard	press (keyboard)	key (delete)
click on the send button	click (button)	name (send)
close the window	click (icon)	name (close)
click on the e-mail task bar	click (task bar)	name (e-mail)
close the window	click (icon)	name (close)

Based on the ground concepts i.e. similarities and differences of concrete concept expressions it was possible to generate more abstract categories and their attributes.

The history category was formed with following actions: the press keyboard (key F5), click on icon named navigation back or forward standard buttons. The history category represents users' actions were the user travelled backward and forward between the user interface parts that s/he has earlier visited. The navigation category involved the users' click actions in different kinds of hyperlinks. Through navigation, the users' tried to become familiar with the different part of the user interface and explored the relevant data in relation to the task.

The extra information category was provided the extra information for the users directly after their interactions. The extra-information category was built based on the users' actions as: the clicks to the dropdown menus, menu bars and start menus. In the examine category the users' checked and looked more detail the information provided on the screen, weather or not the information was accurate. The examine category included the users' actions like: to move up, down, right and left on the screen with different input devices (mouse or keyboard). The users' actions in the examine category were happening particular part of interface or source of information.

The highlight category included the text paint actions. In the highlight category, the users' marked the source of information that could benefit them during the interaction. The users' actions as - click on the body, click on scroll bar, click on icon (automatically fill in the form on Google), click on text area and click on text box - were named as the focus category. In the focus category, users found a certain part of the user interface and marked it with a mouse click.

The process category included the following actions: the click on button name compile, click on button name display, click on context menu name copy option, click on context menu paste option, click on hyperlink name add course, write or paste text, press and delete actions (delete or tab) with keyboard. All the users' actions included in the process category even the users' actions occurred in different parts of user interfaces were the different decision models and used different input devices. In the process category, the users' actively processed a certain source of information. The selection category included with following elements: click the button select all, click on the check box or list box. In the selection category, the users' actions included the selection of a different alternative.

The solution category involved the users' actions as: click on the buttons labelled print, click on send icons and click on print hyperlinks. The users' actions taken in the solution category were the final decisions in relation to the task. The major parts of the solution category actions were toward the task solution, even though the actions occurred in the different part of user interface and were different decision models. Jordan & Henderson (1995:32) state major focus of analytic interest for interaction analysis is the occurrence of problem in a particular activity stage. The error category was formed among the alert windows, system errors and authentication windows. The most of actions were away from the task solution. In the error category the users' supposed that the decision s/he made would be the last and solve the task s/he was trying to complete.

The pop up category involved users' actions such as: the click on buttons and hyperlinks were after the action another window appeared. The pop up category was conducting the users' to work on the part of the interface that appeared. The view category included the following users' actions: click on the hyperlink name and close, click on the icon name and close or resize (maximize/minimize), click on the side menu name Microsoft Word, click on the task bar and click on the title bar and resize (maximize/minimize) and move the window in different directions. The scenery was changed in the view category. In most of the cases, the last action with the users' was to click on the icon name and close and then close the whole user interface. Based on the users' action (N=1836), the concepts, similarities and differences of the phases of learnability were determined. These are presented in Table 15.

TABLE 15. The ground concepts and the conceptual categories.

Concepts Similarities	Concepts Differences	N	Away from the solution	Towards the solution	Conceptual Categories
alert (window)	Message (Auto complete)	1	0	1	error
alert (window)	Message (please enter a subject)	2	2	0	error
alert (window)	Message (please select a message)	1	1	0	error
alert (window)	Message (Please, browse to find the file to attach)	1	1	0	error
alert (window)	Message (Security alert)	2	0	2	error
alert (window)	Message (the following names were not found in the class)	11	11	0	error
alert (window)	Message (This field is only available for students)	2	2	0	error

Concepts Similarities	Concepts Differences	N	Away from the solution	Towards the solution	Conceptual Categories
authentication (window)		1	1	0	error
error message	name (The requested URL was not found on the server)	1	1	0	error
system error	name (the page cannot be displayed)	8	8	0	error
move (mouse button)	direction (down)	165	165	0	examine
move (mouse button)	direction (up)	133	5	128	examine
move (scroll bar)	direction (down)	86	86	0	examine
move (scroll bar)	direction (left)	10	9	1	examine
move (scroll bar)	direction (right)	11	11	0	examine
move (scroll bar)	direction (up)	46	10	36	examine
click (dropdown menu)	name (comparison)	2	2	0	extra information
click (dropdown menu)	name (criteria)	12	12	0	extra information
click (dropdown menu)	name (day 31st option)	1	1	0	extra information

Concepts Similarities	Concepts Differences	N	Away from the solution	Towards the solution	Conceptual Categories
click (dropdown menu)	name (day)	1	1	0	extra information
click (dropdown menu)	name (file)	2	1	1	extra information
click (dropdown menu)	name (folder)	2	2	0	extra information
click (dropdown menu)	name (history back standard buttons)	12	5	7	extra information
click (dropdown menu)	name (month)	3	1	2	extra information
click (dropdown menu)	name (print)	1	0	1	extra information
click (dropdown menu)	name (search)	2	2	0	extra information
click (dropdown menu)	name (select topics)	12	9	3	extra information
click (dropdown menu)	name (September option)	1	0	1	extra information
click (dropdown menu)	name (sorting)	10	7	3	extra information
click (dropdown menu)	name (the start with option)	2	2	0	extra information

Concepts Similarities	Concepts Differences	N	Away from the solution	Towards the solution	Conceptual Categories
click (dropdown menu)	name (topic)	8	6	2	extra information
click (dropdown menu)	name (type)	2	1	1	extra information
click (dropdown menu)	name (URL)	2	0	2	extra information
click (menu bar)	name (file menu)	11	2	9	extra information
click (start menu)		1	0	1	extra information
click (body)	name (context menu)	8	1	7	focus
click (body)		2	0	2	focus
click (body)		1	1	0	focus
click (icon)	name (automatically fill in form on the Google)	1	1	0	focus
click (scroll bar)		1	1	0	focus
click (text area)	name (message)	31	4	27	focus
click (text box)	name (comparison value)	8	8	0	focus
click (text box)	name (e-mail address)	1	1	0	focus
click (text box)	name (first name)	1	1	0	focus

Concepts Similarities	Concepts Differences	N	Away from the solution	Towards the solution	Conceptual Categories
click (text box)	name (last name)	1	1	0	focus
click (text box)	name (password)	10	0	10	focus
click (text box)	name (send to)	14	1	13	focus
click (text box)	name (subject)	32	2	30	focus
click (text box)	name (URL)	2	1	1	focus
click (text box)	name (user name)	1	0	1	focus
click (text box)	name (WebCT ID)	1	1	0	focus
paints (text)	name (e-mail address)	9	1	8	highlight
paints (text)	name (information search course instructions)	6	2	4	highlight
paints (text)	name (signature)	1	1	0	highlight
paints (text)		5	5	0	highlight
click (icon)	name (navigation back standard buttons)	129	74	55	history
click (icon)	name (navigation forward standard buttons)	3	0	3	history

Concepts Similarities	Concepts Differences	N	Away from the solution	Towards the solution	Conceptual Categories
press (keyboard)	key (F5)	1	1	0	history
click (hyperlink)	name (calendar)	19	4	15	navigation
click (hyperlink)	name (chat)	1	1	0	navigation
click (hyperlink)	name (course map)	3	3	0	navigation
click (hyperlink)	name (create myWebCT)	1	1	0	navigation
click (hyperlink)	name (discussion forum)	25	5	20	navigation
click (hyperlink)	name (e-learning hub/show update log)	1	1	0	navigation
click (hyperlink)	name (e-mail)	34	4	30	navigation
click (hyperlink)	name (grade results)	1	1	0	navigation
click (hyperlink)	name (help index)	1	1	0	navigation
click (hyperlink)	name (homepage)	25	13	12	navigation
click (hyperlink)	name (inbox)	3	2	1	navigation
click (hyperlink)	name (information search course instructions)	15	2	13	navigation

Concepts Similarities	Concepts Differences	N	Away from the solution	Towards the solution	Conceptual Categories
click (hyperlink)	name (information search course)	69	25	44	navigation
click (hyperlink)	name (introduction)	3	3	0	navigation
click (hyperlink)	name (manage messenger)	4	4	0	navigation
click (hyperlink)	name (mark all as read)	1	1	0	navigation
click (hyperlink)	name (Mika Laakkonen)	1	0	1	navigation
click (hyperlink)	name (MyWebCT)	5	4	1	navigation
click (hyperlink)	name (net etiquette)	1	1	0	navigation
click (hyperlink)	name (news report travelling guide subject)	3	3	0	navigation
click (hyperlink)	name (next day)	6	6	0	navigation
click (hyperlink)	name (next month)	3	3	0	navigation
click (hyperlink)	name (number nine)	1	1	0	navigation
click (hyperlink)	name (October 8th)	1	1	0	navigation

Concepts Similarities	Concepts Differences	N	Away from the solution	Towards the solution	Conceptual Categories
click (hyperlink)	name (outbox)	2	2	0	navigation
click (hyperlink)	name (previous day)	4	0	4	navigation
click (hyperlink)	name (previous month)	13	2	11	navigation
click (hyperlink)	name (quizzes)	6	6	0	navigation
click (hyperlink)	name (re: testing file transfer subject)	1	1	0	navigation
click (hyperlink)	name (reply)	2	2	0	navigation
click (hyperlink)	name (result of assignments)	2	2	0	navigation
click (hyperlink)	name (return to discussion)	3	3	0	navigation
click (hyperlink)	name (Satu Ihanamäki)	1	1	0	navigation
click (hyperlink)	name (search mail)	1	1	0	navigation
click (hyperlink)	name (September 6th)	1	1	0	navigation
click (hyperlink)	name (show all)	2	2	0	navigation
click (hyperlink)	name (sitemap)	1	1	0	navigation

Concepts Similarities	Concepts Differences	N	Away from the solution	Towards the solution	Conceptual Categories
click (hyperlink)	name (study material assignments)	1	1	0	navigation
click (hyperlink)	name (study material content)	9	2	7	navigation
click (hyperlink)	name (summary)	1	1	0	navigation
click (hyperlink)	name (testing information search subject)	1	1	0	navigation
click (hyperlink)	name (testing subject)	1	1	0	navigation
click (hyperlink)	name (topic all)	19	1	18	navigation
click (hyperlink)	name (topic settings)	1	1	0	navigation
click (hyperlink)	name (tutors contact information)	17	4	13	navigation
click (hyperlink)	name (tutors)	1	0	1	navigation
click (hyperlink)	name (unread)	1	1	0	navigation
click (hyperlink)	name (update listing)	1	1	0	navigation
click (hyperlink)	name (week view)	1	1	0	navigation
click (hyperlink)	name (Maija Koponen)	5	5	0	navigation
click (hyperlink)	name (message folders)	2	2	0	navigation

Concepts Similarities	Concepts Differences	N	Away from the solution	Towards the solution	Conceptual Categories
click (button)	name (attach file)	1	1	0	pop up
click (button)	name (browse)	21	2	19	pop up
click (hyperlink)	name (compose discussion message)	15	0	15	pop up
click (hyperlink)	name (compose mail message)	24	1	23	pop up
click (hyperlink)	name (help)	2	2	0	pop up
click (hyperlink)	name (message to all)	2	2	0	pop up
click (hyperlink)	name (need help)	1	1	0	pop up
click (hyperlink)	name (report layout instructions subject)	1	1	0	pop up
click (hyperlink)	name (search)	1	1	0	pop up
click (hyperlink)	name (subject message)	1	1	0	pop up
click (hyperlink)	name (WebCT instructions)	12	12	0	pop up
click (hyperlink)	name (web mail)	2	0	2	pop up
click (hyperlink)	name (written instructions)	1	1	0	pop up

Concepts Similarities	Concepts Differences	N	Away from the solution	Towards the solution	Conceptual Categories
click (hyperlink)	name (mail message to teacher subject)	1	1	0	pop up
click (hyperlink)	name (mail message)	1	0	1	pop up
click (button)	name (compile)	11	5	6	process
click (button)	name (display)	2	2	0	process
click (context menu)	name (copy option)	2	0	2	process
click (context menu)	name (paste option)	2	0	2	process
click (hyperlink)	name (add course)	1	1	0	process
click (hyperlink)	name (compile)	1	1	0	process
paste (keyboard)	key (ctrl-v)	2	0	2	process
press (keyboard)	key (backspace)	41	41	0	process
press (keyboard)	key (ctrl-c)	5	0	5	process
press (keyboard)	key (ctrl-v)	2	0	2	process
press (keyboard)	key (delete)	3	3	0	process
press (keyboard)	key (tab)	11	0	11	process
write (text)	name (e-mail address)	1	1	0	process

Concepts Similarities	Concepts Differences	N	Away from the solution	Towards the solution	Conceptual Categories
write (text)	name (last name)	1	1	0	process
write (text)	name (message)	47	0	47	process
write (text)	name (name)	1	1	0	process
write (text)	name (password)	17	0	17	process
write (text)	name (send to)	14	1	13	process
write (text)	name (subject)	62	0	62	process
write (text)	name (URL)	1	0	1	process
click (button)	name (select all)	2	2	0	selection
click (check box)	name (bulk)	1	1	0	selection
click (check box)	name (information search course instructions)	7	1	6	selection
click (check box)	name (news report travelling guide)	1	1	0	selection
click (check box)	name (subject)	2	2	0	selection
click (list box)	name (tutor)	14	1	13	selection
click (button)	name (done)	16	3	13	solution
click (button)	name (go)	3	2	1	solution
click (button)	name (ok)	32	1	31	solution

Concepts Similarities	Concepts Differences	N	Away from the solution	Towards the solution	Conceptual Categories
click (button)	name (post)	16	0	16	solution
click (button)	name (print)	10	0	10	solution
click (button)	name (send)	33	7	26	solution
click (button)	name (yes)	1	0	1	solution
click (context menu)	name (close option)	2	0	2	solution
click (context menu)	name (print option)	1	0	1	solution
click (hyperlink)	name (print)	16	1	15	solution
click (hyperlink)	name (log on)	26	0	26	solution
click (icon)	name (explorer)	1	0	1	solution
click (icon)	name (homepage standard buttons)	3	0	3	solution
click (icon)	name (Microsoft Word application)	1	0	1	solution
click (icon)	name (print standard buttons)	5	1	4	solution
click (icon)	name (send)	1	0	1	solution
click (icon)	name (stop standard buttons)	6	3	3	solution

Concepts Similarities	Concepts Differences	N	Away from the solution	Towards the solution	Conceptual Categories
click (menu bar)	name (exit)	1	0	1	solution
click (menu bar)	name (print option)	8	0	8	solution
press (keyboard)	key (enter)	8	1	7	solution
click (hyperlink)	name (close)	1	0	1	view
click (icon)	name (close)	60	13	47	view
click (icon)	resize (maximize)	9	9	0	view
click (icon)	resize (minimize)	17	12	5	view
click (side menu)	name (Microsoft Word)	1	1	0	view
click (task bar)	name (compose message)	3	0	3	view
click (task bar)	name (compose the mail message)	3	1	2	view
click (task bar)	name (e-mail)	1	0	1	view
click (task bar)	name (information search course instructions)	6	6	0	view
click (task bar)	name (mail message)	3	1	2	view
click (task bar)	name (tutors)	15	9	6	view

Concepts Similarities	Concepts Differences	N	Away from the solution	Towards the solution	Conceptual Categories
click (title bar)	resize (maximize)	1	1	0	view
move (window)	direction (east)	4	4	0	view
move (window)	direction (north-west)	2	2	0	view
move (window)	direction (south-east)	9	9	0	view
move (window)	direction (south-west)	1	1	0	view
move (window)	direction (west)	6	6	0	view
	total	**1836**	**796**	**1040**	**1836**

7.6.2 Data analysis in the axial coding phase

In the axial coding phase all the other categories but one was considered as sub-categories. Based on the data, it was found that the learnability phenomenon in the WebCT Virtual Edition software context included the following categories: search, travel, scenery target, activity and solve (Figure 15). All the sub-categories were verified from the data by following the axial coding model. In the axial coding model included the following check points: on a) causal conditions i.e. action which leads to phenomenon appearance, b) phenomenon i.e. central idea, in which way the group of actions are related, c) context, where the actions are realized, d) intervening conditions were interpreted based on goal directions i.e. weather the users actions strategies were successful or unsuccessful, e) actions/interaction strategies, where, the result of action/interaction i.e. consequences of actions can be seen. In addition, users' actions in timeline, goal direction and concept similarities and differences were used to horizontally and vertically to verify the learnability phase found (see Tables 13, 14 and 15 and Appendices 1-15).

1. Search sub-category
   The extra information and examine categories were combined and named as the search sub-category. In the search sub-category, the users searched for the relevant information and checked its relevancy and relation to the task.
2. Travel sub-category
   The history and navigation category were combined and named as travel sub-category. In the travel sub-category, the users mapped out the information.
3. Scenery sub-category
   The characteristics for the pop up and view categories were that the scene chanced after the action. Therefore, the sub-category was named as the scenery
4. Target sub-category
   The highlight and focus sub-categories were merged and named as the target category. In the target category, the users had already found and marked the element they indented to handle.
5. Activity sub-category
   The process category and selection category were merged and named as activity category.
6. Solve sub-category
   The error and solution categories were combined under solve category. The error and solutions categories were opposite each other. The users' actions in the error category were most of the time away from the task solution. However, contrary, the users' actions in the solution category were most of the time toward the task solution. Thus, the solve category's sub-categories were either a good or a bad solution in relation to the task (see Figure 16).

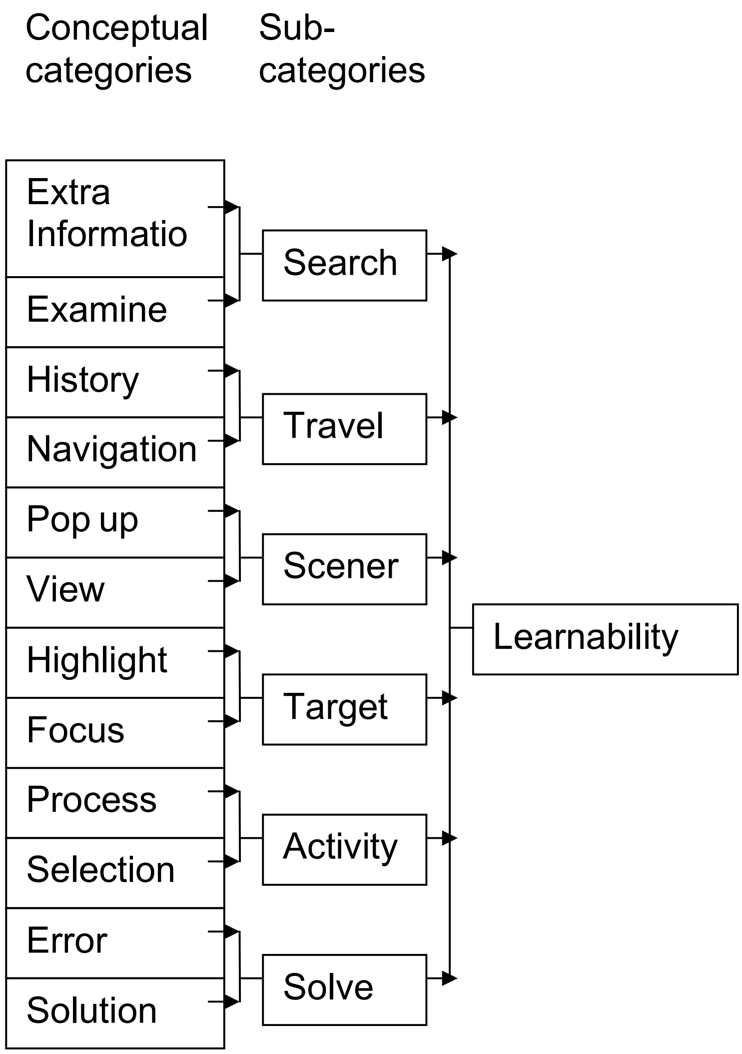

FIGURE 16. The categories of learnability in the context of WebCT Virtual Edition software.

In brief, the categories of learnability were developed and verified based on collected and analysed data that referred to the learnability phenomenon. In other words, the categories of learnability were conceptualised and generated purely by analysing collective data. Moreover, the concepts and categories were determined from data by using logical reasoning. The logic and consistency was a follow-through on the categorizing process.

7.6.3 Data analysis in the selective coding phase

This doctoral dissertation continues with the selective coding phase in order to create a new model of learnability. Järvinen & Järvinen (2000:49) and Strauss & Corbin (1998) have earlier stated that those researchers who develop a certain concept can finish after the axial coding phase. However, those who want to create a new theory must continue to the selective coding phase.

The model of learnability was built and the core category was developed, as were all the other major categories related to it, during the selective coding phase. In other words, the core category was related to the central phenomenon, i.e. learnability and the other categories were surrounded and integrated. Therefore, the central category represents the main theme of the research. A couple of categories in the axial coding phase needed refinement (see Figure 22).

In conclusion, the phenomenon of learnability was investigated within the WebCT Virtual Edition software context by using grounded theory. In general, the grounded theory made it possible to humanize and broaden understanding of the learnability phenomenon. In other words, the method made it possible to investigate the learnability phenomenon from the learning process and human perspective instead of a user interface. In addition, the grounded theory provided the researchers with a method to seek human needs and perceive the different ways humans solve problems during interaction. Finally, when we are aware how human behaviour is directed at a user interface we had better understand the qualities of the user interface as the human perceives them. Therefore, the user interface designer should study design processes more often from the perspective of the humanities, where the human is the focus. Nevertheless, the concise definitions and abstract attributes of learnability from earlier usability studies are still often used. However, user interface designers lack the measurable concrete elements that influence learnability.

The following section presents the research results. As previously stated, this study approached the phenomenon of learnability through using both the traditional objective measures of learnability and grounded theory. The first part of research results illustrates the phenomenon of learnability with the traditional objective measure of learnability: user performance times per task and the directions of user action. The number and rate of errors occurred so seldom that they were not classified and calculated separately. First, the results were interpreted from the individual user point of view in order to clarify the individual characteristics influencing learnability. As mentioned earlier, the use of the traditional objective measure horizontally strengthens the model of learnability, i.e. it enables the analysis of the learnability process in a timeline where the users' actions could be synchronized with time. The results in the second part of the research present the model of learnability that was built using grounded theory, which is a quite rarely used methodological approach within the usability context. As I show, the grounded theory method resulted in more detailed information about the learnability process, i.e. the phases of learnability, than in previous studies. In addition, the results were validated with the objective learnability measurement of human characteristics.

8 RESULTS

As presented in the earlier section, the research results have been determined through the objective measures of learnability, i.e. performance time and the direction of users' action. In addition, grounded theory was used. Although performance time was considered as a key indicator of learnability, here measures of performance time were only used to verify and validate the research results in the quantitative sense of the word and to horizontally strengthen the categories of the model of learnability. The model of learnability is based on data and determined from learnability conceptual categories and sub-categories by using grounded theory. As a result, the non-linear learnability process in a timeline could be presented step by step by showing the connections between the learnability categories of the model of learnability.

The following section presents the main research results. Finally, the model of learnability and non-linear processes of learnability can be adapted in the commercial world of usability design and can be further tested in future learnability studies with different tasks, environments, users and products. Lastly, I must point out that only a few theoretical models of learnability exist and all of those models describe the learnability process linearly. However, this doctoral dissertation proves the non-linear process of learnability needs to be further tested.

8.1 The phenomenon of learnability through objective measurements of learnability

The first research problem was stated as: How learnable is the WebCT Campus Edition software? The two fastest performance times with six tasks were measured with user 10 (366 sec/6 min. 6 sec.) and user 7 (539 sec./8 min 59 sec.), and the two slowest times were measured with user 1 (1529 sec./25 min. 29 sec.) and user 12

(1469 sec./24 min. 29 sec.) The users' linear performances times are presented in Figure 17.

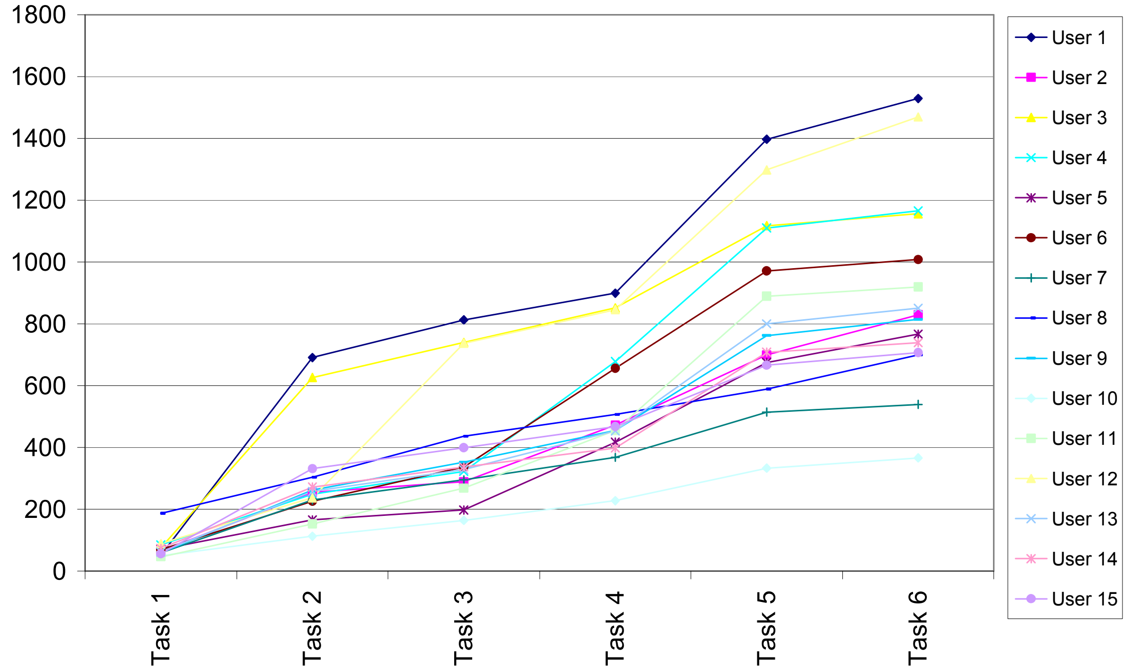

FIGURE 17. Users' linear curves of performance times.

The users' performance times in relation to the tasks followed the same pattern in each task. The exceptions were user 12, who had difficulties in completing task 3 (find from the calendar the first information search course contact day) and user 3, who had difficulties in completing task 2 (print the information search course instructions). Among all users and tasks, user 1 has the greatest difficulty with task 2. The performance time for user 1 in completing task 2 was the slowest of all 638 sec/10 min. 38 sec. The user 7 had the fastest performance time of all for task 6 25 sec. (see Figures 17 and 18).

Figure 17 also indicates that tasks 1 and 6 were the easiest for almost all users. Therefore, the log on and log off parts of the WebCT Virtual Edition software are the most learnable. Task number 5 (send the e-mail to the information search course teacher) was the most difficult for the users. Two reasons can be found for this. The WebCT Campus Edition virtual software did not support the e-mail addresses the students were used to when they needed to contact the teacher (firstname.lastname@ramk.fi). The other reason may be that the user interface confused terminology, tutor vs. teacher. Similar semantic problems were found in Ziefle's (2002:303-311) study with mobile phones. Task numbers 2 (print the information search course instructions), 3 (find from the calendar the first information search course contact day) and 4 (set to the discussion board the new discussion topic to all) were neither easy nor difficult for the users to learn (see Figures 17 and 18).

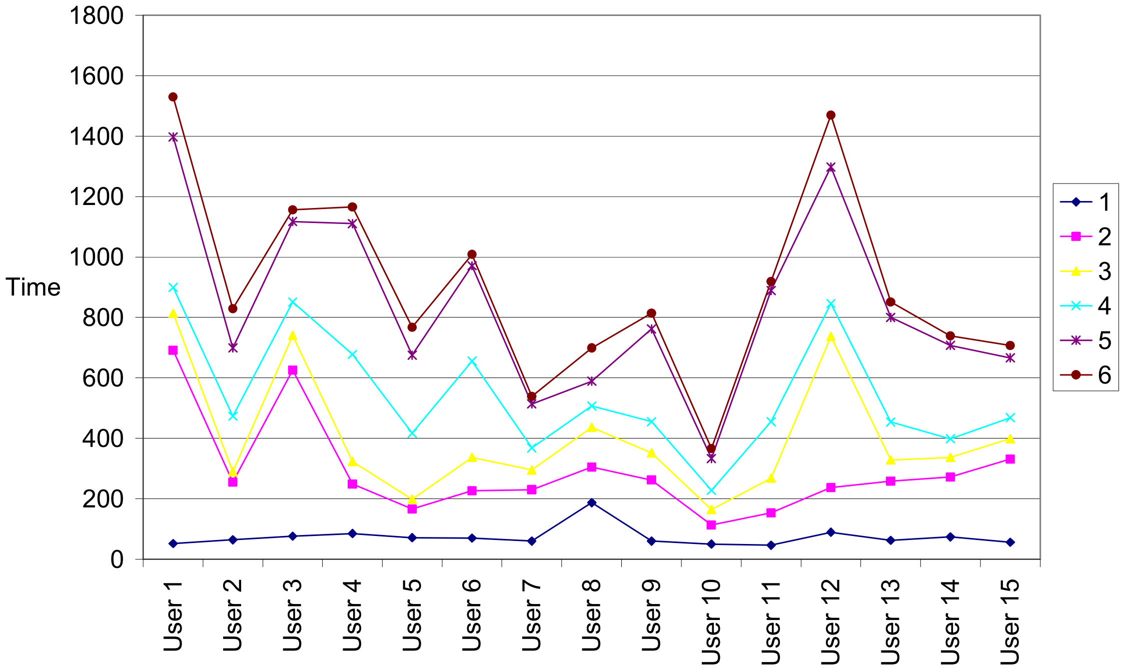

FIGURE 18. Users' performance patterns in relation to the tasks.

In conclusion, the research results showed that the WebCT Campus Edition was relatively easy to learn. In this study, the average time for the polytechnic student to learn the basic features of the WebCT Campus Edition was 904 sec/15 min 4 sec. The variety of tasks that focused on the different user interface parts made it clear to us which parts of the user interface had to be improved. Based on the data, it was found that the e-mail was the most difficult part of the user interface and therefore caused the most learnability problems but the log in and the log out features were the most learnable and easy for the students. Thus, the WebCT Virtual Edition software does not cause or explain the problems the student face in the online learning or high level of dropouts in on-line courses.

The results from the users' actions in relation to the goal direction were investigated in order to find the individual user differences on learnability. As previously stated, we analysed all the users' actions (N=1836) to see weather their actions were towards or away from the task solution. It was found that 1040 of users' actions were toward the task solution and 796 actions away from the task solution; fifty-nine percent (59%) of the actions were toward the task solutions and forty-one percent (41%) away from the task solutions. In addition, the goal direction in relation to the task was one of the attributes that integrated the categories of the model of learnability and verified the learnability non-linear process in more detail. Thus, when studying the phenomenon of the learnability process, i.e. learnability, it is essential to know weather the actions taken are toward or away from the task solution.

The two fastest and two slowest performance times scored by the users were compared in order to find how their learnability process differed in relation to the goal directions. The two fastest times were performed by users 10 and 7. User 10 solved the tasks with 94 actions; sixty-four percent (64%) of those actions were towards the task solutions and thirty-six percent (36%) away from the task solutions. User 7 solved the task with 105 actions; seventy-five percent (75%) of actions were towards the task solutions and only twenty-five percent (25%) away from the task solutions. The two slowest times were recorded by users 1 and 12. User 1 used 196 actions to solve the tasks, which was more than two times the fastest user 10; forty percent (40%) of user 1 actions were towards the solutions and sixty percent (60%) away from the task solutions. User

12 solved the task with 179 actions; forty-six percent (46%) of actions were towards the task solutions and fifty-four percent (54%) away from the task solutions (see Figures 19 and 20).

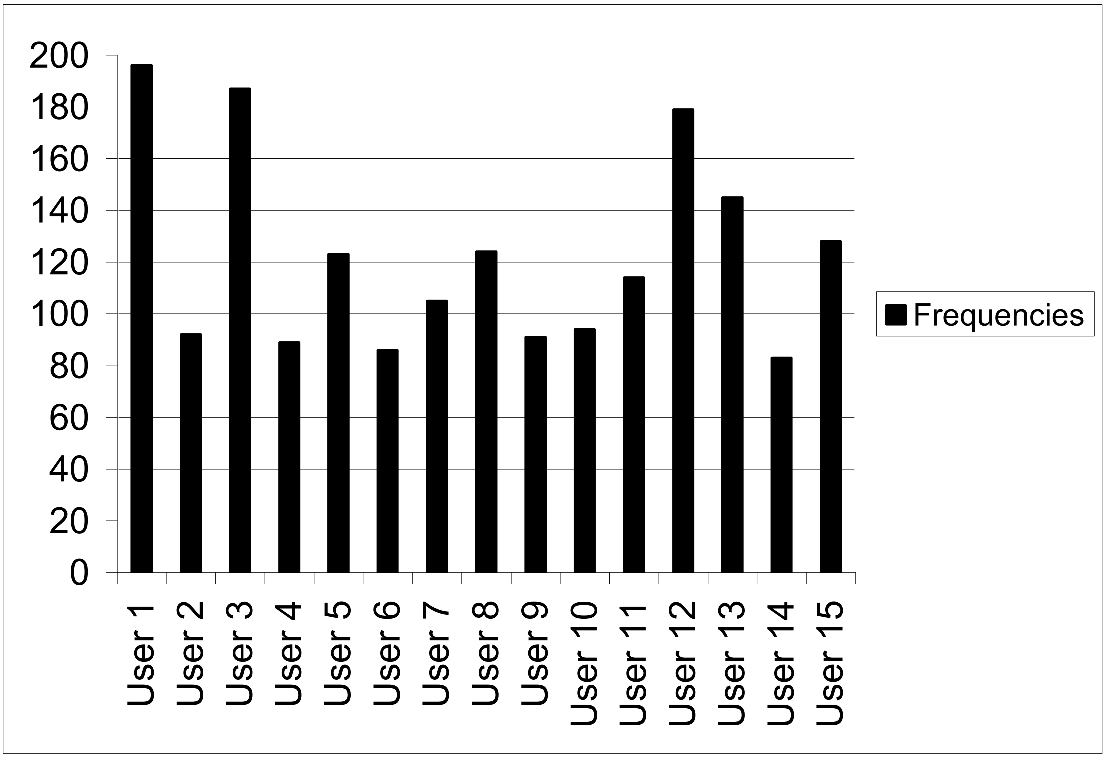

FIGURE 19. Users' action frequencies.

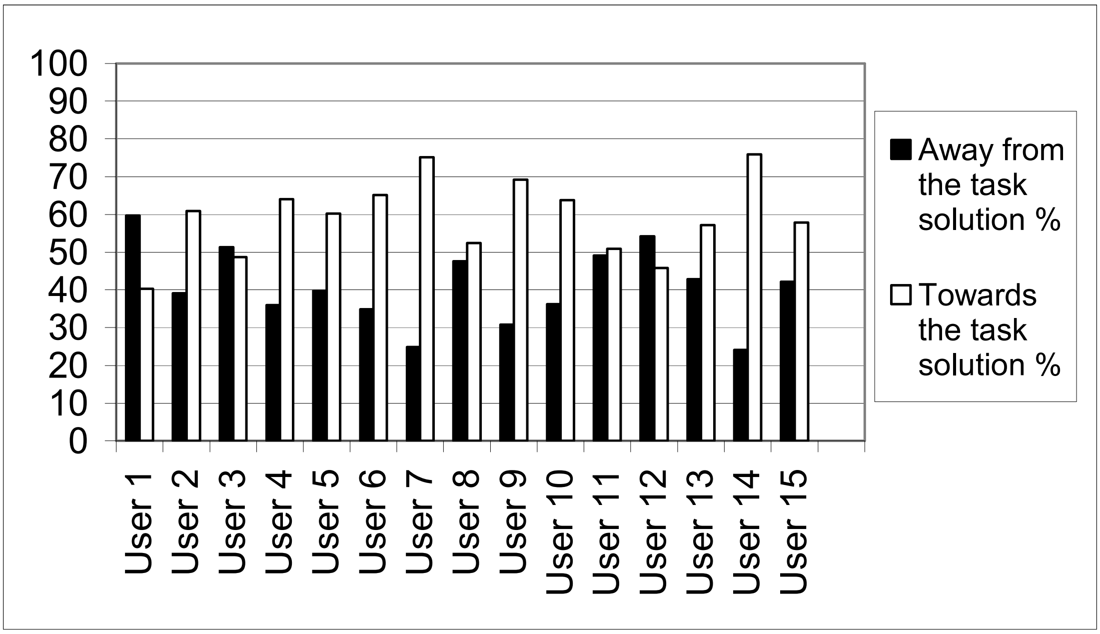

FIGURE 20. Users' actions toward and away from the task solution.

In brief, the results showed us that the two fastest times were performed by the users 10 and 7 and they used fewer actions to solve the tasks correctly than the two slowest times performed users 1 and 12. User 10, who performed the fastest time during the tasks, used half the number of actions than the slowest time performed by user 1. In addition, the actions taken by user 10 and 7 were towards the task solution more often than away from the task solution. However, the actions taken by the users 1 and 12 were more often away from the task solution than towards the task solution.

The scale in both the intensity and delay indicators was 1 to 5, where as the value 1 meant slow intensity and long delay times, and value 5 meant fast intensity and short delay times. Intensity means the number of user actions per second and delay indicates the time between user actions.

As a result, it was found that faster intensity and shorter delay times indicate better performance. The both of the intensity (5) and delay (5) values were the maximum in user 10. The intensity value

(4) and delay value (5) for user 7 were also very high but the intensity value (2) and delay value (3) for user 1 were much lower. User 12's intensity value (2) and delay (3) value were similar to those of user 1. (See Figure 21)

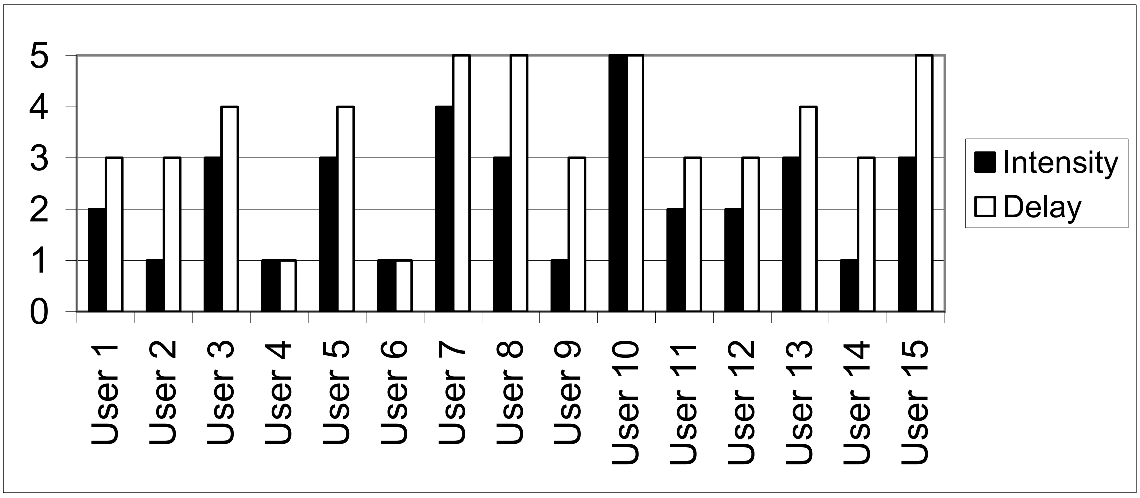

FIGURE 21. Users' intensity and delay values.

The intensity and delay times were also measured. The intensity and delay times are attributes that change during the learnability process and therefore indicate the phenomenon of learnability, i.e. the learnability process in the sense of rhythm and pace. In addition, the attributes of intensity and delay make it possible to interpret human characteristics as temper, cognitive and decision speed. Therefore, it can be assumed that the intensity and delay times can be connected to users' temper, cognitive and decision process. Longer delay times indicate consideration before an action and vice versa. The performance times for users 4 and 6 were not very good and their intensity and delay values were the lowest. However, it must be pointed out that the actions they made were quite often towards the task solution; sixty-four percent of user 4's actions were toward the task solution and sixty-five percent of user 6's actions were toward the task solution. Based on the data, it can be stated that individual users' skills have a major effect on learnability. Furthermore, the results indicate that performance time cannot be the only indicator of learnability. The process of learnability is much more complicated than implied by simplified learning curves. It would be good for a follow-up study to investigate decision intensity, pace and rhythm in relation to task difficulty.

Finally, the research results confirmed that two important issues for usability evaluation, and therefore the evaluation of learnability, are the tasks and the individual characteristics of users. The research results confirmed the results of Nielsen's (1989b:74-91) study, where he analysed 92 published comparisons of the usability of the hypertext system. Nielsen's (1989b:74-91) results showed that 4 of the 10 largest effects (including all of the top 3 effects) in the studies were due to individual differences between users and that 2 were due to task differences.

Variety between tasks and the characteristics of users also explains the part of the learnability of the WebCT Campus Edition. In other words, the variety of the platform's learnability depends on tasks and the characteristic of individual users, thus the phenomenon of learnability and its specific causes to some degree can be explained in relation to the task and the characteristics of users. The result of this study showed that the variety of the WebCT Campus Edition's learnability was higher between the individual users than it was between the different tasks. Therefore, the variety of task difficulty, i.e. the complexity or easiness of the different part of the user interface, has less influence on learnability in the WebCT Campus Edition than the individual users' characteristics do. Therefore, as stated in study by (Helander et al. 1997:834) it is vital to choose the correct learning strategy for the individual user in relation to the level of task difficulty to reduce the learning time.

As mentioned earlier, the learnability categories of the model of learnability, which is presented next, were verified from the data by following the axial coding model. The users' performance times, actions in a timeline, goal directions, concept similarities and differences were used as indicators in building the model of learnability.

8.2 The model of learnability

The other research problem in this study was formed by the following question: How can the phenomenon of learnability be defined in a new way?

This study found two main results. First, the phenomenon of learnability is a non-linear process instead of the progressively developed linear process as presented in earlier studies. In other words, previous studies have illustrated the learnability process purely with a progressively enhanced learning curve. Second, the phenomenon of learnability is not formed with separate attributes of learnability, i.e. the attributes of a user interface, which have been determined from subjective learnability measurements. Instead of the model of learnability, the phenomenon of learnability has been built with learning related to dynamic sub-categories such as information search, data collection, knowledge management, knowledge form, knowledge build and the result of action. Therefore, the phenomenon of learnability cannot be separated from learning, i.e. based on the model of learnability it is possible to interpret human cognitive processes instead of purely the performance skills of users. Figure 22 presents the model of learnability.

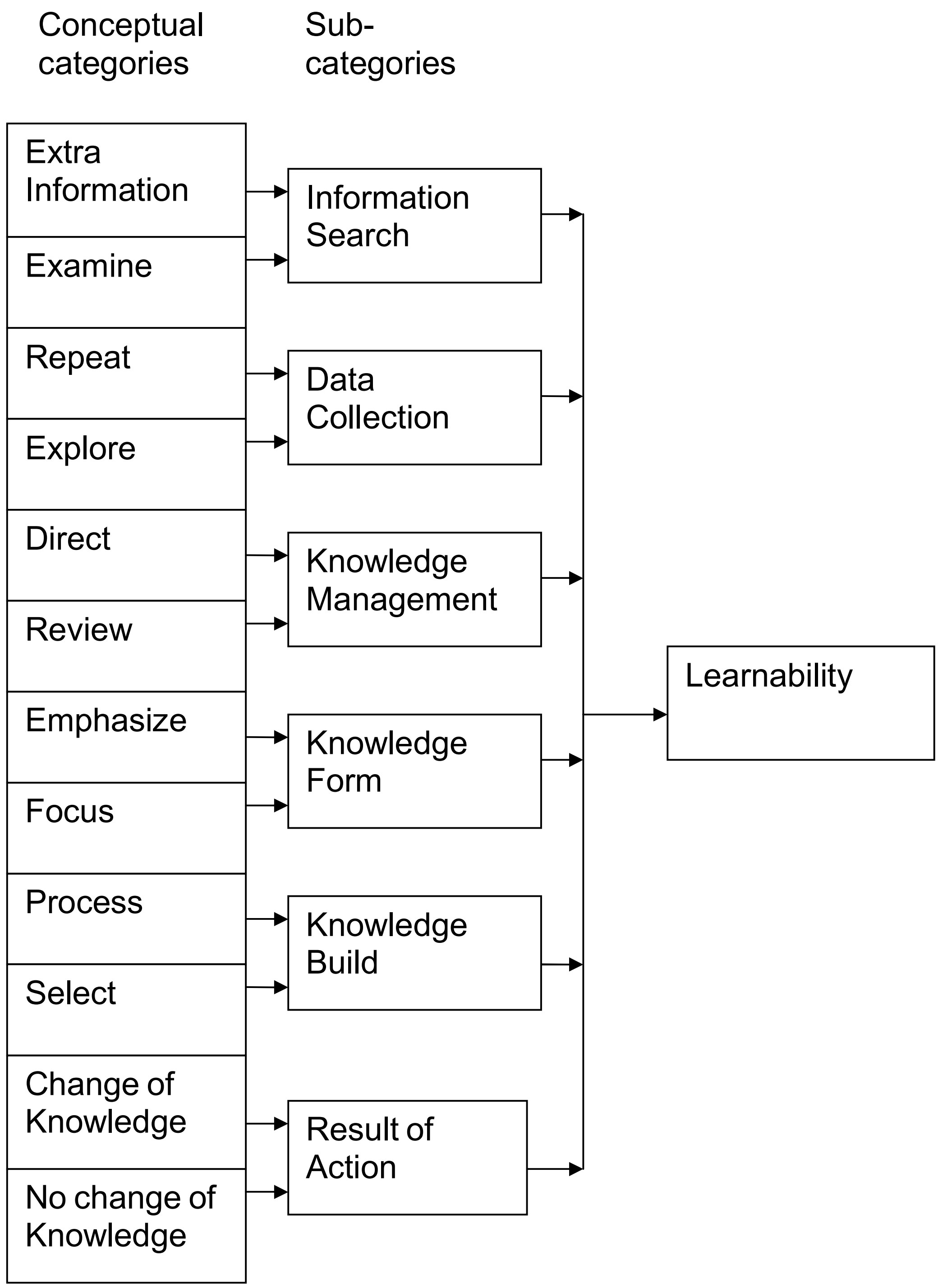

FIGURE 22. The model of learnability.

The sub-categories of the model of learnability – information search, data collection, knowledge management, knowledge form, knowledge build and the result of action – were compared in relation to goal direction in order to clarify the learnability process and efficiency of different learnability categories. The categories of the model of learnability in relation to the goal direction can be seen in Tables 16 and 17. The tables show the frequencies and percent proportions of users' actions towards or away from the task solutions per learnability conceptual category.

TABLE 16. The conceptual categories of the model of learnability in relation to the goal directions. (N).

Conceptual categories	Frequencies (N)	Towards the solution	Away from the solution
Extra information	87	33	54
Examine	451	165	286
Repeat	133	58	75
Explore	327	191	136
Direct	86	60	26
Review	142	67	75
Emphasize	21	12	9
Focus	115	91	24
Process	227	170	57
Select	27	19	8
Change of knowledge	190	171	19
No change of knowledge	30	3	27
Summary	**1836**	**1040**	**796**

TABLE 17. The conceptual categories of the model of learnability in relation to the goal directions. (%).

Conceptual categories	Percent proportion (towards the solution %)	Percent proportion (away from the solution %)	Summary
Extra information	38	62	100
Examine	37	63	100
Repeat	44	56	100
Conceptual categories	Percent proportion (towards the solution %)	Percent proportion (away from the solution %)	Summary
Explore	58	42	100
Direct	70	30	100
Review	47	53	100
Emphasize	57	43	100
Focus	79	21	100
Process	75	25	100
Select	70	30	100
Change of knowledge	90	10	100
No change of knowledge	10	90	100

As a result, it was found that the information search (extra information and examine) conceptual categories are the most ineffective categories of the model of learnability in relation to tasks. Furthermore, the data collection conceptual categories (repeat and explore) were quite ineffective. However, the knowledge management (direct), knowledge form (focus) knowledge build (process and select) categories were the most effective. The users had already found the relevant information and had an overall comprehension of how to solve the task during the knowledge management, knowledge form and knowledge build sub-categories.

The two fastest users, 10 and 7, used actions less often in the extra information and examine conceptual categories of the model of learnability than did users 1 and 12, who had the two slowest times. The actions of users 10 and 7 concentrated more often on the process conceptual category of the model of learnability than did the actions of users 1 and 12. The following tables (Table 19 - 21) show the frequencies and percent proportions of the conceptual categories of model of learnability.

TABLE 18. Users' 1 – 8 frequencies of the conceptual categories of the model of learnability.

Conceptual categories	User 1	User 2	User 3	User 4	User 5	User 6	User 7	User 8
Extra information	14	5	5	2	5	4	8	5
Examine	62	17	43	4	22	29	18	44
Repeat	28	1	29	1	2	0	8	7
Explore	33	18	32	19	27	20	10	25
Direct	5	5	6	7	5	3	5	4
Review	14	7	16	10	14	4	8	4
Emphasize	2	0	4	0	0	0	4	0
Focus	9	6	11	7	10	5	5	9
Process	11	13	24	22	16	10	20	14
Select	1	1	1	2	2	3	0	2
Change of knowledge	15	15	13	13	16	7	15	9
No change of knowledge	2	4	3	2	4	1	4	1

TABLE 19. Users' 9 – 15 frequencies of the conceptual categories of the model of learnability.

Conceptual categories	User 9	User 10	User 11	User 12	User 13	User 14	User 15
Extra information	4	0	3	28	1	2	1
Examine	6	18	35	68	42	15	28
Repeat	8	2	6	8	8	18	7
Explore	24	13	32	18	19	16	21

Conceptual categories	User 9	User 10	User 11	User 12	User 13	User 14	User 15
Direct	5	4	8	6	12	6	5
Review	4	3	5	4	27	3	19
Emphasize	0	8	0	0	0	0	3
Focus	6	10	4	15	8	5	5
Process	16	19	7	16	6	6	27
Select	2	3	3	3	2	1	1
Change of knowledge	13	12	11	12	20	10	9
No change of knowledge	3	2	0	1	0	1	2

TABLE 20. Users' 1 – 8 percent proportions of the conceptual categories of the model of learnability.

Conceptual categories	User 1	User 2	User 3	User 4	User 5	User 6	User 7	User 8
Extra information	7	5	3	2	4	5	8	4
Examine	32	19	23	5	18	34	17	36
Repeat	14	1	16	1	2	0	8	6
Explore	17	20	17	21	22	23	10	20
Direct	3	5	3	8	4	4	5	3
Review	7	8	9	11	11	5	8	3
Emphasize	1	0	2	0	0	0	4	0
Focus	5	7	6	8	8	6	5	7
Process	6	14	13	25	13	12	19	11
Select	1	1	1	2	2	4	0	2
Change of knowledge	8	16	7	15	13	8	14	7
No change of knowledge	1	4	2	2	3	1	4	1
Total (%)	100	100	100	100	100	100	100	100

TABLE 21. Users' 9 - 15 percent proportions of the conceptual categories of the model of learnability.

Conceptual categories	User 9	User 10	User 11	User 12	User 13	User 14	User 15
Extra information	4	0	3	16	0	2	1
Examine	7	19	31	38	29	18	22
Repeat	9	2	5	5	6	22	6
Explore	26	14	28	10	13	19	16
Direct	6	4	7	3	8	7	4
Review	4	3	4	2	19	4	15
Emphasize	0	9	0	0	0	0	2
Focus	7	11	4	8	6	6	4
Process	18	20	6	9	4	7	21
Select	2	3	3	2	1	1	1
Change of knowledge	14	13	10	7	14	12	7
No change of knowledge	3	2	0	1	0	1	2
Total (%)	100	100	100	100	100	100	100

8.3 The non-linear process of learnability

In the following section, I presents that learnability process cannot be described purely with a linear learning curve because the process of learnability is non-linear, i.e. skills are not learnt or acquired linearly. Thus, a better way to describe the learnability process is with a non-linear learnability curve in relation to time and the sub-categories of the model of learnability. The changes between the sub-categories of the model of learnability diminish when the learnability in a timeline and shifts to the process of usability, i.e. efficiency of use (see Figure 23 and Appendices 1-15)

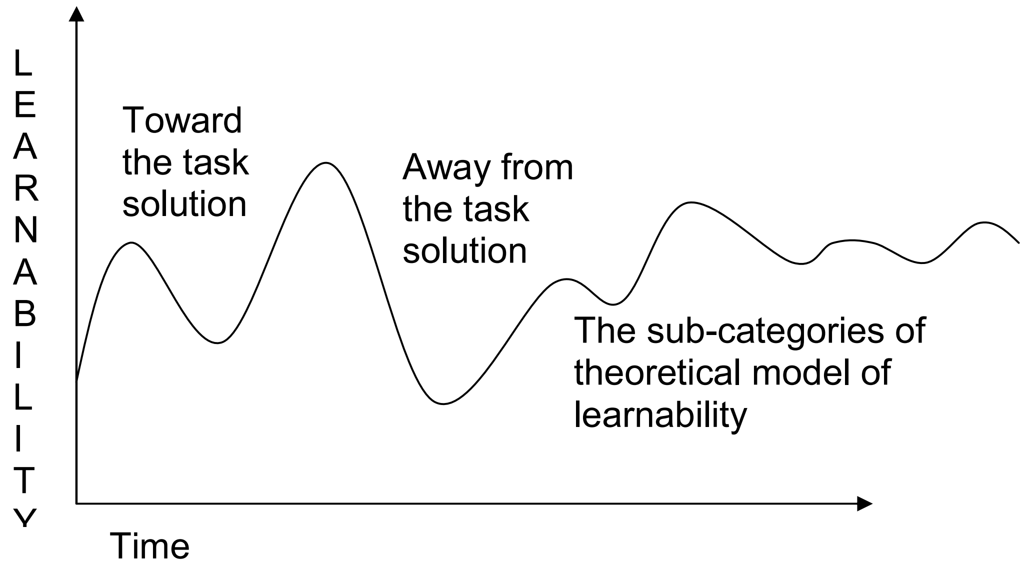

FIGURE 23. The sub-categories of the model of learnability for a hypothetical product.

Moreover, I compare the learnability processes in relation to task difficulty and the individual user's performances, i.e. the learnability process and relationships between the sub-categories of the model of learnability is presented in more detailed.

Based on the data, the sub-categories of the model of learnability changed dynamically in the timeline; in fact, this confirms that learnability process is non-linear. Moreover, the learnability process began quite often with the information search and data collection sub-categories. These two sub-categories were actually the slowest in the learnability process, as presented earlier. In other words, the users' had to move quite regularly between the information search and data collection sub-categories. The actions between these two sub-categories happened more often when the level of task difficulty increased as with task 5 (Send the e-mail to the information search course teacher). However, when the task difficulty level decreased as was the case in the task 1 (Log on to the information search course), the result of action was achieved more easily through the knowledge form and knowledge build sub-categories.

The learnability process of a difficult task includes three major iterative patterns, which describes and proves the non-linear learnability process. Based on the data, three iterative patterns were found: a) data collection-information search, b) knowledge build-knowledge form and c) information search-knowledge management. The knowledge form-knowledge build pattern can be seen in Figure 22, were the learnability process is illustrated with an easy task assignment. In addition, the same kind of learnability knowledge build-knowledge form pattern can be seen with all fifteen users (see Figures 24 and 25).

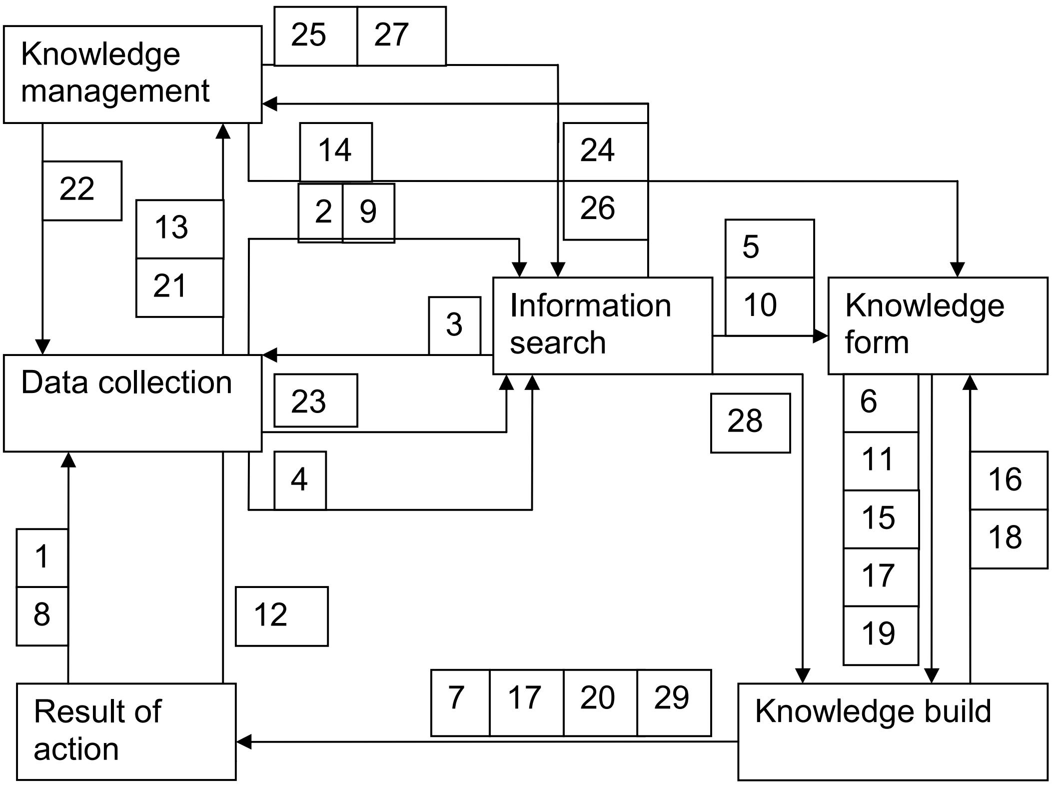

FIGURE 24. User 1's learnability process with difficult task (task 5).

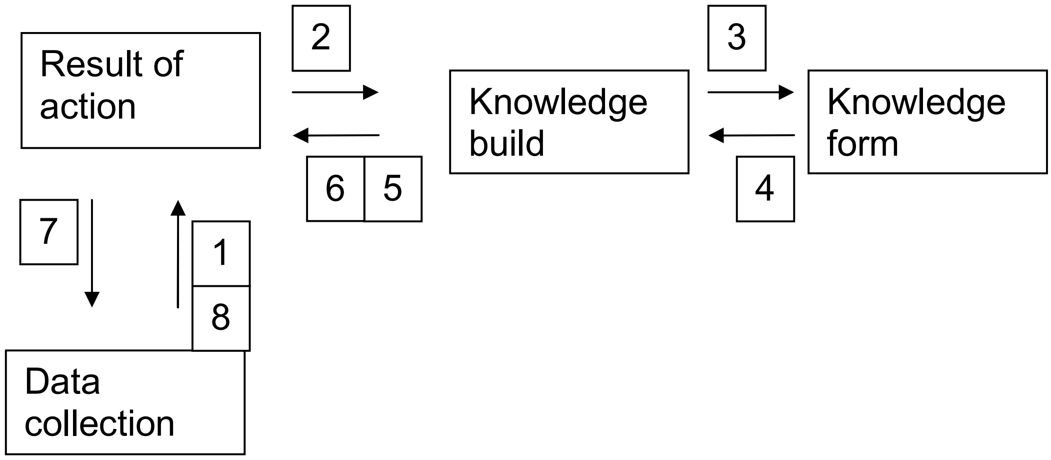

FIGURE 25. User 1's learnability process with easy task (task 1).

Furthermore, this study shows how learnability processes differ between individual users (user 10 and user 1) within the same task (task 2). As stated earlier, the fastest time with six tasks was measured with user 10 (366 sec/6 min. 6 sec.) and the slowest time was measured with user 1 (1529 sec./25 min. 29 sec.). Based on the data, it seems that user 10 could find the right solutions based on the information search sub-category without the need to go through the other categories of learnability, i.e. knowledge build-information search interaction is very effective in the model of learnability. However, the data collection-information search sub-categories form an ineffective loop for user 1. Finally, the data collection-information search pattern seems the most ineffective in relation to the task solution. (Figures 26 and 27)

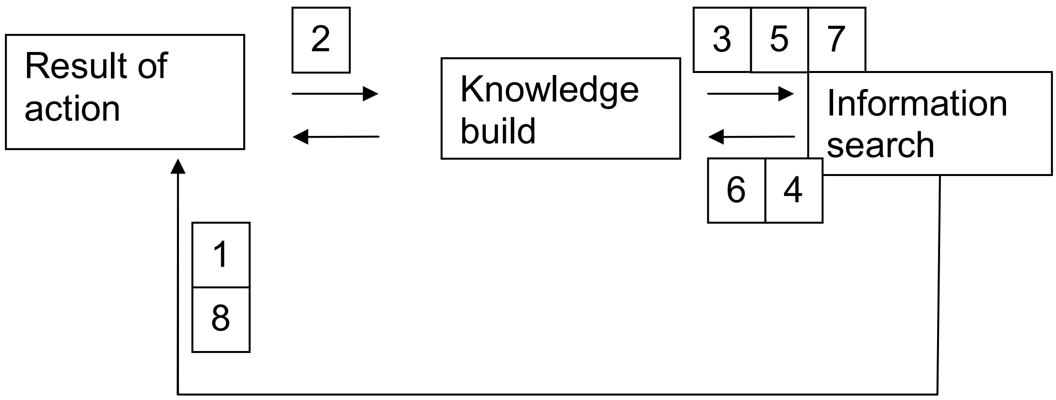

FIGURE 26. User 10's learnability process in task 2.

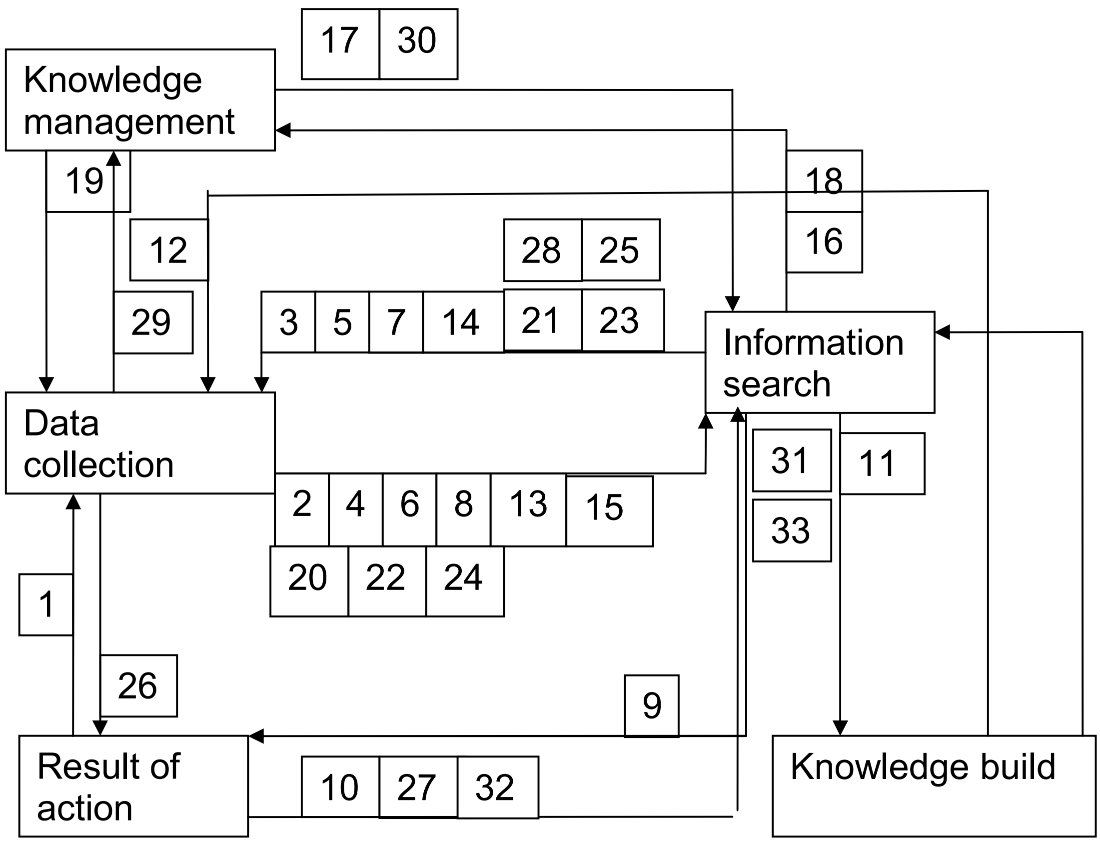

FIGURE 27. User 1's learnability process in task 2.

In conclusion, learnability patterns need to be studied in more detail in order to achieve a better understanding of the learnability process.

The information search sub-category seems to be the most vital category of the model of learnability in relation to task solution, especially when task difficulty increases. A user should have tool during the information search process, i.e. pedagogical strategies to recognize the problematic parts of an interface and to find solutions more easily. In other words, the information search sub-category should lead to the result of action through the knowledge build sub-category.

Finally, the knowledge build-knowledge form pattern is the most effective in relation to task solution, especially when the level of task difficulty is low. Due to the non-linear categories of the model of learnability, no causal relations between the different categories were found. However, the importance of the information search and data collection sub-categories grows with respect to learnability if task difficulty increases. Moreover, the learnability process quite often begins with the information search and data collection sub-categories. Thus, if the information search and data collection sub-categories are well designed they immediately result in the knowledge build category. In other words, there is no need to proceed with the other categories of the model of learnability in order to find the solution, i.e. the valuable data was already obtained in the information search or data collection sub-category, and the result of action can be easily found.

In brief, the learnability process is iterative where the non-linear categories of the model of learnability are dynamically changed.

8.4 Summary

This study presents and validates the model of learnability with objective learnability measures. The model of learnability is a non-linear dynamic process, where each categories of the learnability model has a positive or negative impact on learnability. Based on the data, three iterative patterns were found: a) data collection-information search, b) knowledge build-knowledge form and c) information search-knowledge management. The knowledge form-knowledge build pattern could be seen in easy task assignment. In addition, with the easy task, the same kind of learnability knowledge build-knowledge form pattern could be seen in all fifteen users. As a result of analysing the categories of learnability, it can be stated that the faster users reached out to the knowledge build sub-category, the more learnable was the user interface. The users' own activity could be assumed the most intensive in the knowledge build sub-category, where the user processed the relevant information s/he had already found. However, the data verifies the fact that the information search and data collection sub-categories were the most ineffective and time consuming. Moreover, the data collection-information search pattern was the most ineffective in relation to the task solution. In addition, the learnability process quite often began with the information search and data collection sub-categories. Information search process can also be a very frustrating experience even when the user knows what to look for.

Nevertheless, information search and data collection sub-categories are effective in sense of learning, even though the results indicate that the data collection sub-category is ineffective in relation to performance time. The users' actions in information search and data collection sub-categories are often used to get familiar with the user interface. Therefore, those categories can be considered important in the user interface, when learning the user interface more detailed. In other words, when the user travels in the user interface, s/he does not know were the relevant information is located. The same kind of behaviour can be seen in every day of life, when the human travels to the place s/he has not been visited before. Nevertheless, users do learn during the travel where the relevant information is or is not located. Therefore, we can conclude that the information and data collection sub-categories involve many aspects of learning but as the results indicate, learning an interface is not the most effective when measuring learnability purely with performance time.

Furthermore, the human characteristics as temper, cognitive speed and decision process can be seen to some degree in intensity and delay times. The actions in the two fastest time performed users were intensive and delay times between actions were very short. Those users can be described effective and performance oriented based on traditional learnability measures. On the contrary, there was found also users who took quite a long time before making a decision. Nevertheless, their actions were quite often correct. Despite the traditional way of measuring their learnability with performance time, their learnability rates were among the poorest. Even though, the user can be considered precise, punctual, focused and concentrated during the task.

As stated earlier, there are two main ways to approach user interface design, i.e. two opposite ways to perceive the human being as a learner. The most dominant view has been "keep it simple principals", where the human is perceived as a passive learner. Thus, the user interface designer emphasizes that the graphical user interface should be designed based on user behaviour and culturally passed information. User interface designers' assumptions might be right in the sense of facilitating users' earlier experiences when they interact with the familiar user interface. However, in a new learnability situation old behavioural patters are insufficient and inappropriate in a functional sense. The results in this doctoral dissertation demonstrate that the information and data collection sub-categories slower down the learnability of the user interface, i.e. performance times are increased with all users. In addition, the users' actions in those categories are quite often away from the task solution. Nevertheless, users might learn more about the user interface during first use and become faster and more skilled and efficient users after a certain amount of time they have used the product. In brief, the information search and data collection sub-categories are more related to learning than the learnability of a device, when measuring learnability with traditional metrics.

Furthermore, the results in this study prove that to diminish a novice user's memory load is essential when the intention is to make products more learnable. In other words, recall is prone to errors but users are very good at recognizing objects. Most of the users' decisions were correct when they had more than one option choose from, i.e. the select conceptual category in the model of learnability was quite effective. In addition, if a user focused on the target before the solution, the action taken proved very often to be correct. Moreover, the pop-up windows seem to drawn people's attention very effectively. The direct conceptual category was found very useful in the sense of learnability. Most of the time, when another window appeared it directed the users to make the right decision in relation to the task. The pop-up windows in the direct conceptual category are effectively used to focus people senses in the commercial world. The research result proves that the same elements can be effectively used when learning new software or other devices.

In conclusion, by identifying the specific source of learnability, i.e. the elements based on users' actions that enhance learnability in a task, the results can provide a basis for UI designers' decisions concerning how to modify unacceptably high levels of workload in operational environments and how to create products that are more learnable. In other words, the result of user actions towards or away from task solutions shows us how learnable a product is and what kinds of elements in the user interface enhance or hinder the learnability of a product.

Finally, the ground concept, conceptual categories, sub-categories and the model of learnability as a whole can offer concrete advice for the graphical user interface designer on how to improve the quality of the WebCT Campus Edition's user interface. The model of learnability includes the following sub-categories: information search, data collection, knowledge management, knowledge form, knowledge build and the result of actions within the WebCT Campus Edition software context. However, more longitudinal learnability studies are needed in order to find the relationships between learnability, learning and the categories of the model of learnability.

9 DISCUSSION

9.1 Evaluation

Grounded theory, which primary is sociological method Glaser & Strauss (1967) has been criticised by naïve inductivism and naïve empiricism i.e. relationship between data and theory. The critique was allocated to the basic idea of grounded theory, which emphasis that the only legitimate theories were those, which could be inductively derived by simple generalisation from observable data. And therefore, researcher should ignore the literature of theory, in order to assure that the emergence of categories are not contaminated. Nevertheless, Strauss & Corbin (1998) coding paradigm used in this doctoral dissertation may be contrast with researchers with a strong background in macro-sociology and system theory, because techniques that are more conventional are applied in cognitive psychology and this doctoral dissertation. This study shares the idea of cognitive psychology Kelle (2005) that research investigates independent, knowable phenomenon within the fact that the researcher is part of the phenomenon under investigation and part of the process of the research. Therefore, the criteria that are inline with data driven analysis need to be applied and the criteria, which rely on the grounds of interpretivism, need to be scrutinized. Klein & Myers (1999:67-97), who define seven principles for evaluating validity of knowledge for the phenomenon being studied, provide such criteria. These principles are discussed below in order to evaluate what this doctoral dissertation accomplishes.

First, the fundamental principle of the hermeneutic circle suggests that all human understanding is achieved by iterating between considering the interdependent meaning of parts and the whole that they form. The principle of human understanding is also fundamental to all other principles in that it is a metaprinciple upon which the six other principles expand. Therefore, to follow the fundamental principle of the hermeneutic circle, the learnability categories were kept close to the terms used in the raw data. During the data analysis process, more abstract appropriate concepts and categories were determined by comparing the similarities and differences of concrete concept descriptions. The continued sorting of learnability categories during the data analysis process enabled the identification of the characteristics of the phenomenon of learnability and revealed the features of learnability. In other words, the idea of the hermeneutic circle was used in order to understand the complex whole from the meanings of parts and their interrelationships. The categories of learnability were developed and verified based on collected and analysed data that referred to the learnability phenomenon. The categories of learnability were conceptualised and generated purely by analysing collective data. Moreover, the concepts and categories were determined from data by using logical reasoning. The logic and consistency was a follow-through on the categorizing process.

Second, the principle of contextualisation requires critical reflection on the historical background of the research setting so that the readers can see how the current situation under investigation emerged. An attempt is made to meet these requirements by raising the general and currently unsolved problem of the learnability of user interfaces in the information society. The historical perspective is highlighted by reviewing the definitions of learnability, methodologies, design principles and attributes of learnability drawn from earlier studies. Emphasis is placed on the current need for more learnability studies, which investigates the phenomenon of learnability from the perspective of the human being and learning.

Third, the principle of interaction between researchers and subjects requires critical reflection, as does how the data are socially constructed through the interactions between researchers and participants. One researcher, Licentiate of Education Mika Laakkonen, performed the data collection phase in order to ensure that the interactions between the researcher and the participants remained the same throughout the study. Moreover, data in this study is purely based on the users' actions as recorded on video. During the data observation, two researchers took notes (Licentiate of Education Mika Laakkonen from humanistic background and software engineer Stefan Brandt from the technical background), and every single user action recorded on video film was marked in detail on a timeline. The grounded concepts from the data were described based on the notes. Observing the fifteen video films and learning everything about the setting was a time-consuming, exhausting and demanding task.

Fourth, the principle of abstraction and generalisation is very important and requires the detailed description of the grounded theory data analysis processes, i.e. how the model of learnability has been built. The aim is that the principle of abstraction is met by illustrating in detail the phases of grounded theory data analysis. The grounded theory coding process includes three phases: 1) open coding, 2) axial coding and 3) selective coding.

The open coding phase includes gathering in detail all the users' actions (N=1836). The phenomenon of learnability and its concepts were checked by showing a connection to performance times and goal direction, i.e. the users' action towards and away from the solution. In order to horizontally strengthen the model of learnability that is built, Järvinen & Järvinen (2000:49) and Strauss & Corbin (1998:148–153) emphasize the importance of understanding how the phenomenon changes in a timeline. Furthermore, the concepts were generated from facts by analysing and comparing similarities and differences from concrete concept expressions. In other words, the concrete concept expressions were conceptualised because the main feature of this method is grounding concepts in data, which was used as the building blocks for the model of learnability.

The axial coding phase considered all other categories but one as sub-categories. All the sub-categories were verified from the data by following the axial coding model. The axial coding model included the following check points: a) causal conditions, i.e. the action which led to the appearance of a phenomenon, b) phenomenon, i.e. the central idea, in which way a group of actions was related, c) context, where the actions were realized, d) intervening conditions were interpreted based on goal directions, i.e. weather the users' action strategies were successful or unsuccessful, and e) action/interaction strategies, where the result of action/interaction, the consequences of actions, could be seen.

The selective coding phase built the model of learnability and all the other major categories related to it. In other words, the core category was related to the central phenomenon, i.e. learnability and the other categories that surrounded and integrated with it. A couple of categories in the axial coding phase needed refinement in order to create the model of learnability. Therefore, the central category represents the main theme of the research.

Fifth, the principle *of dialogical reasoning* requires sensitivity to possible contradictions between the theoretical preconceptions guiding the research design and actual findings with subsequent cycles of revision. According to Glaser & Strauss (1967:33), the researcher at the beginning of the analysis process has to focus the general question or problem in mind. In this study, the main question and problem in mind was how to define phenomenon of learnability. Thus, the starting point in this study was to choose the methodology that would enable the study of the phenomenon of learnability without prior assumptions or definitions of learnability. Hence, this study examined the phenomenon of learnability without any preconceived theory that dictates prior research concepts and hypotheses.

Sixth, the principle *of multiple interpretations* requires sensitivity to possible differences in interpretations among the participants. Constant comparison between the data was involved in order to avoid multiple interpretations during the learnability evaluation process. The users' actions in timeline, goal direction and concept similarities and differences were used to horizontally and vertically verify the learnability categories that was found. In other words, the validation of research results involved checking the plausibility of knowledge claims, of ascertaining the strength of empirical evidence and the credibility of the interpretations. Thus, the validation of the research process was a continual process of asking what the key features of the phenomenon of learnability were and why, and also when, where and which actions the users had taken. The process of building the model of learnability included sorting and constructing alternative explanations and holding these against the data until finding the best fit that explained the data. In brief, the model of learnability was built from data by using systematic and inductive incremental development, even though the variation of the user actions under study seemed uniform for 5 users and the research was able to predict the users' actions. A total of 15 users were involved in learnability evaluations in order to ensure that no new user actions appeared. Moreover, the process of collecting similar data during the data collection phase was used to ensure that there were not unsaturated areas in the data.

Finally*, the principle of suspicion* requires sensitivity to possible biases and systematic distortions in the raw data collected from users. Before the actual study, a pilot was conducted with couple of users in order to refine the method and to check the adequacy of the task developed for the learnability evaluation. This enabled an assessment of whether the task to be used in the evaluation met the general criteria. It appeared that task had to be simplified and assignments had to be modified in order to place greater focus at the beginning of the learning process, i.e. the intention in this study was to measure the early stages of the learning process. The data collection involved measuring the users' performance times by compiling all their actions and goal direction in relation to the task. During the data collection process, the researchers had to confirm and recheck the users' actions recorded on video several times. The first observational phase involved measuring the total performance time of each student (N=15) for the given assignment. The times per assignments were calculated from the point, when a student started the assignment and when s/he gave the last input to finish that assignment. The second observation involved collecting every single action (N=1836) from the video material and the actions were synchronized with time. In addition, the actions were defined as to whether they were towards or away from the task solution. In this study, the phenomenon of learnability was observed with Rovaniemi Polytechnic first year students in a natural on-line learning environment. Since the purpose of this study was to analyse the phenomenon of learnability with novice users, the users had no prior experience of on-line learning or any learning environments, i.e. the participants in this study were homogeneous group of individuals.

9.2 Theoretical implications

This doctoral dissertation claims that the human centric view, where the human as a learner is a key actor, should be the main user interface design principle. In fact, from the human centric point of view learnability becomes closer to the concept of learning. However, the most of the earlier learnability studies perceive the human being as passive learner. Therefore, "keep it simple principals" have become the profound and dominant view of user interface design world. According to "keep it simple principals" humans' have difficulties to adopt and learn new things, but instead tends to follow habits learnt, absorb metaphors close to the real world and senses the commonly known physical features. Vice versa, this doctoral dissertation approaches the phenomenon of learnability from the human centric point of view, where the humans' are seen as instinctively curious: they want to learn, and they learn best by active self-directed exploration of their environment. People like to have a sense of control over what they are doing, to see and understand the results of their own actions.

The aim in this doctoral dissertation was to investigate the phenomenon of learnability openly based on users' action in the WebCT Campus Edition virtual learning environment. There are several fundamental contributions made by this study. The first contribution is that I have continued the work of others not only by criticizing the focus of prior learnability studies and analyses of underlying assumptions of the user interface's key role in UI design but I have also emphasized the importance of the study of learning and the human as a key resource in UI design. The second contribution in this doctoral dissertation is the use of the modern methodological approach to define and to analyse the phenomenon of learnability in the usability context. Third, the following main results in this study were found. First, the model of learnability proves that the phenomenon of learnability is a non-linear continued learning process instead of a linearly progressive process as presented in commonly used learning curves. The learning curves are too simplified to present the complicated phenomenon of learnability. Second, the model of learnability proved that the phenomenon of learnability is strongly associated with learning. The model of learnability is built with learning related sub-categories: information search, data collection, knowledge management, knowledge form, knowledge build and result of action. The results show the phenomenon of learnability cannot be formed with the separate attributes of learnability, i.e. the attributes of a user interface that have earlier been determined from subjective learnability measurements. It must be pointed out that it is amazing that the phenomenon of learnability has not earlier been related to learning or modern learning theories but rather it has been formed with the separate attributes of learnability, which actually have been the same as the attributes of a user interface.

In brief, how does this study differ from earlier studies presented? First, this study begins openly to analyse the phenomenon of learnability based on the collected data and uses performance time and goal direction only to horizontally strengthen the model of learnability that is built. Second, this study investigates the phenomenon of learnability from not only the user interface point of view but it also emphases the role of the human and the role of interaction between the human and a user interface, i.e. learnability is seen as the interaction between the user interface and the human being. Third, this study considers the phenomenon of learnability as well as learning as a non-linear process. Thus, learnability cannot be defined with separate attributes that are disassociated with each other or as connections between the properties of learnability that are hard to find. Finally, this doctoral dissertation perceives the human as an active learner and proves that learnability cannot be separated from learning. Therefore, the phenomenon of learnability should more often be analysed from the human point of view. Finally, it must be emphasized that besides the model of learnability presented in this doctoral dissertation, there are only a few other models of learnability that tries to illustrate how skills are actually acquired.

9.3 The concept of learnability

The definition of learnability is not unambiguous. In earlier studies, usability researchers have connected different attributes to the phenomenon of learnability. Some researchers have a more abstract concept (ISO 9241-10, Nielsen (1993:26-37) and others use more concrete indicators that can be measured (van Welie et al. 1999:613-620). In addition, the use of different vocabulary and different epistemology behind the words makes it more difficult to compare the definitions of learnability (see Dix et al. 1998:162, ISO 9241-10). In addition, the same researchers totally lack (Dix et al. 1998:162) the same attributes of learnability, which have been mentioned in several other usability studies and subjective learnability measurements. Moreover, it must be pointed out that the same researchers (Dix et. al. 1998:162) do not include efficiency in the learnability concept. However, several usability researchers (Nielsen 1993:28-31) and Shneiderman 1998:135) associate the concept of learnability directly with efficiency.

Moreover, (Nielsen 1993:31-32 and Holzinger (2005:71-74) the concepts of memorability and relearnability are very close. Nielsen (1993:31-32) and Holzinger (2005:71-74) relates learnability directly to human memory whereas the IsoMetrics Usability Inventory (ISOMetric[S] 1998), which is basis of the ISO 9241 Part 10 standard, uses purely performance time as a key indicator to measure both learnability and relearnability. Actually, in both cases the relearnability measures learning more than it measures learnability because we measure learning instead of performance when a user faces the user interface for a second time and completes the same task after certain period of time, i.e. learnability through comparing the difference between two interactions. Learnability studies only measure the contemporary performance improvement during a task. However, learning is a more permanent change in human behaviour. In other words, the traditional measurements are unable to measure the permanency of the skills acquired during learnability tasks. Based on earlier studies, it can be stated that relearnability is the most learning-oriented attribute of learnability. Thus, relearnability measurements are vital. Furthermore, IsoMetrics (ISOMetric[S] 1998) is the only subjective learnability questionnaire that considers relearnability as one of the attributes of learnability instead of one of the design objectives.

In conclusion, the UI designers' understanding of learning and the characteristics of human beings and human behaviour can be seen to have utmost importance with respect to designing systems for people. A key capability of UI designers is to understand and analyse the way humans learn as well as the characteristics of human behaviour during their interaction with a user interface in order to build the learnable devices. However, UI designers are currently applying only UI design principals to their own observation and thinking. (Shackel 1991:21-38, Nielsen 1993:26-37, Shneiderman 1998:135, Chapanis 1991a:359 - 398, Sinkkonen 2001:215-233, Thagard 1996, Apple Computer Inc. 1987:16, Norman 1990:188-209, Ravden and Johnson 1989:45-74, ISO 9241

1996, Polson and Lewis 1990:191-220, Bevan and Macleod 1994:132–145 and Holcomb and Tharp 1991:49-78). In fact, the phenomenon of learnability seems to be based on human information processing theories.

9.4 Results vs. earlier theory

Even though the data in this research succeeded in generating a useful model of learnability within the software context, it was very hard to withdraw from the canons derived from vigorous quantitative verifications because previous studies have approached the learnability phenomenon from a different perspective. Nevertheless, the model of learnability is discussed through earlier studies findings, which are in line and contrast with the result found in this doctoral dissertation.

In earlier learnability studies, the goal has been to gather subjective learnability ratings in addition to the information provided by earlier empirical studies, which would allow the researcher to create a valid and reliable rating technique for measuring learnability. Thus, usually the first step has been to select the most appropriate subjective learnability measurement and therefore a set of learnability factors. The second step has been to determine how to combine these factors to derive a learnability rate that is sensitive to different sources and definitions of learnability. The final step has been to determine the best procedure for obtaining numeric values for these factors. However, the methodology used in this study differs from earlier usability studies, which have approached the phenomenon of learnability with deductive epistemology using homothetic measurements. A connection can be found to the model of learnability and the phenomenon of learnability as defined in this study as well as to the attributes of learnability that have been presented in earlier studies.

Performance has been considered as the primary indicator of learnability. However, this study measured traditional metrics as performance times and times per task and task direction in relation to the result of actions in order to horizontally strengthen the model of learnability and categories in the phenomenon of learnability. Thus, the performance time and result of action variables validated the theory built from the grounded theory methodological point of view. Hence, the two fastest times performed by the users took fewer actions to solve the task correctly than did the two slowest times performed by the users. In addition, the two fastest users performed solving a task quicker more often than did those who performed the two slowest times. There were also differences in the performance times between tasks. The variety of tasks that focused on the different parts of the user interface clarified which parts of the user interface needed improvement.

What do the results tell us? It is often concluded that educational platforms such as WebCT Campus Edition software cause difficulties for the students because the user interface is between the student and the teacher and therefore interaction and natural argumentation is difficult. First, the result proves that the WebCT Campus Edition software is easy to learn. However, the result does not clarify how the WebCT Campus Edition software functions in a real time learning situation. Second, the research results confirmed that two important issues for the evaluation of usability, and therefore the evaluation of learnability, are the tasks and users' individual characteristics. The result of this study showed that the variety of the WebCT Campus Edition platform's learnability was higher between the individual users than it was between the different tasks.

Therefore, the variety of tasks, i.e. the complexity or easiness of the different parts of the user interface, had less influence on learnability in the WebCT Campus Edition software than did user characteristics.

As previously stated, the different levels of task difficulty affect learnability. Identifying the specific source of learnability in a task could provide a basis for deciding how to modify unacceptably high levels of workload and the kinds of pedagogical strategies that would be efficient in operational environments. However, the specific impacts of the tasks on the learnability of the interface and specific different parts of an interface are unknown. In addition, there is no research data available on how much a task itself explains the phenomenon of learnability and therefore the degree of a user interface's learnability. In addition, the influence level of individual human differences on learnability is currently unknown.

In spite of this, the results verify earlier learnability studies that found that the human differences between users and task explains a certain part of learnability. However, the result does clarify only part of the phenomenon of learnability. Furthermore, it is crucial to specify in which way human characteristics and personalities affect the phenomenon of learnability. Thus, intensity and delay times were measured from data. Analysing the intensity and delay times of users' actions enables us to interpret their cognitive abilities as temper, cognitive and decision speed. In brief, it can be stated that longer delay times indicate consideration or a slow cognitive process before the action, and vice versa. However, it must be pointed out that there were users whose performance times were below the average and their delay times were the longest. Nevertheless, their actions were quite often towards task solution. This confirms the idea that performance time cannot be the primary indicator of learnability. In addition, human cognitive processes as analytic minds are not granted in the traditional way of measuring learnability. It seems that the traditional measurement of learnability mirrors the values of contemporary society, where the human must be impulsive, extrovert, active and effective. On the other hand, the opposite human characteristics are not of value in the current labour market. However, there is a need for a more detailed analysis of human characteristics in relation to learnability.

The phenomenon of learnability cannot purely be explained by the separate attributes of learnability, as has been done in earlier studies. The model of learnability is not based on mechanical memorizing;

on the contrary, it is a learning process that proceeds through the different categories of learnability. The model of learnability sees learnability as a cyclic process where the users' cognitive process can be seen. In other words, the different learnability sub-categories of information search, data collection, knowledge management, knowledge form, knowledge build and the result of action occur and repeat, deepening the level of task difficulty, individual users' skills, device and environment. Moreover, the categories do not follow a certain linear pattern beginning from the information search sub-category and ending with the result of action. Based on the model of learnability, we are able to analyse the users' cognitive processes in the learning situation and the problem solving mechanisms and users' actions in relation to goals. Thus, due to the users' cognitive processes, we can analyse weather their actions are intentional in relation to the task and therefore the problem solving mechanism becomes concrete in the categories of the learnability model and patterns of learnability. In addition, the model of learnability enables us to examine how the different pedagogical strategies and elements of a user interface affect learnability.

The model of learnability discovered in this doctoral dissertation is close to Gagne's phases of learning and therefore to the causal model of learnability presented by Elliott et al. (2002:569). Gagne's phases of learning involve the phases of motivation (expectancy), apprentice (attention, selective perception), acquisition (coding, storage entry), retention (memory storage), recall (retrieval), generalization (transfer), performance (responding) and feedback (reinforcement). Gagne's phases can be related to the model of learnability generated in this study. The information search sub-category equals the apprentice, data collection with acquisition phases, knowledge management with the retention phase, knowledge form with recall and the generalization phase, knowledge build with the performance phase and finally the result of action with the feedback phase. Therefore, first users have to be clear about the goals of the study process. Second, the users' have to know how they work and process a problem. Third, the users' must have the assumption that they are able to solve the problem. In other words, the transparency of operation and transparency of purpose lead to the sense of accommodation and finally the sense of accomplishment (see Elliott et al. (2002:555-556, 567).

Nevertheless, the principle of generalization is discussed as Morse (1994:40) and Brinberg & McGrath (1982:11) put it, the model of learnability is substantive theory that is context bound as long as the generalization of the model of learnability can be proven. Therefore, the model of learnability should be analysed within different contexts and further tested and modified before it can be stated as formal theory, which is more abstract and may be applicable to many settings or other experiences.

In future learnability studies, it would be good to analyse and find the answer to the following questions in different context: How do different media elements such as text, picture, video and animation affect learnability? How do the intensity and delay levels change in relation to task difficulty? What kind of pedagogical strategies are most effective in the sense of learnability for different kinds of products? Which pedagogical strategies should be used in the different categories of the model of learnability? Which elements of the user interface support knowledge building? What are the most vital learning objects inside the learnability categories?

In conclusion, the model of learnability sees the phenomenon of learnability as a process involving different sub-categories: information search, data collection, knowledge management, knowledge form, knowledge build and the result of action. Thus, the phenomenon of learnability cannot be understood through a user interface and the separate attributes of learnability: overall learnability, intuitiveness, consistency, error recovery, task match, and memorability and help desk. However, the definition of learnability currently includes purely the attributes of a user interface rather than the characteristics of the human, i.e. the attributes of learnability are actually the attributes of a user interface. However, based on the data, it can be assumed that some of the attributes of learnability have higher influence and associations on learnability in the different categories than others do. Overall, learnability improves a user interface as a whole. This study does not see overall learnability only from the user interface perspective; therefore, it has positive influence both the human and the user interface. Earlier studies have emphasized that all the attributes of learnability improve only the learnability of user interface. This study interprets the attributes of learnability from the human learning aspect. Therefore, all the attributes of learnability help the human to interact and adopt new products when s/he tries to learn to use a new product for the first time.

In theory, research-based learning can assume to have a positive impact on learnability if human activity is based on thinking instead of a memory-based search process. Memory-based learning is connected to the behaviourism learning theory, whereas modern learning is associated with constructivism, problem-based and research-based learning. However, many humans still try to learn a user interface through trial and error. As pointed out above, the two fastest users solved the tasks correctly with fewer actions, and their actions had more often a positive effect on learnability than did those of the two slowest users. In other words, it must be assumed that those two individual users use different learning and pedagogical strategies or even different learning styles.

9.5 The traditional user interface design and learning

As stated earlier, four elements are always involved in the study of the phenomenon of learnability of system of: user, task, product and environment. The traditional definitions of learnability are very much user interface oriented and therefore, the attributes associated with the phenomenon of learnability are very much the same as the attributes of a user interface. The definitions of learnability do not emphasize the concept of learning, neither they do connect the phenomenon of learnability to modern learning theories. Perhaps learning is thought to be a more continued and slower process than learnability, which emphasizes performance time during a task and the separate attributes of learnability. If this is the case, intellectual tests and school exams do not measure learning skills but rather learnability in the traditional way, i.e. how fast and correct a human performs during a test. However, the model of learnability created in this study focuses on users' ability to learn and adopt new things, process different kinds of knowledge and solve problems, and to conceive and critically evaluate the results of actions. Therefore, it can be stated that in the traditional way of measuring the phenomenon of learnability, it is impossible to capture how the individual users' learn and the profound nature of the effects that learnability has on learning; in brief, the traditional way of measuring purely task performance during a task instead of the cognitive processes. In my opinion, the best way to measure the learnability process is to analyse the human way of behaviour before, during and after the learnability task.

In the following sections, I describe the relationship between learning, the traditional attributes of learnability and the categories of the model of learnability. Consciousness is developed when a human interacts with his/her environment and it has a direct connection on intuitiveness. The human learns the most effectively if s/he is able to find the right solution intuitively, i.e. like learning to how to bicycle. Therefore, intuitiveness has the most effect on the overall learnability of an interface. Intuitiveness can be seen at the beginning of the learning curve. If the product is very intuitive, the user can solve the task right a way. Thus, user interfaces designed for routine assignments, such as dishwashers, ovens, television remote controls, coffee machines and vacuum cleaners, must be the most intuitive. However, in everyday life, equipment is seldom easy to learn and it is becoming increasingly complicated. Therefore, a user rarely reaches the result of action right a way and thus other learnability categories are also part of the learnability process.

Consistency must be assumed to have the most important effect on the knowledge form and knowledge build learnability sub-categories. In addition, consistency also has a major effect on customer behaviour. Hypothetically, it can be thought that consistency becomes a more important attribute of learnability when people grow older. For instance, some people are very persistent in their product selection and are not willing to change their old brand for a new one because they already know how the product functions and they can therefore start to use it immediately. In other words, they do not have to search for information or collect data in order to take the product into use. Moreover, intuitiveness and consistency, attributes of learnability, are related because they both emphasize the prior conventions and expectations of users, but so do the other traditional attributes of learnability, because the traditional user interface design sees the human as a passive learner.

In addition, it can be assumed that the task match strongly affects the knowledge build sub-category, where the user is assumed to interact the most intensively with a product, i.e. for human's who use constructivism learning strategies, the attribute of task match become important. On the other hand, the properties of memorability and error recovery are connected to the behaviourism learning theory, i.e. if a human uses behavioural learning strategies, where learning is based on trial and error, error recovery becomes an important attribute of learnability.

The user interface designed for expert users is more advantageous and has more features to enable the expert user to do assignments more effectively. However, they are more difficult to learn and thus the high quality of the information search and data collection sub-categories of learnability is crucial in order to be successful in their work. However, expert users are usually motivated and willing to examine, explore and search the new features of the software. Moreover, the help desk is a valuable attribute of learnability when the user has to find the right direction, i.e. when s/he does not know what do to next or the user has to review or check whether the actions taken are correct in relation to the task.

The data collection sub-category is related the strongest with the memorability. In the data collection sub-category the user had to repeatedly explore the new knowledge. More memorable the user interface is the less explore and repeat actions are needed. At the conclusion, it can be stated that all the attributes of learnability have a positive effect on learnability. However, the level of influence does differ between categories of the model of learnability.

Furthermore, the traditional definitions of learnability do not take into consideration users' individual learning styles and learning methods as a way of searching information, collecting data, managing, forming and building knowledge. Neither do the definitions of learnability recognize modern learning theories. At the moment, the attributes of learnability are purely connected to knowledge transfer theories. Therefore, learnability seems to be a concept, whose content is difficult to define, particularly with respect to human learning. Modern learning theories emphasize a learner's own activity and collaborative learning. In the theory of constructivism, the learner constructs new knowledge based on his/her earlier knowledge (see Miettinen 2000:276-292). This can be the best seen in the model of learnability, especially in the knowledge management sub-category where the decision is made based on earlier knowledge: the knowledge before the first interaction with the user interface and the knowledge received during the first interaction from the different learnability categories. In addition, the collaborative learning concept is related to socio-constructivism, according to which thinking is developed through social interaction (Lave & Wenger 1991). Collaborative learning means educational methods that encourage learners to cooperate and solve assignments together. In addition, there is a specific modern learning theory particularly created for the information and communication technology context. Computer Supported Collaborative Learning (CSCL) means learning and teaching methods, where modern information and communication technology are used to support users' mutual work to enhance learning (Lehtinen 2003:1-33). However, none of the collaborative learning methods is a part of the current definition of learnability or the model of learnability that is built. Learnability tasks are purely individual user tests. Nevertheless, it would be very good to also measure learnability within the group context. Hence, we seldom solve problems or tasks on our own. It would be good to see if there are any connections to collaborative learning methods. How can modern learning theories be adapted to the phenomenon of learnability?

According to van Welie et al. (1999:613-620), task analysis should provide the information for the requirements of the product, both in the functional sense as well as in the ergonomic and cognitive sense. Learnability tasks are anchored in the real problem situation, and problem-based learning anchors learning to the real problem situation. Instead of forming problems, engineers in general are very good at solving functional problems and correcting errors in user interfaces. There might also be a possibility that engineers are not solving the right problems in the cognitive sense. Therefore, it is important to also identify the real user problems in the cognitive and ergonomic sense. Shackel (1991:21-38) states that one of the measurements of learnability is the human dimension in the ergonomic sense. Basic data about the human dimensions come from anthropometrics. Dimension, which refers to the physical anthropometrics, is used to analyse the human dimension. There often is great diversity in these static measures, which reminds us that there can be no image of an average user even in terms of anthropometrics. These physical measures of static human dimensions are not enough. The measures of dynamic actions such as reach distance while seated, speed of finger presses, or strength of lifting are also necessary when investigating learnability. For instance, at the moment the speed of human finger presses is much faster than the text fill functionality provided in cellular phones. For many users it is irritating when they are forced to wait before the cellular phone allows them to press another key if the next character happens to be located on the same cellular phone button. In conclusion, human dimensions are not part of the current definition on learnability, even though human dimensions are a vital part of HCI interaction.

However, it is also worth noting that it is essential to find the right learning method for novice users; the better-specified learning strategies can be absorbed with less effort devoted to learning. The phenomenon of learnability needs to be analysed through different learning methods, end-users, products, environments and tasks with the varieties of training time and frequency of use. However, it is most important to analyse users' learning styles in relation to different levels of task difficulty. Sein and Bostrom (1989:197-229) give an example of preferred learning style, where some people learn better from abstract descriptions and others learn better from concrete examples. The limitation in this study is that based on collected data, it is impossible to analyse spatial memory, motivation, stress, frustration, learning styles or prejudice toward computers, which are all very important issues when studying learnability. Thus, the categories in the model of learnability do not include goal setting, motivation, orientation or the evaluation of learning styles; neither do they involve teaching or collaboration with other students.

Finally, the model of learnability on its own does not enhance learnability. However, based on the model of learnability that is built, it is possible to analyse human cognitive processes when taking a new product into use. Despite this, we have to find new pedagogical strategies that support and help to enhance learnability in the different categories in the model of learnability. This is especially the case with the information search and data collection sub-categories, which seem to be the most demanding categories in relation to learnability.

The phenomenon of learnability has not been studied in the HCI research area from the learning point of view. Therefore, the collaborative learning and modern learning methods has not been connected to the phenomenon of learnability. At the moment, HCI research and the different kinds of learning environments offered by the new information and communication technology have not been considered important when studying the phenomenon of learnability. Thus, it is understandable that learning is far from the current definitions of learnability. Finally, it is amazing that modern communication technology is seldom used as a didactic tool to help a user learn collaboratively new user interfaces with other more advanced users. This would be the most effective and natural didactic method to help novice users to learn a user interface.

9.6 Practical implications

The most practical measure of learnability is to preserve a users' success in a task. The traditional practices for testing a product are unsuitable for capturing learnability problems, for instance whether a user is able to take a product into use. Hence, the testing methods and metrics for measuring learnability are applied from usability testing. Although the traditional attributes of learnability most of the time improve learnability, a new approach to the phenomenon is necessarily. Perhaps the lack of research to improve the learnability of products suggests that we do need better research methods and new tools to investigate and study learnability.

Since some categories of the model of learnability are more time consuming and demanding than others are, it would be wise to build separate user interfaces for novice and expert users, where the novice user can more quickly reach a proficient level of work. In addition, work that does not need profound and deep knowledge before making a decision desperately needs a more simplified user interface, where users' can immediately start completing their assignments. It still is hard to adopt the new information and communication technology in every day of life. Users have to learn to use the new information and communication technology better or user interface designers have to learn to design user interfaces that meet the demands of users and match the demands of their assignments. In brief, the level of technology is high in Finland but the use and benefit of modern technology is low among common citizens.

The model of learnability based on the users' actions within the context of the WebCT Campus Edition included six distinctive but associated sub-categories of learnability and consisted of twelve conceptual categories. The model of learnability was build inductively, so the different categories could be opened with detailed parts. In other words, the patterns of learnability found in this study provide the UI designer with concrete advice on how to improve the learnability of devices and therefore the quality of a user interface. Based on the data, three iterative patterns were found: a) data collection-information search, b) knowledge build-knowledge form and c) information search-knowledge management. Furthermore, these three major iterative patterns illustrate the non-linear learnability process. Therefore, the different parts of the categories of the model of learnability can be studied and evaluated separately. In addition, the categories in the phenomenon of learnability enable the establishment of a specific learnability measurement for a graphical user interface. There is currently no separate learnability measurement and the model of learnability is one of the few models of learnability. However, the model of learnability might not immediately be practical but it could provide information on the development of a practical tool such as user inspection methods as well as make better predictors of performance.

Furthermore, relearnability is one of the objectives of designing a device. The knowledge management sub-category is associated with relearnability and the concept of reusability, i.e. users should be able to review the information and data they have searched and collected during their first interactions. The reusability of information and data is crucial in the sense of relearnability. Therefore, many manufactures would like to understand product replacement challenges better from the learning perspective, i.e. the perspective of the categories of the theoretical model of learnability. Product replacement with the same brand should not disrupt the use of the familiar properties or applications, existing accessories and existing data content of the product. However, the common problem is that the familiar properties, applications of product and data content are hard to locate in a new product and even the vital content for the user has totally disappeared. In addition, it is certainly a challenge to tell a user what a new device can do. It is often the case that even expert users are unaware of all phone capabilities and use only a few properties of a device on a weekly basis. The users' daily tasks must be matched with the properties of a product; otherwise, the product is useless.

As computer systems become cheaper and more powerful, it seems certain that learnability factors will become increasingly dominant in the acceptance decisions and service adoption made by users and purchasers. The first-use experience will shape expectations for future interaction and use. If a user interface is hard to learn, it might cause frustration and the motivation to learn the user interface will probably diminish. In other words, successful or unsuccessful first use is reflected in the users' future decisions and actions. For example, a user may not start using the videoconferencing tools if the first trial fails, or s/he may select another brand with the next product purchase. In addition, highly learnable products reduce support cost and improve customer satisfaction. Thus, evaluating learnability is important for manufacturers because it is vital them to know whether the new product is better than its predecessors are and better than those sold by competitors. Moreover, most technological products are being advertised and sold based on how easy they are to learn and use.

How can services and goods be made more learnable? The result found that when analysed, the phenomenon of learnability could easily be adapted to the production of goods and services. In the future, it might be possible for people to choose the most suitable user interface based on their cognitive processes, learning styles and the tasks they perform daily with the product. The start up application could ask the user couple of questions and set a perfect personalized user interface just for him/her.

10 CONCLUSION

Although the challenge of learnability is known and admitted among users, designers, manufacturers, and research communities, there is an astonishingly small amount of published research in this field. The recent literature on human-computer interaction does not address the issue of learnability sufficiently. That might be one of the reasons why the definitions and measurements of learnability are quite far from the human characteristics and modern learning theories. In addition, learnability is purely associated with user performance skills, and the measurement of knowledge is abandoned. The model of learnability in this study emphasizes the measurement of knowledge and human cognitive processes.

The concept of learnability needs to be studied in more detail and not merely in the user interface context where the technology has a key role. At the moment, the definition of learnability is very narrow and needs to be broadened. How do people learn? How should people's learning be supported? What makes learning possible? Studying learnability as a phenomenon cannot be separated from learning. Learning is a continuous process, where human interacts with the environment. The learning process is in time scale much slower and continues process than learnability. Learnability studies currently consider implicitly the individual as the learner, and they do not discuss how a team or a collective learns to use a product through collaboration. Nor do they discuss the specific learnability problems of products created for the support of cooperative work. Also, this study takes implicitly individual as the learner and does not discuss how a team or collective learns to use a product in their collaborative work nor the specific learnability problems of products created for the support of cooperative work. Therefore, regarding particularly the social and collaborative aspects of learning, qualitative approaches could be beneficial in studying learnability because they reveal the underlying problems and possibilities of use by studying the future context of use, and they still include the automated ‘tacit’ knowledge inherent in users’ tasks (Kujala 2003:1-16). This kind of point of view would be important for the future studies made on this field. The concept of learnability should be studied more deeply, and HCI researchers should find new ways of describing the phenomenon. These viewpoints are important for the future studies in this field. In this way, research could provide us a more holistic and thorough understanding of the phenomenon of learnability.

The earlier usability researchers’ have concentrated to analyse the user interface. The definitions of learnability focus totally on the user interface. Therefore, the human characteristics and cognitive processes are not part of current definition on learnability, even they have a major effect on performance and the performance is considered as a key indicator of learnability. Therefore, instead of talking about the efficiency and effectiveness of a user interface more attention should be paid to modern learning theories, human characteristics, cognitive processes and different kinds of tasks and level of task difficulties. In that way, we are able to also improve the user interfaces efficiency, effectiveness and the most important level of users’ satisfaction. In conclusion, the research on learnability phenomena ought to focus especially on human characteristics and its cognitive processes because spatial memory, motivation, goals, stress, temper, impulsiveness, frustration, learning styles, reasoning abilities or prejudice toward computers are very important issues when studying learnability.

The relearnability of a product is rarely tested. A follow up study would be very beneficial in order to measure relearnability. Many of the initial problems faced by users may disappear or change when they have used the WebCT educational software for a certain time. However, during the first interaction, an individual’s learning process may focus on the different parts of the interface and the effect of the different attributes of learnability. For instance, when the same user interacts with the same user interface the second time s/he may concentrate on using the same or new parts of the interface. In the first case, relearnability has more influence on learnability. It can therefore be assumed that human behaviour, decision-making and cognitive models are very stubborn. Many of us find ourselves doing the same morning procedures, sitting in the same chair during lunch, telling the same jokes, using the same expressions, sleeping the same position etc. Hence, it is easier to change a user interface than it is to change human behaviour and therefore it might be wise to begin to analyse human characteristics, cognitive processes and learning, if we want design products that are more learnable. In addition, the phenomenon of learnability needs to be analysed with different users, tasks, environments and tools in order to gain a more holistic picture of the phenomenon. The standardization activities would also be useful for the definition of learnability.

Even in this study, the definition of learnability is still too narrow and technical. However, its review is appropriate within the context of learning and human cognitive processes. One accomplishment of this study was to challenge usability designers to broaden their understanding of the phenomenon of learnability and to move ahead from performance time oriented learnability studies to studying learning processes from the human centric point of view, i.e. where the key actor is human as a learner and his/her behaviour. It is also important to find new ways of describing learnability instead of linear learning curves. The learnability model and the learnability patterns in this doctoral dissertation indicate that learnability, i.e. the learning process, is non-linear. Therefore, future learnability studies should concentrate on analysing non-linear learning processes from the human centric point of view, where the actions of the human being as a learner are the key to more learnable interfaces, i.e. we need in to find the key element that enhances learnability and on the other hand, that causes learnability problems for humans. However, the concept of learnability needs even more deep discussion on the different interpretations or argumentation than this dissertation can offer. Finally, the following issues needs to be clarified in future learnability studies. First, we ought to be able to define the moment when easy to learn changes to easy to use. Second, we ought to study in detail the processes of learnability in different natural environments with real users using a variety of qualitative methods, i.e. still too many learnability studies are performed in laboratory settings and with same methods for product prototypes. Thus, there is real demand for learnability studies performed in real environments. In addition, recent learnability studies have focused almost purely on technical products. For this reason, it is also important to perform learnability studies with other products. Third, we should openly discuss how the concept of learnability is related to learning and modern learning theories. Fourth, we ought to discover how tasks, individual human and other environments and the product itself affect learnability. All the four questions relate to each other. Usability experts cannot solve these questions by themselves; they desperately need help from sociologists, educationalists and ethnographical specialists in cultural issues.

Finally, theory building is a never-ending cyclic process. The model of learnability is a theorem before it is validated as a theory. Future studies must test and validate the model of learnability with created measurements. Based on the new theory of learnability and the validated new learnability measurement, it is possible to improve the learnability of the technological devices and services developed in the different sectors of society such as education, health care, culture and transportation. Finally, more learnability research, where the human is a key actor, is needed in order to bring marketing slogan "be clicked" closer to reality and to every one of us - "Learnability Makes Things Click – but how to click learnability."

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APPENDICES

Appendix 1

APPENDIX 1. User 1's categories of the model of learnability.

Concepts (concrete)	minutes	seconds	tenth	Assignments	Conceptual categories	Sub-categories
click on the log on hyperlink	0	1	1	1	solution	result of action
written user name	0	11	23	1	process	knowledge build
click on the password text box	0	13	24	1	focus	knowledge form
written password	0	18	24	1	process	knowledge build
press on the enter key on the keyboard	0	19	24	1	solution	result of action
system error (the page cannot be displayed)	0	20	4	1	error	result of action
navigation back	0	23	1	1	history	data collection
click on the log on hyperlink	0	29	4	1	solution	result of action
click on the log on hyperlink	0	41	7	1	solution	result of action
click on the information search course hyperlink	0	52	14	1	navigation	data collection
click on the information search course hyperlink	1	9	23	2	navigation	data collection
navigation back	1	18	12	2	history	data collection
navigation back	1	36	1	2	history	data collection
navigation back	1	39	7	2	history	data collection
navigation back	1	45	16	2	history	data collection
navigation back	1	50	11	2	history	data collection
vertical scroll down with scroll bar	1	56	24	2	examine	Information search
vertical scroll up with scroll bar	2	12	23	2	examine	Information search
click on the information search course hyperlink	2	21	24	2	navigation	data collection
click on the tutors contact information hyperlink	2	31	11	2	navigation	data collection
vertical scroll down with scroll bar	2	37	8	2	examine	Information search
navigation back	2	48	8	2	history	data collection
click on the information search course hyperlink	2	55	14	2	navigation	data collection
click on the study material content hyperlink	3	1	15	2	navigation	data collection
vertical scroll down with scroll bar	3	11	1	2	examine	Information search
navigation back	3	20	24	2	history	data collection
navigation back	3	26	6	2	history	data collection
navigation back	3	27	21	2	history	data collection
navigation back	3	33	3	2	history	data collection
navigation back	3	36	5	2	history	data collection
navigation back	3	39	4	2	history	data collection
navigation back	3	43	19	2	history	data collection

click on the one step history back on the standard buttons	3	48	2	2	extra information	Information search
click on the one step history back on the standard buttons	3	49	23	2	extra information	Information search
click on the one step history back on the standard buttons	3	51	22	2	extra information	Information search
click on the two step history back on the standard buttons	3	53	22	2	extra information	Information search
click on the log on hyperlink	3	56	15	2	solution	result of action
vertical scroll down with scroll bar	4	24	13	2	examine	Information search
vertical scroll up with scroll bar	4	26	10	2	examine	Information search
vertical scroll down with scroll bar	4	27	11	2	examine	Information search
click on the add course hyperlink	4	44	7	2	process	knowledge build
navigation back	5	1	2	2	history	data collection
vertical scroll down with scroll bar	5	5	1	2	examine	Information search
vertical scroll down with scroll bar	5	24	19	2	examine	Information search
click on the information search course hyperlink	5	35	2	2	navigation	data collection
click on the quizzes hyperlink	5	53	9	2	navigation	data collection
click on the quizzes hyperlink	5	56	20	2	navigation	data collection
click on the course map hyperlink	6	4	24	2	navigation	data collection
vertical scroll down with scroll bar	6	15	3	2	examine	Information search
click on the WebCT instructions hyperlink	6	24	24	2	pop up	knowledge management
horizontal scroll right with the scroll bar	6	34	22	2	examine	Information search
vertical scroll down with scroll bar	6	42	4	2	examine	Information search
vertical scroll down with scroll bar	7	0	11	2	examine	Information search
vertical scroll down with scroll bar	7	10	18	2	examine	Information search
vertical scroll down with scroll bar	7	11	21	2	examine	Information search
vertical scroll down with scroll bar	7	16	8	2	examine	Information search
vertical scroll down with scroll bar	7	20	7	2	examine	Information search
vertical scroll down with scroll bar	7	23	21	2	examine	Information search
vertical scroll down with scroll bar	7	26	15	2	examine	Information search
close the window	7	32	9	2	view	knowledge management
navigation back	7	43	7	2	history	data collection
navigation back	7	51	4	2	history	data collection
click on the one step history back on the standard buttons	7	55	20	2	extra information	Information search
click on the six step history back on the standard buttons	7	59	13	2	extra information	Information search
vertical scroll down with scroll bar	8	29	22	2	examine	Information search
vertical scroll down with scroll bar	8	35	5	2	examine	Information search
vertical scroll up with scroll bar	8	38	0	2	examine	Information search
vertical scroll down with scroll bar	8	38	15	2	examine	Information search

vertical scroll down with scroll bar	8	43	1	2	examine	Information search
click on the quizzes hyperlink	8	48	1	2	navigation	data collection
vertical scroll down with scroll bar	8	58	12	2	examine	Information search
navigation back	9	6	7	2	history	data collection
navigation back	9	13	16	2	history	data collection
click on the one step history back on the standard buttons	9	16	0	2	extra information	Information search
click on the two step history back on the standard buttons	9	19	11	2	extra information	Information search
vertical scroll down with scroll bar	9	27	7	2	examine	Information search
vertical scroll up with scroll bar	9	33	0	2	examine	Information search
vertical scroll down with scroll bar	9	33	18	2	examine	Information search
vertical scroll up with scroll bar	9	43	10	2	examine	Information search
click on the information search course hyperlink	9	49	19	2	navigation	data collection
click on the print hyperlink	10	7	12	2	solution	result of action
vertical scroll down with scroll bar	10	29	3	2	examine	Information search
vertical scroll up with scroll bar	10	36	21	2	examine	Information search
click on the information search course instructions hyperlink	10	39	20	2	navigation	data collection
maximize the window	10	55	9	2	view	knowledge management
vertical scroll down with scroll bar	11	0	11	2	examine	Information search
vertical scroll up with scroll bar	11	3	12	2	examine	Information search
click on the menu bar file option	11	5	16	2	extra information	Information search
click on the menu bar print option	11	8	1	2	solution	result of action
click on the menu bar file option	11	13	8	2	extra information	Information search
click on the print button	11	31	0	2	solution	result of action
vertical scroll down with scroll bar	11	56	18	3	examine	Information search
vertical scroll up with scroll bar	12	0	11	3	examine	Information search
vertical scroll down with scroll bar	12	3	15	3	examine	Information search
click on the calendar hyperlink	12	20	10	3	navigation	data collection
vertical scroll down with scroll bar	12	32	5	3	examine	Information search
click scroll bar	12	50	24	3	focus	knowledge form
click on the next month hyperlink	13	5	6	3	navigation	data collection
vertical scroll down with scroll bar	13	8	12	3	examine	Information search
vertical scroll up with scroll bar	13	14	6	3	examine	Information search
vertical scroll down with scroll bar	13	16	23	3	examine	Information search
vertical scroll up with scroll bar	13	18	1	3	examine	Information search
click on the previous month hyperlink	13	22	16	3	navigation	data collection
vertical scroll down with scroll bar	13	25	1	3	examine	Information search

click on the discussion forum hyperlink	13	44	11	4	navigation	data collection
click on the topic all hyperlink	13	48	21	4	navigation	data collection
click on the discussion forum hyperlink	14	1	14	4	navigation	data collection
click on the compose discussion message hyperlink	14	10	21	4	pop up	knowledge management
click on the message text area	14	15	7	4	focus	knowledge form
click on the subject text box	14	21	9	4	focus	knowledge form
written subject	14	33	10	4	process	knowledge build
click on the message text area	14	33	16	4	focus	knowledge form
written message	14	52	22	4	process	knowledge build
click on the post button	14	59	3	4	solution	result of action
click on the topic all hyperlink	15	5	22	5	navigation	data collection
navigation back	15	21	22	5	history	data collection
click on the e-mail hyperlink	15	24	23	5	navigation	data collection
click on the message folders hyperlink	15	46	15	5	navigation	data collection
navigation back	15	50	24	5	history	data collection
navigation back	16	4	21	5	history	data collection
click on the one step history back on the standard buttons	16	9	0	5	extra information	Information search
click on the e-mail hyperlink	16	26	3	5	navigation	data collection
navigation back	16	44	12	5	history	data collection
click on the one step history back on the standard buttons	17	0	8	5	extra information	Information search
click on the URL text box	17	13	0	5	focus	knowledge form
press on the backspace key on the keyboard	17	16	3	5	process	knowledge build
press on the enter key on the keyboard	17	20	24	5	solution	result of action
click on the log on hyperlink	17	24	10	5	solution	result of action
click on the information search course hyperlink	17	46	18	5	navigation	data collection
click on the e-mail hyperlink	17	54	14	5	navigation	data collection
click on the manage messenger hyperlink	18	1	16	5	navigation	data collection
navigation back	18	6	6	5	history	data collection
click on the message folders hyperlink	18	20	10	5	navigation	data collection
navigation back	18	28	12	5	history	data collection
click on the tutors contact information hyperlink	18	41	15	5	navigation	data collection
vertical scroll down with scroll bar	18	46	11	5	examine	Information search
vertical scroll up with scroll bar	18	47	14	5	examine	Information search
vertical scroll down with scroll bar	18	49	18	5	examine	Information search
vertical scroll down with scroll bar	18	53	0	5	examine	Information search
vertical scroll up with scroll bar	18	56	21	5	examine	Information search

vertical scroll up with scroll bar	19	1	12	5	examine	Information search
vertical scroll up with scroll bar	19	4	18	5	examine	Information search
vertical scroll down with scroll bar	19	5	11	5	examine	Information search
vertical scroll up with scroll bar	19	9	13	5	examine	Information search
Paints the e-mail address	19	20	9	5	highlight	knowledge form
Paints the e-mail address	19	34	7	5	highlight	knowledge form
press on the ctrl-c keys on the keyboard	19	34	8	5	process	knowledge build
click on the e-mail hyperlink	19	38	23	5	navigation	data collection
click on the inbox hyperlink	19	46	20	5	navigation	data collection
navigation back	19	54	6	5	history	data collection
click on the outbox hyperlink	19	56	13	5	navigation	data collection
navigation back	20	2	1	5	history	data collection
click on the manage messenger hyperlink	20	9	20	5	navigation	data collection
navigation back	20	14	11	5	history	data collection
click on the compose mail message hyperlink	20	16	13	5	pop up	knowledge management
click on the send to text box	20	19	23	5	focus	knowledge form
press on the ctrl-v keys on the keyboard	20	22	17	5	process	knowledge build
paste the send to text box	20	22	18	5	process	knowledge build
click on the subject text box	20	25	20	5	focus	knowledge form
written subject	20	42	11	5	process	knowledge build
click on the message text area	20	43	10	5	focus	knowledge form
written message	21	12	15	5	process	knowledge build
click on the send button	21	17	1	5	solution	result of action
alert window message (the following names were not found in the class)	21	18	2	5	error	result of action
click on the ok button	21	26	0	5	solution	result of action
minimize the window	21	39	0	5	view	knowledge management
click on the tutors contact information hyperlink	21	41	24	5	navigation	data collection
vertical scroll down with scroll bar	21	45	18	5	examine	Information search
vertical scroll up with scroll bar	21	56	15	5	examine	Information search
vertical scroll down with scroll bar	21	57	10	5	examine	Information search
click on the information search course instructions task bar	21	58	21	5	view	knowledge management
click on the information search course instructions task bar	22	1	4	5	view	knowledge management
click on the compose message task bar	22	3	10	5	view	knowledge management
click on the tutors task bar	22	19	16	5	view	knowledge management
click on the compose message task bar	22	21	1	5	view	knowledge management

click on the browse button	22	26	5	5	pop up	knowledge management
vertical scroll down with scroll bar	22	32	4	5	examine	Information search
close the window	22	37	13	5	view	knowledge management
click on the browse button	22	40	7	5	pop up	knowledge management
vertical scroll down with scroll bar	22	45	23	5	examine	Information search
vertical scroll down with scroll bar	22	52	10	5	examine	Information search
click on the tutor list box	23	9	22	5	selection	knowledge build
click on the done button	23	11	26	5	solution	result of action
click on the send button	23	17	15	5	solution	result of action
vertical scroll down with scroll bar	23	33	10	6	examine	Information search
click on the tutors task bar	23	37	15	6	view	knowledge management
click on the information search course instructions task bar	23	38	5	6	view	knowledge management
click on the tutors task bar	23	39	20	6	view	knowledge management
vertical scroll up with scroll bar	24	4	0	6	examine	Information search
vertical scroll down with scroll bar	24	7	9	6	examine	Information search
vertical scroll up with scroll bar	24	25	6	6	examine	Information search
vertical scroll down with scroll bar	24	25	17	6	examine	Information search
close the window	24	52	0	6	view	knowledge management
click on the one step history back on the standard buttons	24	56	17	6	extra information	Information search
click on the six step history back on the standard buttons	24	59	10	6	extra information	Information search
close the window	25	28	24	6	view	knowledge management

Appendix 2

APPENDIX 2. User 2's categories of the model of learnability.

Concepts (concrete)	minutes	seconds	tenth	Assignments	Conceptual categories	Sub-categories
click on the log on hyperlink	0	4	9	1	solution	result of action
written user name	0	16	12	1	process	knowledge build
click on the password text box	0	18	11	1	focus	knowledge form
written password	0	21	23	1	process	knowledge build
click on the ok button	0	24	8	1	solution	result of action
system error (the page cannot be displayed)	0	25	14	1	error	result of action
navigation back	0	30	21	1	history	data collection
click on the log on hyperlink	0	34	11	1	solution	result of action
click on the information search course hyperlink	1	3	22	1	navigation	data collection
click on the information search course hyperlink	1	26	10	2	navigation	data collection
click on the information search course hyperlink	1	59	7	2	navigation	data collection
click on the study material content hyperlink	2	13	4	2	navigation	data collection
click on the information search course instructions hyperlink	2	22	24	2	navigation	data collection
vertical scroll down with scroll bar	2	32	10	2	examine	information search
vertical scroll up with scroll bar	2	38	7	2	examine	information search
click on the print hyperlink	2	55	11	2	solution	result of action
click on the information search course instructions hyperlink	3	14	20	2	navigation	data collection
vertical scroll down with scroll bar	3	35	24	2	examine	information search
vertical scroll up with scroll bar	3	39	16	2	examine	information search
maximize the window	3	42	1	2	view	knowledge management
vertical scroll down with scroll bar	3	51	8	2	examine	information search
vertical scroll up with scroll bar	3	58	5	2	examine	information search
click on the menu bar file option	4	2	7	2	extra information	information search
click on the menu bar print option	4	4	6	2	solution	result of action
click on the print button	4	14	5	2	solution	result of action
vertical scroll down with scroll bar	4	39	21	3	examine	information search
click on the calendar hyperlink	4	40	6	3	navigation	data collection
vertical scroll down with scroll bar	4	43	18	3	examine	information search
click on the discussion forum hyperlink	5	0	7	4	navigation	data collection
click on the topic all hyperlink	5	6	4	4	navigation	data collection
click on the message to all hyperlink	5	50	11	4	pop up	knowledge management
click on the close hyperlink	5	55	3	4	view	knowledge management

click on the sorting dropdown menu	6	13	19	4	extra information	information search
close the sorting dropdown menu	6	15	13	4	extra information	information search
click on the go button	6	19	19	4	solution	result of action
alert window message (please select a message)	6	19	20	4	error	result of action
click on the ok button	6	20	17	4	solution	result of action
horizontal scroll right with the scroll bar	6	37	17	4	examine	information search
horizontal scroll left with the scroll bar	6	38	24	4	examine	information search
click on the select topics dropdown menu	6	52	15	4	extra information	information search
close the select topics dropdown menu	6	55	9	4	extra information	information search
click on the compose discussion message hyperlink	7	1	14	4	pop up	knowledge management
click on the message text area	7	5	5	4	focus	knowledge form
written message	7	11	12	4	process	knowledge build
press on the backspace key on the keyboard	7	13	5	4	process	knowledge build
written message	7	36	13	4	process	knowledge build
click on the subject text box	7	40	16	4	focus	knowledge form
written subject	7	48	11	4	process	knowledge build
click on the post button	7	52	24	4	solution	result of action
click on the e-mail hyperlink	8	1	13	5	navigation	data collection
click on the compose mail message hyperlink	8	12	20	5	pop up	knowledge management
close the window	8	20	18	5	view	knowledge management
click on the information search course hyperlink	8	52	8	5	navigation	data collection
click on the study material content hyperlink	8	59	10	5	navigation	data collection
vertical scroll down with scroll bar	9	4	16	5	examine	information search
click on the tutors contact information hyperlink	9	19	5	5	navigation	data collection
vertical scroll down with scroll bar	9	23	10	5	examine	information search
vertical scroll down with scroll bar	9	27	1	5	examine	information search
vertical scroll up with scroll bar	9	31	3	5	examine	information search
click on the information search course instructions task bar	9	40	11	5	view	knowledge management
click on the tutors task bar	9	41	10	5	view	knowledge management
click on the e-mail hyperlink	9	43	18	5	navigation	data collection
click on the compose mail message hyperlink	9	46	19	5	pop up	knowledge management
click on the subject text box	9	48	12	5	focus	knowledge form
written send to	9	52	19	5	process	knowledge build
press on the backspace key on the keyboard	9	53	5	5	process	knowledge build
written send to	9	59	2	5	process	knowledge build
click on the message text area	10	1	1	5	focus	knowledge form

written message	10	17	0	5	process	knowledge build
press on the backspace key on the keyboard	10	17	2	5	process	knowledge build
written message	10	27	1	5	process	knowledge build
alert window message (please enter a subject)	10	40	12	5	error	result of action
click on the send button	10	40	12	5	solution	result of action
click on the ok button	10	41	15	5	solution	result of action
click on the subject text box	10	42	21	5	focus	knowledge form
click on the send button	10	51	11	5	solution	result of action
written subject	10	51	11	5	process	knowledge build
alert window message (the following names were not found in the class)	10	53	3	5	error	result of action
click on the ok button	11	1	0	5	solution	result of action
click on the browse button	11	12	21	5	pop up	knowledge management
vertical scroll down with scroll bar	11	15	13	5	examine	information search
click on the tutor list box	11	33	16	5	selection	knowledge build
click on the done button	11	35	3	5	solution	result of action
click on the send button	11	40	19	5	solution	result of action
click on the information search course hyperlink	12	27	13	6	navigation	data collection
click on the homepage hyperlink	12	36	8	6	navigation	data collection
click on the e-learning hub/show update log hyperlink	12	57	13	6	navigation	data collection
click on the homepage hyperlink	13	26	2	6	navigation	data collection
horizontal scroll right with the scroll bar	13	38	23	6	examine	information search
horizontal scroll left with the scroll bar	13	39	18	6	examine	information search
close the window	13	45	7	6	view	knowledge management
close the window	13	49	13	6	view	knowledge management

Appendix 3

APPENDIX 3. User 3's categories of the model of learnability.

Concepts (concrete)	minutes	seconds	tenth	Assignments	Conceptual categories	Sub-categories
click on the log on hyperlink	0	2	14	1	result of action	result of action
written user name	0	7	0	1	process	knowledge build
press on the backspace key on the keyboard	0	7	22	1	process	knowledge build
written user name	0	10	14	1	process	knowledge build
press on the backspace key on the keyboard	0	11	7	1	process	knowledge build
written user name	0	20	19	1	process	knowledge build
press on the tab key on the keyboard	0	23	3	1	process	knowledge build
written password	0	25	16	1	process	knowledge build
click on the ok button	0	28	7	1	result of action	result of action
vertical scroll down with the mouse scroll button	1	10	18	1	examine	information search
vertical scroll up with the mouse scroll button	1	11	0	1	examine	information search
click on the information search course hyperlink	1	15	20	1	navigation	data collection
click on the information search course hyperlink	1	31	13	2	navigation	data collection
click on the study material content hyperlink	1	39	11	2	navigation	data collection
navigation back	1	44	24	2	history	data collection
navigation back	1	49	4	2	history	data collection
navigation back	1	53	0	2	history	data collection
navigation back	2	14	7	2	history	data collection
navigation back	2	17	19	2	history	data collection
navigation forward	2	45	11	2	history	data collection
click on the information search course hyperlink	2	56	9	2	navigation	data collection
click on the WebCT instructions hyperlink	2	58	11	2	pop up	knowledge management
vertical scroll down with scroll bar	3	6	0	2	examine	information search
vertical scroll up with scroll bar	3	10	9	2	examine	information search
maximize the window	3	12	5	2	view	knowledge management
vertical scroll down with scroll bar	3	13	13	2	examine	information search
vertical scroll up with scroll bar	3	17	10	2	examine	information search
click on the menu bar file option	3	21	12	2	extra information	information search
vertical scroll down with the mouse scroll button	3	37	13	2	examine	information search
vertical scroll up with the mouse scroll button	3	43	24	2	examine	information search
close the window	3	44	11	2	view	knowledge management
click on the information search course hyperlink	3	49	3	2	navigation	data collection

vertical scroll down with scroll bar	3	53	21	2	examine	information search
vertical scroll up with scroll bar	3	55	0	2	examine	information search
navigation back	4	5	21	2	history	data collection
navigation back	4	12	2	2	history	data collection
navigation back	4	22	6	2	history	data collection
click on the information search course hyperlink	4	33	0	2	navigation	data collection
click on the WebCT instructions hyperlink	4	39	1	2	pop up	knowledge management
maximize the window	4	44	4	2	view	knowledge management
vertical scroll down with the mouse scroll button	4	46	14	2	examine	information search
vertical scroll up with the mouse scroll button	4	48	11	2	examine	information search
close the window	4	51	1	2	view	knowledge management
click on the study material assignments hyperlink	4	53	19	2	navigation	data collection
vertical scroll down with the mouse scroll button	5	1	10	2	examine	information search
vertical scroll up with the mouse scroll button	5	2	16	2	examine	information search
navigation back	5	4	10	2	history	data collection
click on the information search course hyperlink	5	12	9	2	navigation	data collection
click on the information search course hyperlink	5	17	23	2	navigation	data collection
click on the information search course hyperlink	5	17	30	2	navigation	data collection
click on the information search course hyperlink	5	27	0	2	navigation	data collection
navigation back	5	45	4	2	history	data collection
navigation back	5	46	20	2	history	data collection
navigation back	5	48	17	2	history	data collection
navigation back	5	54	0	2	history	data collection
navigation back	5	58	16	2	history	data collection
navigation forward	6	0	5	2	history	data collection
click on the homepage hyperlink	6	7	14	2	navigation	data collection
click on the print hyperlink	6	49	16	2	result of action	result of action
navigation back	6	59	12	2	history	data collection
click on the WebCT instructions hyperlink	7	2	15	2	pop up	knowledge management
vertical scroll down with the mouse scroll button	7	8	8	2	examine	information search
vertical scroll up with the mouse scroll button	7	13	12	2	examine	information search
vertical scroll down with the mouse scroll button	7	17	0	2	examine	information search
vertical scroll down with scroll bar	7	23	19	2	examine	information search
vertical scroll up with scroll bar	7	24	10	2	examine	information search
close the window	7	30	4	2	view	knowledge management
click on the MyWebCT hyperlink	7	55	10	2	navigation	data collection

vertical scroll down with the mouse scroll button	7	58	22	2	examine	information search
vertical scroll down with scroll bar	8	3	12	2	examine	information search
vertical scroll up with scroll bar	8	12	0	2	examine	information search
click on the information search course hyperlink	8	19	18	2	navigation	data collection
click on the automatically fill in form on the Google tool bar	8	28	21	2	focus	knowledge form
click on the information search course hyperlink	8	44	16	2	navigation	data collection
click on the grade results hyperlink	8	48	5	2	navigation	data collection
alert window (This field is only available for students)	8	48	18	2	result of action	result of action
click on the ok button	8	49	16	2	result of action	result of action
click on the study material content hyperlink	8	54	22	2	navigation	data collection
vertical scroll down with the mouse scroll button	8	57	21	2	examine	information search
vertical scroll up with the mouse scroll button	9	7	0	2	examine	information search
click on the MyWebCT hyperlink	9	9	4	2	navigation	data collection
vertical scroll down with scroll bar	9	11	19	2	examine	information search
vertical scroll up with scroll bar	9	12	22	2	examine	information search
vertical scroll down with scroll bar	9	17	9	2	examine	information search
vertical scroll up with scroll bar	9	20	4	2	examine	information search
close the window	9	24	12	2	view	knowledge management
click on the information search course instructions hyperlink	9	41	15	2	navigation	data collection
vertical scroll down with the mouse scroll button	9	47	22	2	examine	information search
vertical scroll up with the mouse scroll button	9	48	16	2	examine	information search
finish to paint the information search course instructions	9	49	17	2	highlight	knowledge form
starts to paint the information search course instructions	9	55	8	2	highlight	knowledge form
click on the right mouse button and the context menu appears	10	2	23	2	focus	knowledge form
click on the print option on the context menu	10	4	12	2	result of action	result of action
click on the print button	10	25	19	2	result of action	result of action
navigation back	11	17	19	3	history	data collection
navigation back	11	22	18	3	history	data collection
navigation back	11	27	19	3	history	data collection
navigation back	11	32	18	3	history	data collection
navigation back	11	39	0	3	history	data collection
click on the calendar hyperlink	11	54	7	3	navigation	data collection
navigation back	12	26	17	4	history	data collection
click on the discussion forum hyperlink	12	30	3	4	navigation	data collection
click on the topic all hyperlink	12	36	4	4	navigation	data collection
click on the sorting dropdown menu	12	56	4	4	extra information	information search

close the sorting dropdown menu	12	58	13	4	extra information	information search
click on the topic dropdown menu	13	18	11	4	extra information	information search
click on the compose discussion message hyperlink	13	18	11	4	pop up	knowledge management
click on the topic dropdown menu	13	23	10	4	extra information	information search
click on the subject text box	13	24	18	4	focus	knowledge form
written subject	13	27	7	4	process	knowledge build
press on the backspace key on the keyboard	13	28	12	4	process	knowledge build
written subject	13	36	19	4	process	knowledge build
click on the message text area	13	38	9	4	focus	knowledge form
written message	13	42	12	4	process	knowledge build
press on the backspace key on the keyboard	13	42	13	4	process	knowledge build
written message	13	55	15	4	process	knowledge build
press on the backspace key on the keyboard	13	55	16	4	process	knowledge build
written message	13	58	18	4	process	knowledge build
click on the post button	14	10	12	4	result of action	result of action
click on the information search course hyperlink	14	41	20	5	navigation	data collection
navigation back	14	48	0	5	history	data collection
click on the homepage hyperlink	14	54	18	5	navigation	data collection
click on the information search course hyperlink	15	2	19	5	navigation	data collection
click on the study material content hyperlink	15	7	14	5	navigation	data collection
vertical scroll down with the mouse scroll button	15	10	23	5	examine	information search
vertical scroll up with the mouse scroll button	15	17	13	5	examine	information search
click on the introduction hyperlink	15	21	17	5	navigation	data collection
vertical scroll down with the mouse scroll button	15	28	0	5	examine	information search
vertical scroll down with the mouse scroll button	15	34	19	5	examine	information search
vertical scroll up with the mouse scroll button	15	35	11	5	examine	information search
navigation back	15	39	13	5	history	data collection
navigation back	15	40	21	5	history	data collection
navigation back	15	45	23	5	history	data collection
navigation back	15	50	22	5	history	data collection
click on the tutors contact information hyperlink	15	54	19	5	navigation	data collection
vertical scroll down with the mouse scroll button	15	55	24	5	examine	information search
vertical scroll up with the mouse scroll button	15	59	23	5	examine	information search
vertical scroll down with the mouse scroll button	16	1	23	5	examine	information search
vertical scroll down with the mouse scroll button	16	5	8	5	examine	information search
Paints the e-mail address	16	10	6	5	highlight	knowledge form

press on the ctrl-c keys on the keyboard	16	10	7	5	process	knowledge build
click on the right mouse button and the context menu appears	16	12	0	5	focus	knowledge form
click on the copy option on the context menu	16	12	19	5	process	knowledge build
click on the e-mail hyperlink	16	15	24	5	navigation	data collection
click on the compose mail message hyperlink	16	24	18	5	pop up	knowledge management
click on the send to text box	16	28	0	5	focus	knowledge form
click on the right mouse button and the context menu appears	16	28	3	5	focus	knowledge form
click on the paste option on the context menu	16	28	18	5	process	knowledge build
click on the subject text box	16	30	19	5	focus	knowledge form
written subject	16	37	10	5	process	knowledge build
click on the message text area	16	37	14	5	focus	knowledge form
written message	16	48	18	5	process	knowledge build
press on the backspace key on the keyboard	16	48	20	5	process	knowledge build
written message	16	50	12	5	process	knowledge build
click on the send button	16	52	5	5	result of action	result of action
alert window message (the following names were not found in the class)	16	55	2	5	result of action	result of action
click on the ok button	17	3	2	5	result of action	result of action
starts to move the window (south-east)	17	13	8	5	view	knowledge management
finish to move the window (south-east)	17	14	15	5	view	knowledge management
starts to move the window (north-west)	17	14	30	5	view	knowledge management
finish to move the window (north-west)	17	17	22	5	view	knowledge management
click on the send to text box	17	19	8	5	focus	knowledge form
written send to	17	27	5	5	process	knowledge build
alert window message (the following names were not found in the class)	17	28	20	5	result of action	result of action
click on the send button	17	28	20	5	result of action	result of action
click on the ok button	17	30	13	5	result of action	result of action
click on the send to text box	17	32	13	5	focus	knowledge form
Paints the e-mail address	17	33	6	5	highlight	knowledge form
press on the delete key on the keyboard	17	34	18	5	process	knowledge build
starts to move the window (south-east)	17	47	13	5	view	knowledge management
finish to move the window (south-east)	17	48	11	5	view	knowledge management
starts to move the window (west)	17	48	11	5	view	knowledge management
finish to move the window (west)	17	49	11	5	view	knowledge management
navigation back	17	51	19	5	history	data collection

click on the mail message task bar	18	5	16	5	view	knowledge management
click on the browse button	18	13	8	5	pop up	knowledge management
vertical scroll down with scroll bar	18	19	10	5	examine	information search
vertical scroll up with scroll bar	18	20	10	5	examine	information search
vertical scroll down with scroll bar	18	22	1	5	examine	information search
vertical scroll up with scroll bar	18	22	17	5	examine	information search
click on the tutor list box	18	28	7	5	selection	knowledge building
click on the done button	18	32	4	5	result of action	result of action
click on the send button	18	37	6	5	result of action	result of action
click on the homepage hyperlink	18	49	0	6	navigation	data collection
click on the homepage hyperlink	19	2	7	6	navigation	data collection
click on the homepage hyperlink	19	6	22	6	navigation	data collection
close the window	19	16	24	6	view	knowledge management

Appendix 4

APPENDIX 4. User 4's categories of the model of learnability.

Concepts (concrete)	minutes	seconds	tenth	Assignments	Conceptual categories	Sub-categories
click on the log on hyperlink	0	2	3	1	solution	result of action
written user name	0	14	22	1	process	knowledge build
click on the password text box	0	16	18	1	focus	knowledge form
written password	0	23	1	1	process	knowledge build
click on the ok button	0	24	12	1	solution	result of action
click on the information search course hyperlink	1	23	21	1	navigation	data collection
click on the print hyperlink	1	37	4	2	solution	result of action
navigation back	1	45	5	2	history	data collection
click on the WebCT instructions hyperlink	1	58	21	2	pop up	knowledge management
close the window	2	22	7	2	view	knowledge management
click on the WebCT instructions hyperlink	2	44	6	2	pop up	knowledge management
close the window	3	1	6	2	view	knowledge management
click on the print hyperlink	3	13	22	2	solution	result of action
click on the information search course instructions check box	3	36	10	2	selection	knowledge build
click on the compile button	3	40	21	2	process	knowledge build
click on the information search course instructions hyperlink	3	48	19	2	navigation	data collection
click on the print button	4	8	0	2	solution	result of action
vertical scroll down with scroll bar	4	20	2	3	examine	information search
click on the calendar hyperlink	5	6	11	3	navigation	data collection
vertical scroll down with scroll bar	5	18	7	3	examine	information search
vertical scroll down with scroll bar	5	23	15	3	examine	information search
click on the discussion forum hyperlink	5	32	7	4	navigation	data collection
click on the topic all hyperlink	5	53	18	4	navigation	data collection
maximize the window	6	5	13	4	view	knowledge management
click on the select topics dropdown menu	6	40	20	4	extra information	information search
close the select topics dropdown menu	6	47	1	4	extra information	information search
close the window	7	18	10	4	view	knowledge management
click on the return to discussion hyperlink	7	21	21	4	navigation	data collection
click on the topic all hyperlink	7	41	19	4	navigation	data collection
click on the news report travelling guide subject hyperlink	7	49	3	4	navigation	data collection
close the window	8	0	2	4	view	knowledge management
click on the return to discussion hyperlink	8	4	2	4	navigation	data collection

click on the topic all hyperlink	8	10	5	4	navigation	data collection
click on the report layout instructions subject hyperlink	8	34	6	4	pop up	knowledge management
click on the reply hyperlink	8	46	16	4	navigation	data collection
close the window	8	53	12	4	view	knowledge management
click on the testing subject hyperlink	9	21	10	4	navigation	data collection
close the window	9	36	16	4	view	knowledge management
click on the update listing hyperlink	10	12	2	4	navigation	data collection
click on the compose discussion message hyperlink	10	28	9	4	pop up	knowledge management
click on the subject text box	10	32	21	4	focus	knowledge form
press on the backspace key on the keyboard	10	36	22	4	process	knowledge build
written subject	10	36	22	4	process	knowledge build
written subject	10	48	3	4	process	knowledge build
click on the message text area	10	51	1	4	focus	knowledge form
press on the backspace key on the keyboard	10	52	5	4	process	knowledge build
written message	10	52	5	4	process	knowledge build
press on the backspace key on the keyboard	10	55	6	4	process	knowledge build
written message	10	55	6	4	process	knowledge build
written message	11	6	21	4	process	knowledge build
click on the post button	11	17	21	4	solution	result of action
click on the e-mail hyperlink	11	35	14	5	navigation	data collection
click on the compose mail message hyperlink	11	49	19	5	pop up	knowledge management
click on the send to text box	11	56	21	5	focus	knowledge form
written send to	12	12	0	5	process	knowledge build
press on the backspace key on the keyboard	12	15	21	5	process	knowledge build
close the window	12	33	4	5	view	knowledge management
click on the information search course instructions hyperlink	14	5	4	5	navigation	data collection
click on the stop icon on the standard buttons	14	42	19	5	solution	result of action
click on the homepage hyperlink	14	46	15	5	navigation	data collection
click on the tutors contact information hyperlink	14	53	15	5	navigation	data collection
click on the e-mail hyperlink	15	2	20	5	navigation	data collection
click on the compose mail message hyperlink	15	12	2	5	pop up	knowledge management
click on the send to text box	15	20	10	5	focus	knowledge form
written send to	15	31	2	5	process	knowledge build
click on the subject text box	15	33	3	5	focus	knowledge form
written subject	15	35	6	5	process	knowledge build
press on the backspace key on the keyboard	15	35	7	5	process	knowledge build

written subject	15	41	24	5	process	knowledge build
click on the message text area	15	42	18	5	focus	knowledge form
written message	15	53	80	5	process	knowledge build
press on the backspace key on the keyboard	15	53	81	5	process	knowledge build
written message	15	57	16	5	process	knowledge build
press on the backspace key on the keyboard	15	57	17	5	process	knowledge build
written message	16	1	6	5	process	knowledge build
click on the send button	16	4	20	5	solution	result of action
alert window message (the following names were not found in the class)	16	6	7	5	error	result of action
click on the ok button	16	10	23	5	solution	result of action
click on the send button	16	45	7	5	solution	result of action
alert window message (the following names were not found in the class)	16	52	12	5	error	result of action
click on the ok button	16	55	14	5	solution	result of action
click on the browse button	17	55	20	5	pop up	knowledge management
vertical scroll down with scroll bar	18	2	19	5	examine	information search
click on the tutor list box	18	22	19	5	selection	knowledge build
click on the done button	18	27	2	5	solution	result of action
click on the send button	18	30	6	5	solution	result of action
close the window	19	22	17	6	view	knowledge management
close the window	19	24	22	6	view	knowledge management

Appendix 5

APPENDIX 5. User 5's categories of the model of learnability.

Concepts (concrete)	minutes	seconds	tenth	Assignments	Conceptual categories	Sub-categories
click on the log on hyperlink	0	6	19	1	solution	result of action
written user name	0	20	21	1	process	knowledge build
click on the password text box	0	21	12	1	focus	knowledge form
written password	0	26	11	1	process	knowledge build
click on the ok button	0	28	5	1	solution	result of action
system error (the page cannot be displayed)	0	29	13	1	error	result of action
navigation back	0	33	2	1	history	data collection
click on the log on hyperlink	0	39	5	1	solution	result of action
click on the information search course hyperlink	1	11	7	1	navigation	data collection
click on the information search course hyperlink	1	25	10	2	navigation	data collection
click on the study material content hyperlink	1	34	1	2	navigation	data collection
vertical scroll down with the mouse scroll button	1	39	18	2	examine	information search
vertical scroll up with the mouse scroll button	1	41	7	2	examine	information search
click on the information search course instructions hyperlink	1	49	10	2	navigation	data collection
vertical scroll down with the mouse scroll button	1	55	20	2	examine	information search
vertical scroll up with the mouse scroll button	1	55	30	2	examine	information search
vertical scroll down with the mouse scroll button	1	59	2	2	examine	information search
vertical scroll up with the mouse scroll button	2	7	10	2	examine	information search
vertical scroll down with the mouse scroll button	2	8	18	2	examine	information search
vertical scroll up with the mouse scroll button	2	10	3	2	examine	information search
click on the menu bar file option	2	29	4	2	extra information	information search
click on the menu bar print option	2	35	5	2	solution	result of action
click on the print button	2	45	12	2	solution	result of action
click on the homepage hyperlink	2	57	14	3	navigation	data collection
click on the calendar hyperlink	3	0	20	3	navigation	data collection
vertical scroll down with the mouse scroll button	3	12	11	3	examine	information search
vertical scroll up with the mouse scroll button	3	12	12	3	examine	information search
click on the discussion forum hyperlink	3	30	11	4	navigation	data collection
click on the topic all hyperlink	3	33	19	4	navigation	data collection
click on the news report travelling guide check box	3	43	23	4	selection	knowledge build
click on the news report travelling guide subject hyperlink	3	45	1	4	navigation	data collection
close the window	3	52	4	4	view	knowledge management

click on the discussion forum hyperlink	4	7	1	4	navigation	data collection
click on the topic all hyperlink	4	20	0	4	navigation	data collection
click on the sorting dropdown menu	4	32	12	4	extra information	information search
close the sorting dropdown menu	4	33	23	4	extra information	information search
horizontal scroll right with the scroll bar	4	35	12	4	examine	information search
horizontal scroll left with the scroll bar	4	36	12	4	examine	information search
navigation back	4	44	24	4	history	data collection
click on the discussion forum hyperlink	4	52	20	4	navigation	data collection
click on the topic all hyperlink	5	8	3	4	navigation	data collection
click on the select topics dropdown menu	5	12	4	4	extra information	information search
close the select topics dropdown menu	5	14	6	4	extra information	information search
click on the news report travelling guide subject hyperlink	5	19	3	4	navigation	data collection
click on the reply hyperlink	5	23	1	4	navigation	data collection
click on the message text area	5	26	8	4	focus	knowledge form
close the window	5	33	17	4	view	knowledge management
click on the unread hyperlink	5	52	8	4	navigation	data collection
click on the show all hyperlink	6	1	13	4	navigation	data collection
click on the re: testing file transfer subject hyperlink	6	10	19	4	navigation	data collection
close the window	6	20	2	4	view	knowledge management
click on the compose discussion message hyperlink	6	26	9	4	pop up	knowledge management
click on the message text area	6	30	9	4	focus	knowledge form
written message	6	37	21	4	process	knowledge build
press on the backspace key on the keyboard	6	37	22	4	process	knowledge build
written message	6	43	14	4	process	knowledge build
alert window message (please enter a subject)	6	47	24	4	error	result of action
click on the post button	6	47	24	4	solution	result of action
click on the ok button	6	49	21	4	solution	result of action
click on the subject text box	6	51	5	5	focus	knowledge form
written subject	6	55	10	5	process	knowledge build
click on the post button	6	57	9	5	solution	result of action
click on the e-mail hyperlink	7	18	11	5	navigation	data collection
click on the compose mail message hyperlink	7	25	16	5	pop up	knowledge management
close the window	7	33	20	5	view	knowledge management
click on the search mail hyperlink	7	45	6	5	navigation	data collection
click on the mail message to teacher subject hyperlink	7	55	10	5	pop up	knowledge management
close the window	7	59	20	5	view	knowledge management

click on the e-mail hyperlink	8	8	0	5	navigation	data collection
click on the e-mail hyperlink	8	9	1	5	navigation	data collection
click on the homepage hyperlink	8	15	15	5	navigation	data collection
click on the tutors hyperlink	8	22	13	5	navigation	data collection
vertical scroll down with the mouse scroll button	8	23	21	5	examine	information search
vertical scroll up with the mouse scroll button	8	26	10	5	examine	information search
click on the compose message task bar	8	31	19	5	view	knowledge management
click on the send to text box	8	34	5	5	focus	knowledge form
press on the backspace key on the keyboard	8	45	5	5	process	knowledge build
written send to	8	45	16	5	process	knowledge build
written send to	8	50	19	5	process	knowledge build
click on the subject text box	8	53	3	5	focus	knowledge form
written subject	8	57	8	5	process	knowledge build
click on the message text area	8	58	15	5	focus	knowledge form
written message	9	8	21	5	process	knowledge build
click on the send button	9	14	14	5	solution	result of action
alert window message (the following names were not found in the class)	9	14	15	6	error	result of action
click on the ok button	9	17	21	6	solution	result of action
click on the send to text box	9	22	9	6	focus	knowledge form
written send to	9	23	3	6	process	knowledge build
click on the send button	9	24	12	6	solution	result of action
alert window message (the following names were not found in the class)	9	26	2	6	error	result of action
click on the ok button	9	29	0	6	solution	result of action
starts to move the window (east)	9	32	14	6	view	knowledge management
finish to move the window (east)	9	33	14	6	view	knowledge management
click on the send to text box	9	38	4	6	focus	knowledge form
press on the backspace key on the keyboard	9	44	10	6	process	knowledge build
written send to	9	55	2	6	process	knowledge build
click on the send button	9	56	17	6	solution	result of action
click on the send button	10	2	23	6	solution	result of action
starts to move the window (south-west)	10	34	6	6	view	knowledge management
click on the browse button	10	48	18	6	pop up	knowledge management
click on the tutor list box	10	55	18	6	selection	knowledge build
click on the done button	11	0	19	6	solution	result of action

click on the send to text box	11	8	11	6	focus	knowledge form
press on the backspace key on the keyboard	11	9	20	6	process	knowledge build
written send to	11	13	15	6	process	knowledge build
click on the send button	11	17	9	6	solution	result of action
close the window	11	21	9	6	view	knowledge management
click on the tutors task bar	11	23	1	6	view	knowledge management
click on the tutors task bar	11	24	18	6	view	knowledge management
vertical scroll down with the mouse scroll button	11	26	0	6	examine	information search
vertical scroll up with the mouse scroll button	11	28	22	6	examine	information search
click on the homepage hyperlink	11	33	21	6	navigation	data collection
click on the MyWebCT hyperlink	12	9	16	6	navigation	data collection
click on the sitemap hyperlink	12	12	15	6	navigation	data collection
click on the help hyperlink	12	14	8	6	pop up	knowledge management
vertical scroll down with the mouse scroll button	12	19	6	6	examine	information search
vertical scroll up with the mouse scroll button	12	22	15	6	examine	information search
close the window	12	24	0	6	view	knowledge management
vertical scroll down with the mouse scroll button	12	26	1	6	examine	information search
vertical scroll up with the mouse scroll button	12	31	30	6	examine	information search
vertical scroll down with scroll bar	12	41	11	6	examine	information search
vertical scroll up with scroll bar	12	42	20	6	examine	information search
close the window	12	47	9	6	view	knowledge management

Appendix 6

APPENDIX 6. User 6's categories of the model of learnability.

Concepts (concrete)	minutes	seconds	tenth	Assignments	Conceptual categories	Sub-categories
click on the log on hyperlink	0	2	21	1	solution	result of action
written user name	0	17	1	1	process	knowledge build
click on the password text box	0	17	2	1	focus	knowledge form
written password	0	22	14	1	process	knowledge build
click on the ok button	0	22	23	1	solution	result of action
click on the information search course hyperlink	1	10	9	1	navigation	data collection
click on the print hyperlink	1	25	4	2	solution	result of action
vertical scroll down with the mouse scroll button	1	42	17	2	examine	information search
vertical scroll up with the mouse scroll button	1	48	6	2	examine	information search
click on the information search course instructions check box	1	59	20	2	selection	knowledge build
vertical scroll down with the mouse scroll button	2	15	7	2	examine	information search
vertical scroll up with the mouse scroll button	2	17	4	2	examine	information search
vertical scroll down with the mouse scroll button	2	26	20	2	examine	information search
vertical scroll up with the mouse scroll button	2	38	10	2	examine	information search
click on the information search course instructions hyperlink	2	47	13	2	navigation	data collection
maximize the window	2	56	0	2	view	knowledge management
vertical scroll down with the mouse scroll button	3	2	5	2	examine	information search
vertical scroll up with the mouse scroll button	3	3	3	2	examine	information search
vertical scroll down with the mouse scroll button	3	13	4	2	examine	information search
vertical scroll up with the mouse scroll button	3	24	1	2	examine	information search
vertical scroll down with the mouse scroll button	3	26	12	2	examine	information search
vertical scroll up with the mouse scroll button	3	35	3	2	examine	information search
click on the print icon on the standard buttons	3	46	10	2	solution	result of action
click on the calendar hyperlink	5	15	4	3	navigation	data collection
vertical scroll down with the mouse scroll button	5	19	4	3	examine	information search
vertical scroll up with the mouse scroll button	5	21	24	3	examine	information search
vertical scroll down with the mouse scroll button	5	38	16	4	examine	information search
vertical scroll up with the mouse scroll button	5	43	19	4	examine	information search
vertical scroll down with the mouse scroll button	5	46	7	4	examine	information search
click on the discussion forum hyperlink	5	53	10	4	navigation	data collection
click on the topic all hyperlink	6	8	21	4	navigation	data collection
click on the select topics dropdown menu	7	0	0	4	extra information	information search

close the select topics dropdown menu	7	5	1	4	extra information	information search
click on the sorting dropdown menu	7	24	0	4	extra information	information search
close the sorting dropdown menu	7	27	21	4	extra information	information search
click on the return to discussion hyperlink	8	29	17	4	navigation	data collection
click on the topic all hyperlink	8	35	24	4	navigation	data collection
click on the show all hyperlink	8	42	21	4	navigation	data collection
click on the mark all as read hyperlink	9	37	21	4	navigation	data collection
click on the compose discussion message hyperlink	9	49	23	4	pop up	knowledge management
maximize the window	9	54	1	4	view	knowledge management
click on the subject text box	9	58	4	4	focus	knowledge form
written subject	10	10	4	4	process	knowledge build
click on the message text area	10	10	19	4	focus	knowledge form
written message	10	24	0	4	process	knowledge build
press on the backspace key on the keyboard	10	24	1	4	process	knowledge build
written message	10	29	8	4	process	knowledge build
click on the post button	11	0	17	4	solution	result of action
click on the e-mail hyperlink	11	21	18	5	navigation	data collection
click on the calendar hyperlink	12	11	4	5	navigation	data collection
click on the net etiquette hyperlink	12	14	13	5	navigation	data collection
error message (The requested URL was not found on the server)	12	15	5	5	error	result of action
click on the e-mail hyperlink	12	16	10	5	navigation	data collection
click on the e-mail hyperlink	12	28	7	5	navigation	data collection
click on the information search course hyperlink	13	0	15	5	navigation	data collection
click on the homepage hyperlink	13	9	2	5	navigation	data collection
click on the tutors contact information hyperlink	13	27	5	5	navigation	data collection
vertical scroll down with the mouse scroll button	13	30	18	5	examine	information search
vertical scroll up with the mouse scroll button	13	44	5	5	examine	information search
vertical scroll up with the mouse scroll button	13	53	13	5	examine	information search
vertical scroll up with the mouse scroll button	14	8	1	5	examine	information search
vertical scroll up with the mouse scroll button	14	13	15	5	examine	information search
click on the Maija Koponen hyperlink	14	17	3	5	navigation	data collection
vertical scroll down with the mouse scroll button	14	18	22	5	examine	information search
vertical scroll up with the mouse scroll button	14	19	9	5	examine	information search
vertical scroll down with the mouse scroll button	14	40	10	5	examine	information search
vertical scroll up with the mouse scroll button	14	41	0	5	examine	information search
vertical scroll down with the mouse scroll button	14	43	13	5	examine	information search

vertical scroll up with the mouse scroll button	14	46	19	5	examine	information search
click on the e-mail hyperlink	14	59	14	5	navigation	data collection
click on the e-mail hyperlink	15	7	20	5	navigation	data collection
click on the compose mail message hyperlink	15	14	6	5	pop up	knowledge management
click on the browse button	15	21	10	5	pop up	knowledge management
vertical scroll down with scroll bar	15	26	13	5	examine	information search
click on the tutor list box	15	31	15	5	selection	knowledge build
click on the done button	15	33	10	5	solution	result of action
click on the subject text box	15	37	2	5	focus	knowledge form
written subject	15	43	6	5	process	knowledge build
click on the message text area	15	45	8	5	focus	knowledge form
written message	15	58	0	5	process	knowledge build
press on the backspace key on the keyboard	15	58	1	5	process	knowledge build
written message	16	10	11	5	process	knowledge build
click on the send button	16	11	18	5	solution	result of action
close the window	16	32	24	6	view	knowledge management
click on the information search course instructions check box	16	35	21	6	selection	knowledge build
close the window	16	49	5	6	view	knowledge management

Appendix 7

APPENDIX 7. User 7's categories of the model of learnability.

Concepts (concrete)	minutes	seconds	tenth	Assignments	Conceptual categories	Sub-categories
click on the log on hyperlink	0	4	18	1	solution	result of action
written user name	0	11	14	1	process	knowledge build
press on the backspace key on the keyboard	0	11	15	1	process	knowledge build
written user name	0	14	2	1	process	knowledge build
press on the tab key on the keyboard	0	17	13	1	process	knowledge build
written password	0	21	6	1	process	knowledge build
press on the enter key on the keyboard	0	22	0	1	solution	result of action
vertical scroll down with the mouse scroll button	0	49	7	1	examine	information search
click on the information search course hyperlink	0	59	11	1	navigation	data collection
click on the WebCT instructions hyperlink	1	31	21	2	pop up	knowledge management
maximize window (click on title bar)	1	37	9	2	view	knowledge management
vertical scroll down with scroll bar	1	39	17	2	examine	information search
vertical scroll up with scroll bar	1	51	0	2	examine	information search
vertical scroll down with scroll bar	1	54	13	2	examine	information search
close the window	1	58	24	2	view	knowledge management
click on the information search course hyperlink	2	5	9	2	navigation	data collection
click on the study material content hyperlink	2	13	22	2	navigation	data collection
vertical scroll down with the mouse scroll button	2	19	4	2	examine	information search
vertical scroll up with the mouse scroll button	2	19	17	2	examine	information search
click on the introduction hyperlink	2	23	0	2	navigation	data collection
vertical scroll down with the mouse scroll button	2	28	0	2	examine	information search
vertical scroll up with the mouse scroll button	2	30	6	2	examine	information search
navigation back	2	32	9	2	history	data collection
click on the information search course instructions hyperlink	2	34	21	2	navigation	data collection
vertical scroll down with the mouse scroll button	2	46	3	2	examine	information search
vertical scroll down with scroll bar	2	49	13	2	examine	information search
vertical scroll up with scroll bar	2	50	20	2	examine	information search
vertical scroll down with the mouse scroll button	2	59	13	2	examine	information search
vertical scroll up with the mouse scroll button	3	0	7	2	examine	information search
starts to paint the information search course instructions	3	2	21	2	highlight	knowledge form
finish to paint the information search course instructions	3	11	8	2	highlight	knowledge form
press on the ctrl-c keys on the keyboard	3	11	10	2	process	knowledge build

click on the start menu	3	14	12	2	extra information	information search
click on the Microsoft Word application shortcut icon	3	18	11	2	solution	result of action
press on the ctrl-c keys on the keyboard	3	23	0	2	process	knowledge build
vertical scroll up with scroll bar	3	29	6	2	examine	information search
close the Microsoft Word side menu	3	34	19	2	view	knowledge management
click on the menu bar file option	3	37	18	2	extra information	information search
click on the menu bar print option	3	38	17	2	solution	result of action
click on the ok button	3	49	4	2	solution	result of action
minimize the window	4	6	24	3	view	knowledge management
navigation back	4	9	4	3	history	data collection
navigation back	4	14	13	3	history	data collection
navigation back	4	16	12	3	history	data collection
navigation back	4	21	14	3	history	data collection
click on the calendar hyperlink	4	26	4	3	navigation	data collection
click on the month dropdown menu	4	40	13	3	extra information	information search
click on the September option on the dropdown menu	4	43	1	3	extra information	information search
click on the go button	4	45	2	3	solution	result of action
navigation back	5	3	2	4	history	data collection
navigation back	5	4	19	4	history	data collection
click on the discussion forum hyperlink	5	7	4	4	navigation	data collection
click on the compose discussion message hyperlink	5	19	7	4	pop up	knowledge management
click on the topic dropdown menu	5	25	23	4	extra information	information search
close the topic dropdown menu	5	28	4	4	extra information	information search
click on the subject text box	5	29	0	4	focus	knowledge form
written subject	5	33	1	4	process	knowledge build
click on the message text area	5	36	22	4	focus	knowledge form
written message	5	53	16	4	process	knowledge build
click on the attach file button	5	59	5	4	pop up	knowledge management
alert window (Please, browse to find the file to attach)	6	1	0	4	error	result of action
click on the ok button	6	4	18	4	solution	result of action
click on the post button	6	8	3	4	solution	result of action
navigation back	6	17	24	5	history	data collection
click on the tutors contact information hyperlink	6	28	5	5	navigation	data collection
vertical scroll down with the mouse scroll button	6	31	1	5	examine	information search
vertical scroll up with the mouse scroll button	6	31	14	5	examine	information search
vertical scroll down with the mouse scroll button	6	34	20	5	examine	information search

vertical scroll up with the mouse scroll button	6	34	33	5	examine	information search
Paints the e-mail address	6	48	17	5	highlight	knowledge form
press on the ctrl-c keys on the keyboard	6	48	18	5	process	knowledge build
click on the e-mail hyperlink	6	53	14	5	navigation	data collection
minimize the window	7	14	4	5	view	knowledge management
click on the explorer shortcut icon	7	15	19	5	solution	result of action
click on the URL dropdown menu	7	20	10	5	extra information	information search
close the URL dropdown menu	7	24	8	5	extra information	information search
click on the URL text box	7	24	15	5	focus	knowledge form
press on the backspace key on the keyboard	7	26	8	5	process	knowledge build
written the URL (tlmail.ramk.fi)	7	32	22	5	process	knowledge build
click on the web mail hyperlink	7	34	8	5	pop up	knowledge management
alert window (Security alert)	7	34	24	5	error	result of action
click on the ok button	7	35	0	5	solution	result of action
click on the web mail hyperlink	7	37	5	5	pop up	knowledge management
alert window (Security alert)	7	37	6	5	error	result of action
click on the ok button	7	38	6	5	solution	result of action
written user name	7	42	1	5	process	knowledge build
press on the tab key on the keyboard	7	42	20	5	process	knowledge build
written password	7	45	5	5	process	knowledge build
press on the enter key on the keyboard	7	45	6	5	solution	result of action
alert window (Auto complete)	7	45	17	5	error	result of action
click on the yes button	7	46	14	5	solution	result of action
click on the inbox hyperlink	7	48	20	5	navigation	data collection
click on the send icon	7	52	0	5	solution	result of action
press on the ctrl-v keys on the keyboard	7	55	11	5	process	knowledge build
paste the send to text box	7	55	12	5	process	knowledge build
click on the subject text box	7	57	19	5	focus	knowledge form
written subject	8	11	20	5	process	knowledge build
click on the message text area	8	14	21	5	focus	knowledge form
written message	8	31	1	5	process	knowledge build
Paints the signature	8	31	18	5	highlight	knowledge form
press on the delete key on the keyboard	8	32	10	5	process	knowledge build
click on the send button	8	33	23	5	solution	result of action
close the window	8	38	2	6	view	knowledge management
click on the e-mail task bar	8	40	19	6	view	knowledge management

close the window	8	59	8	6 view	knowledge management

Appendix 8

APPENDIX 8. User 8's categories of the model of learnability.

Concepts (concrete)	minutes	seconds	tenth	Assignments	Conceptual categories	Sub-categories
click on the log on hyperlink	0	4	17	1	solution	result of action
written user name	0	13	2	1	process	knowledge build
press on the tab key on the keyboard	0	16	0	1	process	knowledge build
written password	0	22	5	1	process	knowledge build
click on the ok button	0	23	23	1	solution	result of action
system error (the page cannot be displayed)	0	25	4	1	error	result of action
navigation back	0	31	7	1	history	data collection
click on the need help hyperlink	0	42	1	1	navigation	data collection
close the window	0	51	17	1	view	knowledge management
click on the create myWebCT hyperlink	0	53	22	1	navigation	data collection
click on the first name text box	0	58	18	1	focus	knowledge form
written name	1	2	24	1	process	knowledge build
click on the last name text box	1	8	3	1	focus	knowledge form
written last name	1	12	15	1	process	knowledge build
click on the e-mail address text box	1	14	7	1	focus	knowledge form
written e-mail address	1	26	11	1	process	knowledge build
vertical scroll down with the mouse scroll button	1	29	0	1	examine	information search
click on the WebCT ID text box	1	45	3	1	focus	knowledge form
vertical scroll down with the mouse scroll button	1	52	0	1	examine	information search
vertical scroll up with the mouse scroll button	2	9	10	1	examine	information search
vertical scroll down with the mouse scroll button	2	10	12	1	examine	information search
vertical scroll up with the mouse scroll button	2	11	14	1	examine	information search
navigation back	2	15	3	1	history	data collection
click on the log on hyperlink	2	18	6	1	solution	result of action
vertical scroll down with the mouse scroll button	2	47	15	1	examine	information search
vertical scroll up with the mouse scroll button	2	48	0	1	examine	information search
vertical scroll down with the mouse scroll button	2	51	10	1	examine	information search
vertical scroll up with the mouse scroll button	2	54	18	1	examine	information search
click on the information search course hyperlink	3	7	8	1	navigation	data collection
click on the print hyperlink	3	24	14	2	solution	result of action
vertical scroll down with the mouse scroll button	3	46	16	2	examine	information search
vertical scroll up with the mouse scroll button	3	47	2	2	examine	information search

click on the information search course instructions check box	3	51	4	2	selection	knowledge build
vertical scroll down with the mouse scroll button	3	52	10	2	examine	information search
vertical scroll up with the mouse scroll button	3	52	23	2	examine	information search
vertical scroll down with the mouse scroll button	3	56	17	2	examine	information search
vertical scroll down with the mouse scroll button	3	59	6	2	examine	information search
vertical scroll up with the mouse scroll button	4	2	0	2	examine	information search
click on the file dropdown menu	4	12	7	2	extra information	information search
click on the information search course instructions hyperlink	4	20	20	2	navigation	data collection
starts to move the window (south-east)	4	28	2	2	view	knowledge management
vertical scroll down with the mouse scroll button	4	30	13	2	examine	information search
vertical scroll down with the mouse scroll button	4	39	0	2	examine	information search
vertical scroll up with the mouse scroll button	4	40	0	2	examine	information search
vertical scroll down with the mouse scroll button	4	41	1	2	examine	information search
click on the file dropdown menu	4	44	13	2	extra information	information search
click on the print dropdown menu	4	50	1	2	extra information	information search
click on the print button	5	4	10	2	solution	result of action
close the window	5	22	20	3	view	knowledge management
click on the calendar hyperlink	5	27	10	3	navigation	data collection
vertical scroll down with the mouse scroll button	5	43	8	3	examine	information search
click on the number nine hyperlink	6	5	22	3	navigation	data collection
click on the previous day hyperlink	6	11	4	3	navigation	data collection
click on the previous day hyperlink	6	12	0	3	navigation	data collection
click on the previous day hyperlink	6	13	3	3	navigation	data collection
click on the previous day hyperlink	6	16	5	3	navigation	data collection
click on the next day hyperlink	6	18	22	3	navigation	data collection
click on the next day hyperlink	6	21	13	3	navigation	data collection
click on the next day hyperlink	6	22	10	3	navigation	data collection
click on the next day hyperlink	6	23	14	3	navigation	data collection
click on the next day hyperlink	6	25	20	3	navigation	data collection
click on the next day hyperlink	6	27	12	3	navigation	data collection
click on the calendar hyperlink	6	32	3	3	navigation	data collection
vertical scroll down with the mouse scroll button	6	34	22	3	examine	information search
click on the next month hyperlink	6	38	17	3	navigation	data collection
vertical scroll down with the mouse scroll button	6	41	18	3	examine	information search
vertical scroll up with the mouse scroll button	6	42	6	3	examine	information search
click on the next month hyperlink	6	44	15	3	navigation	data collection

vertical scroll down with the mouse scroll button	6	49	1	3	examine	information search
vertical scroll up with the mouse scroll button	6	51	20	3	examine	information search
vertical scroll down with the mouse scroll button	6	53	2	3	examine	information search
vertical scroll up with the mouse scroll button	6	53	19	3	examine	information search
vertical scroll down with the mouse scroll button	6	56	1	3	examine	information search
vertical scroll up with the mouse scroll button	6	57	2	3	examine	information search
vertical scroll down with the mouse scroll button	6	58	17	3	examine	information search
vertical scroll up with the mouse scroll button	6	59	20	3	examine	information search
click on the previous month hyperlink	7	1	22	3	navigation	data collection
click on the previous month hyperlink	7	5	23	3	navigation	data collection
click on the previous month hyperlink	7	9	3	3	navigation	data collection
click on the discussion forum hyperlink	7	23	12	4	navigation	data collection
click on the compose discussion message hyperlink	7	37	10	4	pop up	knowledge management
click on the subject text box	7	42	18	4	focus	knowledge form
written subject	7	46	24	4	process	knowledge build
click on the message text area	7	50	10	4	focus	knowledge form
written message	7	57	7	4	process	knowledge build
press on the backspace key on the keyboard	7	57	19	4	process	knowledge build
written message	7	59	19	4	process	knowledge build
press on the backspace key on the keyboard	8	0	14	4	process	knowledge build
written message	8	17	6	4	process	knowledge build
click on type dropdown menu	8	19	21	4	extra information	information search
close the type dropdown menu	8	21	13	4	extra information	information search
click on the post button	8	27	10	4	solution	result of action
click on the e-mail hyperlink	8	42	7	5	navigation	data collection
click on the compose mail message hyperlink	8	48	22	5	pop up	knowledge management
click on the browse button	8	53	10	5	pop up	knowledge management
vertical scroll down with the mouse scroll button	9	3	1	5	examine	information search
vertical scroll up with the mouse scroll button	9	3	12	5	examine	information search
vertical scroll down with the mouse scroll button	9	4	14	5	examine	information search
vertical scroll up with the mouse scroll button	9	4	18	5	examine	information search
click on the tutor list box	9	17	12	5	selection	knowledge build
click on the done button	9	25	8	5	solution	result of action
click on the message text area	9	29	12	6	focus	knowledge form
click on the subject text box	9	32	21	6	focus	knowledge form
written subject	9	36	14	6	process	knowledge build

click on the message text area	9	39	8	6	focus	knowledge form
written message	9	46	24	6	process	knowledge build
click on the send button	9	49	21	6	solution	result of action
click on the help hyperlink	10	29	1	6	pop up	knowledge management
vertical scroll down with the mouse scroll button	10	32	12	6	examine	information search
vertical scroll up with the mouse scroll button	10	33	5	6	examine	information search
vertical scroll down with the mouse scroll button	10	33	23	6	examine	information search
vertical scroll up with the mouse scroll button	10	34	19	6	examine	information search
vertical scroll down with the mouse scroll button	10	35	9	6	examine	information search
vertical scroll up with the mouse scroll button	10	37	3	6	examine	information search
vertical scroll down with the mouse scroll button	10	44	7	6	examine	information search
click on the help index hyperlink	10	46	14	6	navigation	data collection
vertical scroll down with the mouse scroll button	10	51	3	6	examine	information search
close the window	11	2	6	6	view	knowledge management
navigation back	11	19	18	6	history	data collection
navigation back	11	23	16	6	history	data collection
navigation back	11	25	16	6	history	data collection
navigation back	11	28	11	6	history	data collection
navigation back	11	32	11	6	history	data collection
click on the homepage on the standard buttons	11	39	19	6	solution	result of action

Appendix 9

APPENDIX 9. User 9's categories of the model of learnability.

Concepts (concrete)	minutes	seconds	tenth	Assignments	Conceptual categories	Sub-categories
click on the log on hyperlink	0	0	11	1	solution	result of action
written user name	0	16	13	1	process	knowledge build
click on the password text box	0	18	11	1	focus	knowledge form
written password	0	23	3	1	process	knowledge build
click on the ok button	0	24	0	1	solution	result of action
system error (the page cannot be displayed)	0	26	2	1	error	result of action
navigation back	0	28	15	1	history	data collection
click on the log on hyperlink	0	31	6	1	solution	result of action
click on the information search course hyperlink	1	1	0	1	navigation	data collection
click on the tutors contact information hyperlink	1	23	8	2	navigation	data collection
click on the WebCT instructions hyperlink	1	43	9	2	pop up	knowledge management
vertical scroll down with scroll bar	2	9	22	2	examine	information search
close the window	2	13	10	2	view	knowledge management
navigation back	2	19	4	2	history	data collection
click on the information search course hyperlink	2	24	14	2	navigation	data collection
click on the study material content hyperlink	2	33	0	2	navigation	data collection
click on the information search course instructions hyperlink	2	50	14	2	navigation	data collection
alert window (This field is only available for students)	3	6	6	2	error	result of action
click on the result of assignments hyperlink	3	6	6	2	navigation	data collection
click on the ok button	3	10	1	2	solution	result of action
click on the print hyperlink	3	19	18	2	solution	result of action
click on the information search course instructions check box	3	48	2	2	selection	knowledge build
click on the compile button	3	53	14	2	process	knowledge build
navigation back	4	0	5	3	history	data collection
click on the compile button	4	1	11	2	process	knowledge build
vertical scroll down with scroll bar	4	11	9	2	examine	information search
vertical scroll up with scroll bar	4	14	8	2	examine	information search
click on the print icon on the standard buttons	4	22	22	2	solution	result of action
close the window	4	44	24	3	view	knowledge management
navigation back	4	48	19	3	history	data collection
click on the calendar hyperlink	4	57	24	3	navigation	data collection
click on the previous month hyperlink	5	21	3	3	navigation	data collection

click on the previous month hyperlink	5	23	11	3	navigation	data collection
click on the compile hyperlink	5	29	17	3	process	knowledge build
navigation back	5	37	1	3	history	data collection
click on the discussion forum hyperlink	6	7	12	4	navigation	data collection
click on the topic all hyperlink	6	11	12	4	navigation	data collection
click on the select topics dropdown menu	6	34	12	4	extra information	information search
close the select topics dropdown menu	6	36	17	4	extra information	information search
click on the sorting dropdown menu	6	38	2	4	extra information	information search
close the sorting dropdown menu	6	40	1	4	extra information	information search
click on the discussion forum hyperlink	6	49	8	4	navigation	data collection
click on the compose discussion message hyperlink	6	56	7	4	pop up	knowledge management
click on the subject text box	7	0	22	4	focus	knowledge form
written subject	7	5	16	4	process	knowledge build
press on the backspace key on the keyboard	7	5	17	4	process	knowledge build
written subject	7	8	1	4	process	knowledge build
press on the backspace key on the keyboard	7	8	2	4	process	knowledge build
written subject	7	8	11	4	process	knowledge build
click on the message text area	7	11	16	4	focus	knowledge form
written message	7	32	3	4	process	knowledge build
click on the post button	7	35	11	4	solution	result of action
click on the e-mail hyperlink	7	48	4	5	navigation	data collection
click on the manage messenger hyperlink	8	12	3	5	navigation	data collection
navigation back	8	21	22	5	history	data collection
click on the homepage hyperlink	8	56	19	5	navigation	data collection
click on the information search course hyperlink	9	6	5	5	navigation	data collection
click on the information search course hyperlink	9	8	21	5	navigation	data collection
navigation back	9	14	13	5	history	data collection
click on the tutors contact information hyperlink	9	17	21	5	navigation	data collection
click on the Maija Koponen hyperlink	9	25	22	5	navigation	data collection
vertical scroll up with scroll bar	9	30	13	5	examine	information search
vertical scroll down with scroll bar	9	37	17	5	examine	information search
vertical scroll up with scroll bar	9	41	2	5	examine	information search
click on the e-mail hyperlink	10	7	24	5	navigation	data collection
click on the outbox hyperlink	10	15	14	5	navigation	data collection
navigation back	10	34	11	5	history	data collection
click on the inbox hyperlink	10	37	18	5	navigation	data collection

click on the subject message hyperlink	10	48	4	5	pop up	knowledge management
close the window	10	59	7	5	view	knowledge management
click on the e-mail hyperlink	11	4	7	5	navigation	data collection
click on the compose mail message hyperlink	11	7	20	5	pop up	knowledge management
click on the send to text box	11	11	15	5	focus	knowledge form
written message	11	27	20	5	process	knowledge build
click on the subject text box	11	30	21	5	focus	knowledge form
written subject	11	36	12	5	process	knowledge build
press on the backspace key on the keyboard	11	38	0	5	process	knowledge build
written subject	11	46	21	5	process	knowledge build
click on the message text area	11	48	4	5	focus	knowledge form
written message	11	53	21	5	process	knowledge build
click on the send button	11	57	12	5	solution	result of action
alert window message (the following names were not found in the class)	11	58	4	5	error	result of action
click on the ok button	12	3	20	5	solution	result of action
click on the browse button	12	20	9	5	pop up	knowledge management
click on the tutor list box	12	25	19	5	selection	knowledge build
click on the done button	12	29	0	5	solution	result of action
click on the send button	12	36	5	5	solution	result of action
click on the send button	12	38	23	5	solution	result of action
click on the send button	12	42	4	5	solution	result of action
click on the homepage hyperlink	13	5	11	6	navigation	data collection
close the window	13	34	0	6	view	knowledge management

Appendix 10

APPENDIX 10. User 10's categories of the model of learnability.

Concepts (concrete)	minutes	seconds	tenth	Assignments	Conceptual categories	Sub-categories
click on the log on hyperlink	0	1	1	1	solution	result of action
written user name	0	7	1	1	process	knowledge build
press on the enter key on the keyboard	0	7	18	1	solution	result of action
press on the enter key on the keyboard	0	8	12	1	solution	result of action
written user name	0	9	15	1	process	knowledge build
press on the tab key on the keyboard	0	10	4	1	process	knowledge build
press on the enter key on the keyboard	0	14	15	1	solution	result of action
written password	0	14	15	1	process	knowledge build
authentication window	0	14	24	1	error	result of action
click on the user name text box	0	18	14	1	focus	knowledge form
Paints the e-mail address	0	20	5	1	highlight	knowledge form
press on the backspace key on the keyboard	0	21	1	1	process	knowledge build
click on the password text box	0	22	11	1	focus	knowledge form
written password	0	26	2	1	process	knowledge build
press on the enter key on the keyboard	0	27	1	1	solution	result of action
vertical scroll down with the mouse scroll button	0	45	9	1	examine	information search
vertical scroll up with the mouse scroll button	0	48	24	1	examine	information search
click on the information search course hyperlink	0	50	0	1	navigation	data collection
click on the print hyperlink	1	1	14	2	solution	result of action
click on the select all button	1	22	1	2	selection	knowledge build
click on the compile button	1	24	3	2	process	knowledge build
click on the select all button	1	26	20	2	selection	knowledge build
vertical scroll down with the mouse scroll button	1	28	15	2	examine	information search
vertical scroll up with the mouse scroll button	1	30	0	2	examine	information search
vertical scroll up with the mouse scroll button	1	31	24	2	examine	information search
click on the information search course instructions check box	1	35	23	2	selection	knowledge build
vertical scroll up with the mouse scroll button	1	36	6	2	examine	information search
click on the compile button	1	38	10	2	process	knowledge build
vertical scroll down with the mouse scroll button	1	45	9	2	examine	information search
vertical scroll up with the mouse scroll button	1	48	20	2	examine	information search
click on the print icon on the standard buttons	1	53	1	2	solution	result of action
minimize the window	2	3	0	3	view	knowledge management

vertical scroll down with the mouse scroll button	2	4	1	3	examine	information search
vertical scroll up with the mouse scroll button	2	4	18	3	examine	information search
navigation back	2	9	6	3	history	data collection
click on the calendar hyperlink	2	13	9	3	navigation	data collection
vertical scroll down with the mouse scroll button	2	17	23	3	examine	information search
Paints the text	2	23	10	3	highlight	knowledge form
vertical scroll up with the mouse scroll button	2	26	24	3	examine	information search
vertical scroll down with the mouse scroll button	2	32	0	3	examine	information search
vertical scroll up with the mouse scroll button	2	33	5	3	examine	information search
vertical scroll down with the mouse scroll button	2	38	0	3	examine	information search
vertical scroll up with the mouse scroll button	2	39	0	3	examine	information search
click on the previous month hyperlink	2	40	12	3	navigation	data collection
Paints the text	2	44	12	3	highlight	knowledge form
click on the homepage hyperlink	2	51	0	3	navigation	data collection
click on the chat hyperlink	2	55	0	4	navigation	data collection
click on the topic all hyperlink	3	1	0	4	navigation	data collection
click on the compose discussion message hyperlink	3	22	6	4	pop up	knowledge management
starts to move the window (south-east)	3	24	19	4	view	knowledge management
finish to move the window (south-east)	3	25	12	4	view	knowledge management
click on the message text area	3	29	19	4	focus	knowledge form
click on the subject text box	3	30	22	4	focus	knowledge form
written subject	3	34	1	4	process	knowledge build
press on the tab key on the keyboard	3	34	21	4	process	knowledge build
written message	3	42	21	4	process	knowledge build
press on the backspace key on the keyboard	3	42	22	4	process	knowledge build
written message	3	43	8	4	process	knowledge build
click on the post button	3	47	19	4	solution	result of action
click on the MyWebCT hyperlink	3	57	14	5	navigation	data collection
click on the information search course hyperlink	4	2	0	5	navigation	data collection
click on the information search course hyperlink	4	4	21	5	navigation	data collection
click on the homepage hyperlink	4	11	10	5	navigation	data collection
vertical scroll down with the mouse scroll button	4	13	11	5	examine	information search
click on the information search course hyperlink	4	15	19	5	navigation	data collection
click on the tutors contact information hyperlink	4	33	8	5	navigation	data collection
vertical scroll down with the mouse scroll button	4	35	11	5	examine	information search
Paints the text	4	38	7	5	highlight	knowledge form

click on the text	4	38	22	5	focus	knowledge form
Paints the text	4	40	12	5	highlight	knowledge form
Paints the text	4	41	7	5	highlight	knowledge form
Paints the e-mail address	4	44	4	5	highlight	knowledge form
click on the right mouse button and the context menu appears	4	44	21	5	focus	knowledge form
click on the copy option on the context menu	4	46	11	5	process	knowledge build
navigation back	4	50	0	5	history	data collection
click on the e-mail hyperlink	4	51	19	5	pop up	knowledge management
click on the compose mail message hyperlink	4	54	22	5	pop up	knowledge management
click on the subject text box	4	57	23	5	focus	knowledge form
click on the send to text box	4	58	7	5	focus	knowledge form
click on the right mouse button and the context menu appears	4	58	16	5	focus	knowledge form
click on the paste option on the context menu	4	59	9	5	process	knowledge build
click on the subject text box	5	0	7	5	focus	knowledge form
written subject	5	2	22	5	process	knowledge build
press on the tab key on the keyboard	5	3	17	5	process	knowledge build
written message	5	14	13	5	process	knowledge build
click on the send button	5	16	17	5	solution	result of action
alert window message (the following names were not found in the class)	5	21	13	5	error	result of action
click on the ok button	5	21	24	5	solution	result of action
Paints the e-mail address	5	24	6	5	highlight	knowledge form
press on the delete key on the keyboard	5	24	17	5	process	knowledge build
click on the browse button	5	26	6	5	pop up	knowledge management
click on the send button	5	32	12	5	solution	result of action
click on the MyWebCT hyperlink	5	43	1	6	navigation	data collection
click on the homepage on the standard buttons	6	4	21	6	solution	result of action

Appendix 11

APPENDIX 11. User 11's categories of the model of learnability.

Concepts (concrete)	minutes	seconds	tenth	Assignments	Conceptual categories	Sub-categories
click on the log on hyperlink	0	0	17	1	solution	result of action
written user name	0	8	13	1	process	knowledge build
press on the tab key on the keyboard	0	9	8	1	process	knowledge build
written password	0	13	6	1	process	knowledge build
click on the ok button	0	14	1	1	solution	result of action
click on the information search course hyperlink	0	37	22	1	navigation	data collection
click on the print hyperlink	0	51	2	2	solution	result of action
navigation back	1	0	16	2	history	data collection
click on the print hyperlink	1	6	15	2	solution	result of action
click on the print hyperlink	1	10	15	2	solution	result of action
click on the information search course instructions hyperlink	1	33	13	2	navigation	data collection
vertical scroll down with the mouse scroll button	1	50	10	2	examine	information search
maximize the window	1	55	18	2	view	knowledge management
vertical scroll down with the mouse scroll button	1	58	8	2	examine	information search
vertical scroll down with the mouse scroll button	2	2	1	2	examine	information search
vertical scroll up with the mouse scroll button	2	12	24	2	examine	information search
click on the menu bar file option	2	15	21	2	extra information	information search
click on the menu bar print option	2	17	15	2	solution	result of action
click on the print button	2	32	15	2	solution	result of action
navigation back	2	45	22	2	history	data collection
click on the information search course hyperlink	2	52	0	2	navigation	data collection
click on the calendar hyperlink	2	56	3	2	navigation	data collection
vertical scroll down with the mouse scroll button	3	2	7	2	examine	information search
click on the information search course hyperlink	3	20	5	2	navigation	data collection
navigation back	3	25	3	2	history	data collection
click on the October 8th hyperlink	3	29	22	2	navigation	data collection
navigation back	3	33	15	2	history	data collection
click on the information search course hyperlink	3	53	6	3	navigation	data collection
click on the homepage hyperlink	4	1	23	3	navigation	data collection
click on the calendar hyperlink	4	8	21	3	navigation	data collection
vertical scroll down with the mouse scroll button	4	14	5	3	examine	information search

vertical scroll up with the mouse scroll button	4	17	7	3	examine	information search
vertical scroll down with the mouse scroll button	4	17	18	3	examine	information search
click on the previous month hyperlink	4	22	11	3	navigation	data collection
click on the discussion forum hyperlink	4	42	19	4	navigation	data collection
click on the topic all hyperlink	4	45	8	4	navigation	data collection
vertical scroll down with the mouse scroll button	4	54	6	4	examine	information search
click on the subject check box	4	56	9	4	selection	knowledge build
click on the message to all hyperlink	4	58	2	4	pop up	knowledge management
close the window	5	10	24	4	view	knowledge management
click on the subject check box	5	13	16	4	selection	knowledge build
vertical scroll up with the mouse scroll button	5	17	4	4	examine	information search
vertical scroll down with the mouse scroll button	5	18	21	4	examine	information search
click on the select topics dropdown menu	5	32	8	4	extra information	information search
click on the select topics dropdown menu	5	34	5	4	extra information	information search
click on the discussion forum hyperlink	5	37	1	4	navigation	data collection
navigation back	6	0	12	4	history	data collection
click on the discussion forum hyperlink	6	20	6	4	navigation	data collection
click on the information search course hyperlink	6	29	6	4	navigation	data collection
click on the discussion forum hyperlink	6	33	16	4	navigation	data collection
click on the topic settings hyperlink	6	44	8	4	navigation	data collection
click on the discussion forum hyperlink	6	56	19	4	navigation	data collection
click on the compose discussion message hyperlink	7	2	6	4	pop up	knowledge management
click on the subject text box	7	8	12	4	focus	knowledge form
written subject	7	11	13	4	process	knowledge build
click on the message text area	7	17	11	4	focus	knowledge form
written message	7	28	10	4	process	knowledge build
click on the post button	7	35	5	4	solution	result of action
click on the mail message hyperlink	7	50	7	5	pop up	knowledge management
click on the compose mail message hyperlink	7	52	7	5	pop up	knowledge management
click on the browse button	7	56	8	5	pop up	knowledge management
vertical scroll down with the mouse scroll button	7	59	16	5	examine	information search
horizontal scroll right with the scroll bar	8	15	22	5	examine	information search
horizontal scroll left with the scroll bar	8	17	3	5	examine	information search
horizontal scroll right with the scroll bar	8	19	12	5	examine	information search
vertical scroll down with scroll bar	8	20	23	5	examine	information search
horizontal scroll left with the scroll bar	8	23	8	5	examine	information search

horizontal scroll right with the scroll bar	8	26	20	5	examine	information search
vertical scroll down with scroll bar	8	29	4	5	examine	information search
horizontal scroll left with the scroll bar	8	34	16	5	examine	information search
minimize the window	8	42	13	5	view	knowledge management
click on the information search course hyperlink	8	56	23	5	navigation	data collection
click on the information search course hyperlink	9	14	14	5	navigation	data collection
vertical scroll down with the mouse scroll button	9	18	1	5	examine	information search
vertical scroll up with the mouse scroll button	9	27	24	5	examine	information search
click on the introduction hyperlink	9	37	20	5	navigation	data collection
click on the course map hyperlink	10	17	5	5	navigation	data collection
vertical scroll down with the mouse scroll button	10	23	8	5	examine	information search
click on the written instructions hyperlink	10	31	23	5	pop up	knowledge management
close the window	10	36	22	5	view	knowledge management
click on the information search course hyperlink	10	38	11	5	navigation	data collection
vertical scroll down with the mouse scroll button	10	42	7	5	examine	information search
click on the discussion forum hyperlink	10	59	0	5	navigation	data collection
click on the stop icon on the standard buttons	11	47	3	5	solution	result of action
click on the calendar hyperlink	11	50	17	5	navigation	data collection
click on the previous month hyperlink	11	58	4	5	navigation	data collection
click on the September 6th hyperlink	12	4	6	5	navigation	data collection
navigation back	12	10	9	5	history	data collection
click on the information search course hyperlink	12	23	16	5	navigation	data collection
click on the homepage hyperlink	13	30	16	5	navigation	data collection
click on the tutors contact information hyperlink	13	38	21	5	navigation	data collection
vertical scroll down with the mouse scroll button	13	41	11	5	examine	information search
vertical scroll down with the mouse scroll button	13	46	12	5	examine	information search
vertical scroll up with the mouse scroll button	13	48	0	5	examine	information search
click on the e-mail hyperlink	13	52	7	5	navigation	data collection
click on the compose mail message hyperlink	13	56	11	5	pop up	knowledge management
click on the browse button	13	59	18	5	pop up	knowledge management
horizontal scroll right with the scroll bar	14	4	3	5	examine	information search
horizontal scroll left with the scroll bar	14	7	5	5	examine	information search
horizontal scroll right with the scroll bar	14	11	10	5	examine	information search
vertical scroll down with scroll bar	14	14	22	5	examine	information search
horizontal scroll left with the scroll bar	14	16	11	5	examine	information search
horizontal scroll right with the scroll bar	14	23	12	5	examine	information search

vertical scroll down with scroll bar	14	25	0	5	examine	information search
horizontal scroll left with the scroll bar	14	26	10	5	examine	information search
click on the tutor list box	14	30	24	5	selection	knowledge build
click on the done button	14	33	10	5	solution	result of action
click on the subject text box	14	35	7	6	focus	knowledge form
written subject	14	38	2	6	process	knowledge build
click on the message text area	14	39	2	6	focus	knowledge form
written message	14	47	2	6	process	knowledge build
click on the send button	14	49	1	6	solution	result of action
click on the homepage hyperlink	15	12	13	6	navigation	data collection
close the window	15	19	0	6	view	knowledge management

Appendix 12

APPENDIX 12. User 12's categories of the model of learnability.

Concepts (concrete)	minutes	seconds	tenth	Assignments	Conceptual categories	Sub-categoires
click on the log on hyperlink	0	8	19	1	solution	result of action
written user name	0	19	1	1	process	knowledge build
press on the backspace key on the keyboard	0	19	13	1	process	knowledge build
written user name	0	22	8	1	process	knowledge build
click on the password text box	0	25	19	1	focus	knowledge form
written password	0	29	19	1	process	knowledge build
click on the ok button	0	31	6	1	solution	result of action
system error (the page cannot be displayed)	0	32	4	1	error	result of action
navigation back	0	39	14	1	history	data collection
click on the log on hyperlink	0	47	15	1	solution	result of action
click on the information search course hyperlink	1	27	5	2	navigation	data collection
click on the print hyperlink	2	7	20	2	solution	result of action
click on the information search course instructions check box	2	27	21	2	selection	knowledge build
vertical scroll down with scroll bar	2	29	12	2	examine	information search
vertical scroll up with the mouse scroll button	2	32	15	2	examine	information search
click on the print icon on the standard buttons	2	56	17	2	solution	result of action
click on the compile button	3	37	19	2	process	knowledge build
click on the print icon on the standard buttons	3	57	15	2	solution	result of action
close the window	4	28	8	3	view	knowledge management
click on the discussion forum hyperlink	4	34	13	3	navigation	data collection
vertical scroll down with the mouse scroll button	4	45	4	3	examine	information search
vertical scroll up with the mouse scroll button	4	46	6	3	examine	information search
vertical scroll down with the mouse scroll button	4	47	21	3	examine	information search
vertical scroll up with the mouse scroll button	4	48	10	3	examine	information search
vertical scroll down with the mouse scroll button	4	58	0	3	examine	information search
vertical scroll up with the mouse scroll button	5	0	12	3	examine	information search
click on the week view hyperlink	5	18	11	3	navigation	data collection
vertical scroll down with the mouse scroll button	5	21	9	3	examine	information search
vertical scroll up with the mouse scroll button	5	22	7	3	examine	information search
navigation back	5	25	18	3	history	data collection
click on the compile button	5	36	5	3	process	knowledge build
click on the criteria dropdown menu	5	42	6	3	extra information	information search

click on the criteria dropdown menu	5	44	21	3	extra information	information search
click on the comparison value	5	46	1	3	focus	knowledge form
click on the comparison value	5	47	22	3	focus	knowledge form
click on the criteria dropdown menu	5	49	4	3	extra information	information search
click on the criteria dropdown menu	5	55	3	3	extra information	information search
click on the comparison value	5	56	18	3	focus	knowledge form
click on the comparison value	6	25	3	3	focus	knowledge form
navigation back	6	26	13	3	history	data collection
click on the calendar hyperlink	6	36	15	3	navigation	data collection
click on the month dropdown menu	6	43	19	3	extra information	information search
click on the month dropdown menu	6	44	13	3	extra information	information search
vertical scroll down with the mouse scroll button (focus on month dropdown menu)	6	56	90	3	examine	information search
vertical scroll down with the mouse scroll button (focus on month dropdown menu)	7	7	0	3	examine	information search
vertical scroll down with the mouse scroll button	7	9	7	3	examine	information search
click on the body element	7	9	19	3	focus	knowledge form
vertical scroll up with the mouse scroll button	7	10	17	3	examine	information search
vertical scroll down with the mouse scroll button	7	11	16	3	examine	information search
vertical scroll up with the mouse scroll button	7	11	18	3	examine	information search
vertical scroll down with the mouse scroll button	7	16	0	3	examine	information search
vertical scroll up with the mouse scroll button	7	16	2	3	examine	information search
vertical scroll down with the mouse scroll button	7	20	20	3	examine	information search
vertical scroll up with the mouse scroll button	7	21	3	3	examine	information search
vertical scroll down with the mouse scroll button	7	22	8	3	examine	information search
vertical scroll up with the mouse scroll button	7	22	16	3	examine	information search
click on the compile button	7	36	2	3	process	knowledge build
click on the comparison value	7	44	22	3	focus	knowledge form
click on the start with option dropdown menu	7	47	16	3	extra information	information search
click on the day dropdown menu	7	50	8	3	extra information	information search

click on the day 31st option dropdown menu	7	52	7	3	extra information	information search
click on the display button	8	0	19	3	process	knowledge build
click on the compile button	8	17	5	3	process	knowledge build
click on the criteria dropdown menu	8	37	23	3	extra information	information search
click on the criteria dropdown menu	8	42	5	3	extra information	information search
click on the criteria dropdown menu	8	49	20	3	extra information	information search
click on the criteria dropdown menu	8	52	10	3	extra information	information search
click on the comparison value	8	56	4	3	focus	knowledge form
click on the start with option dropdown menu	8	58	9	3	extra information	information search
click on the bulk check box	9	3	2	3	selection	knowledge build
click on the display button	9	4	0	3	process	knowledge build
click on the compile button	9	14	9	3	process	knowledge build
vertical scroll down with scroll bar	9	34	16	3	examine	information search
vertical scroll up with the mouse scroll button	9	38	21	3	examine	information search
vertical scroll down with the mouse scroll button	9	39	24	3	examine	information search
vertical scroll down with the mouse scroll button	9	42	18	3	examine	information search
vertical scroll up with the mouse scroll button	9	42	99	3	examine	information search
vertical scroll up with the mouse scroll button	9	45	9	3	examine	information search
click on the compile button	10	1	5	3	process	knowledge build
click on the criteria dropdown menu	10	55	11	3	extra information	information search
click on the criteria dropdown menu	11	1	0	3	extra information	information search
click on the comparison value	11	1	14	3	focus	knowledge form
click on the comparison value	11	3	12	3	focus	knowledge form
navigation back	11	20	13	3	history	data collection
click on the go button	11	37	20	3	solution	result of action
vertical scroll down with the mouse scroll button	11	48	22	3	examine	information search
vertical scroll down with the mouse scroll button	11	50	16	3	examine	information search
vertical scroll up with the mouse scroll button	11	51	0	3	examine	information search
vertical scroll down with the mouse scroll button	11	52	5	3	examine	information search

vertical scroll up with the mouse scroll button	11	52	10	3	examine	information search
vertical scroll down with the mouse scroll button	11	52	12	3	examine	information search
vertical scroll up with the mouse scroll button	11	52	18	3	examine	information search
vertical scroll down with the mouse scroll button	11	55	17	3	examine	information search
vertical scroll up with the mouse scroll button	11	56	0	3	examine	information search
click on the previous month hyperlink	12	0	18	3	navigation	data collection
click on the discussion forum hyperlink	12	29	13	4	navigation	data collection
vertical scroll down with the mouse scroll button	12	43	13	4	examine	information search
vertical scroll up with the mouse scroll button	12	45	1	4	examine	information search
click on the topic all hyperlink	12	50	13	4	navigation	data collection
navigation back	13	12	3	4	history	data collection
click on the compose discussion message hyperlink	13	27	18	4	pop up	knowledge management
click on the topic dropdown menu	13	34	17	4	extra information	information search
click on the topic dropdown menu	13	35	11	4	extra information	information search
click on the topic dropdown menu	13	37	2	4	extra information	information search
click on the topic dropdown menu	13	39	0	4	extra information	information search
click on the subject text box	13	41	15	4	focus	knowledge form
written subject	13	44	21	4	process	knowledge build
click on the message text area	13	46	6	4	focus	knowledge form
written message	14	0	4	4	process	knowledge build
click on the post button	14	6	6	4	solution	result of action
click on the e-mail hyperlink	14	15	24	5	navigation	data collection
click on the compose mail message hyperlink	14	39	22	5	pop up	knowledge management
click on the browse button	14	47	15	5	pop up	knowledge management
vertical scroll up with the mouse scroll button	14	49	15	3	examine	information search
vertical scroll down with scroll bar	14	53	17	5	examine	information search
vertical scroll up with scroll bar	14	55	13	5	examine	information search
vertical scroll down with scroll bar	14	56	15	5	examine	information search
vertical scroll up with scroll bar	14	58	15	5	examine	information search
close the window	15	4	2	5	view	knowledge management
close the window	15	14	11	5	view	knowledge management
click on the manage messenger hyperlink	15	37	13	5	navigation	data collection

navigation back	15	42	8	5	history	data collection
click on the search hyperlink	15	51	21	5	pop up	knowledge management
click on the search dropdown menu	15	55	11	5	extra information	information search
click on the search dropdown menu	15	56	10	5	extra information	information search
click on the folder dropdown menu	15	57	12	5	extra information	information search
click on the folder dropdown menu	15	58	0	5	extra information	information search
click on the criteria dropdown menu	15	58	22	5	extra information	information search
click on the criteria dropdown menu	16	1	9	5	extra information	information search
click on the comparison dropdown menu	16	2	12	5	extra information	information search
click on the comparison dropdown menu	16	4	2	5	extra information	information search
close the window	16	6	20	5	view	knowledge management
navigation back	17	16	24	5	history	data collection
click on the course map hyperlink	17	27	10	5	navigation	data collection
vertical scroll down with the mouse scroll button	17	33	10	5	examine	information search
vertical scroll up with the mouse scroll button	17	38	1	5	examine	information search
vertical scroll up with the mouse scroll button	17	43	10	5	examine	information search
vertical scroll up with the mouse scroll button	17	45	0	5	examine	information search
vertical scroll up with the mouse scroll button	17	47	5	5	examine	information search
vertical scroll down with the mouse scroll button	18	2	19	5	examine	information search
vertical scroll up with the mouse scroll button	18	4	18	5	examine	information search
vertical scroll down with the mouse scroll button	18	11	15	5	examine	information search
vertical scroll down with the mouse scroll button	18	15	17	5	examine	information search
vertical scroll down with the mouse scroll button	18	19	14	5	examine	information search
vertical scroll down with the mouse scroll button	18	21	4	5	examine	information search
vertical scroll up with the mouse scroll button	18	23	15	5	examine	information search
vertical scroll down with the mouse scroll button	18	24	15	5	examine	information search
vertical scroll up with the mouse scroll button	18	24	20	5	examine	information search
vertical scroll down with the mouse scroll button	18	24	50	5	examine	information search
vertical scroll up with the mouse scroll button	18	25	0	5	examine	information search

vertical scroll down with the mouse scroll button	18	25	5	5	examine	information search
vertical scroll up with the mouse scroll button	18	25	22	5	examine	information search
vertical scroll down with the mouse scroll button	18	25	25	5	examine	information search
vertical scroll up with the mouse scroll button	18	26	95	5	examine	information search
navigation back	18	35	10	5	history	data collection
click on the information search course hyperlink	18	51	10	5	navigation	data collection
click on the tutors contact information hyperlink	19	3	14	5	navigation	data collection
vertical scroll down with scroll bar	19	12	2	5	examine	information search
vertical scroll up with scroll bar	19	14	20	5	examine	information search
click on the Maija Koponen hyperlink	19	16	23	5	navigation	data collection
vertical scroll down with scroll bar	19	25	1	5	examine	information search
vertical scroll up with scroll bar	19	30	13	5	examine	information search
click on the e-mail hyperlink	19	33	9	5	navigation	data collection
click on the e-mail hyperlink	20	33	18	5	navigation	data collection
click on the compose mail message hyperlink	20	47	17	5	pop up	knowledge management
click on the send to text box	20	54	13	5	focus	knowledge form
click on the browse button	21	1	15	5	pop up	knowledge management
click on the tutor list box	21	12	14	5	selection	knowledge build
click on the done button	21	14	2	5	solution	result of action
click on the subject text box	21	15	14	6	focus	knowledge form
written subject	21	19	21	6	process	knowledge build
click on the message text area	21	22	13	6	focus	knowledge form
written message	21	34	19	6	process	knowledge build
click on the send button	21	37	5	6	solution	result of action
click on the send button	22	7	23	6	solution	result of action
click on the homepage hyperlink	22	31	20	6	navigation	data collection
click on the homepage hyperlink	23	52	6	6	navigation	data collection
click on the Mika Laakkonen hyperlink	24	9	8	6	navigation	data collection
click on the homepage on the standard buttons	24	30	24	6	solution	result of action

Appendix 13

APPENDIX 13. User 13's categories of the model of learnability.

Concepts (concrete)	minutes	seconds	tenth	Assignments	Conceptual categories	Sub-categories
click on the log on hyperlink	0	6	5	1	solution	result of action
written user name	0	19	21	1	process	knowledge build
click on the password text box	0	21	13	1	focus	knowledge form
written password	0	26	4	1	process	knowledge build
click on the ok button	0	27	15	1	solution	result of action
click on the information search course hyperlink	1	2	11	1	navigation	data collection
click on the WebCT instructions hyperlink	1	23	11	2	pop up	knowledge management
vertical scroll down with the mouse scroll button	1	30	8	2	examine	information search
vertical scroll down with the mouse scroll button	1	34	0	2	examine	information search
vertical scroll up with the mouse scroll button	1	36	1	2	examine	information search
vertical scroll down with the mouse scroll button	1	38	18	2	examine	information search
close the window	1	40	9	2	view	knowledge management
click on the print hyperlink	1	44	22	2	solution	result of action
click on the stop icon on the standard buttons	1	49	12	2	solution	result of action
click on the print hyperlink	1	51	16	2	solution	result of action
navigation back	1	56	1	2	history	data collection
click on the information search course hyperlink	2	5	14	2	navigation	data collection
click on the result of assignments hyperlink	2	16	13	2	navigation	data collection
vertical scroll down with the mouse scroll button	2	22	15	2	examine	information search
vertical scroll down with the mouse scroll button	2	26	12	2	examine	information search
vertical scroll up with the mouse scroll button	2	27	4	2	examine	information search
vertical scroll down with the mouse scroll button	2	27	7	2	examine	information search
vertical scroll up with the mouse scroll button	2	28	8	2	examine	information search
navigation back	2	51	1	2	history	data collection
navigation back	2	55	23	2	history	data collection
navigation back	2	59	15	2	history	data collection
click on the print hyperlink	3	17	17	2	solution	result of action
click on the stop icon on the standard buttons	3	26	19	2	solution	result of action
click on the information search course instructions hyperlink	3	38	20	2	navigation	data collection
maximize the window	3	53	2	2	view	knowledge management
vertical scroll down with the mouse scroll button	3	55	4	2	examine	information search
vertical scroll up with the mouse scroll button	3	57	0	2	examine	information search

vertical scroll down with the mouse scroll button	3	57	1	2	examine	information search
vertical scroll up with the mouse scroll button	3	58	0	2	examine	information search
click on the menu bar file option	4	0	2	2	extra information	information search
click on the menu bar print option	4	3	9	2	solution	result of action
click on the print button	4	18	14	2	solution	result of action
navigation back	4	36	4	3	history	data collection
click on the calendar hyperlink	4	42	15	3	navigation	data collection
vertical scroll down with the mouse scroll button	4	56	5	3	examine	information search
vertical scroll up with the mouse scroll button	4	59	2	3	examine	information search
vertical scroll down with the mouse scroll button	4	59	14	3	examine	information search
vertical scroll up with the mouse scroll button	5	0	12	3	examine	information search
click on the previous month hyperlink	5	6	8	3	navigation	data collection
click on the discussion forum hyperlink	5	38	22	4	navigation	data collection
click on the topic all hyperlink	5	48	6	4	navigation	data collection
click on the discussion forum hyperlink	6	37	8	4	navigation	data collection
vertical scroll down with the mouse scroll button	6	40	16	4	examine	information search
vertical scroll up with the mouse scroll button	6	42	9	4	examine	information search
vertical scroll down with the mouse scroll button	6	48	19	4	examine	information search
vertical scroll up with the mouse scroll button	6	49	17	4	examine	information search
click on the topic all hyperlink	6	51	23	4	navigation	data collection
click on the compose discussion message hyperlink	6	57	2	4	pop up	knowledge management
click on the subject text box	7	2	20	4	focus	knowledge form
written subject	7	7	1	4	process	knowledge build
click on the message text area	7	10	5	4	focus	knowledge form
written message	7	24	12	4	process	knowledge build
click on the post button	7	32	21	4	solution	result of action
click on the e-mail hyperlink	7	56	11	5	navigation	data collection
click on the compose mail message hyperlink	8	7	18	5	pop up	knowledge management
click on the browse button	8	11	20	5	pop up	knowledge management
vertical scroll down with scroll bar	8	22	9	5	examine	information search
vertical scroll up with scroll bar	8	22	18	5	examine	information search
minimize the window	8	25	6	5	view	knowledge management
minimize the window	8	26	6	5	view	knowledge management
click on the homepage hyperlink	8	34	24	5	navigation	data collection
click on the tutors contact information hyperlink	8	48	5	5	navigation	data collection
vertical scroll down with the mouse scroll button	8	52	13	5	examine	information search

vertical scroll up with the mouse scroll button	8	54	0	5	examine	information search
click on the Maija Koponen hyperlink	8	55	15	5	navigation	data collection
vertical scroll down with the mouse scroll button	9	1	3	5	examine	information search
vertical scroll up with the mouse scroll button	9	2	5	5	examine	information search
click on the compose mail message hyperlink	9	7	17	5	pop up	knowledge management
click on the browse button	9	10	1	5	pop up	knowledge management
press on the F5 key on the keyboard	9	13	18	5	history	data collection
vertical scroll down with scroll bar	9	18	17	5	examine	information search
vertical scroll up with scroll bar	9	20	18	5	examine	information search
vertical scroll down with scroll bar	9	30	16	5	examine	information search
vertical scroll up with scroll bar	9	30	22	5	examine	information search
minimize the window	9	33	12	5	view	knowledge management
minimize the window	9	35	18	5	view	knowledge management
click on the compose mail message hyperlink	9	40	2	5	pop up	knowledge management
click on the compose the mail message task bar	9	41	13	5	view	knowledge management
click on the tutors task bar	9	43	1	5	view	knowledge management
minimize the window	9	45	4	5	view	knowledge management
click on the information search course instructions task bar	9	47	4	5	view	knowledge management
click on the homepage hyperlink	9	50	8	5	navigation	data collection
click on the tutors contact information hyperlink	9	53	2	5	navigation	data collection
vertical scroll down with the mouse scroll button	9	55	14	5	examine	information search
vertical scroll up with the mouse scroll button	9	55	22	5	examine	information search
click on the Satu Ihanamäki hyperlink	10	1	11	5	navigation	data collection
vertical scroll down with the mouse scroll button	10	15	0	5	examine	information search
vertical scroll up with the mouse scroll button	10	15	21	5	examine	information search
vertical scroll up with the mouse scroll button	10	18	8	5	examine	information search
vertical scroll down with the mouse scroll button	10	19	10	5	examine	information search
vertical scroll up with the mouse scroll button	10	24	10	5	examine	information search
vertical scroll down with the mouse scroll button	10	25	0	5	examine	information search
vertical scroll up with the mouse scroll button	10	25	10	5	examine	information search
vertical scroll down with the mouse scroll button	10	25	20	5	examine	information search
vertical scroll down with the mouse scroll button	10	29	15	5	examine	information search
click on the e-mail hyperlink	10	33	8	5	navigation	data collection
click on the compose mail message hyperlink	10	38	17	5	pop up	knowledge management
click on the browse button	10	40	19	5	pop up	knowledge management
click on the tutor list box	10	47	2	5	selection	knowledge build

click on the done button	10	49	5	5	solution	result of action
click on the done button	10	53	13	5	solution	result of action
minimize the window	10	55	0	5	view	knowledge management
click on the tutors task bar	10	59	12	5	view	knowledge management
click on the compose the mail message task bar	11	2	18	5	view	knowledge management
click on the tutors task bar	11	6	19	5	view	knowledge management
click on the done button	11	11	23	5	solution	result of action
minimize the window	11	19	4	5	view	knowledge management
close the window	11	20	19	5	view	knowledge management
click on the tutors task bar	11	21	22	5	view	knowledge management
click on the done button	11	25	0	5	solution	result of action
click on the mail message task bar	11	31	12	5	view	knowledge management
click on the information search course instructions task bar	11	32	24	5	view	knowledge management
close the window	11	34	17	5	view	knowledge management
click on the tutors task bar	11	36	4	5	view	knowledge management
click on the tutors task bar	11	36	12	5	view	knowledge management
close the window	11	38	1	5	view	knowledge management
click on the compose mail message hyperlink	11	42	7	5	pop up	knowledge management
minimize the window	12	10	3	5	view	knowledge management
click on the compose the mail message task bar	12	16	1	5	view	knowledge management
click on the right mouse button and the context menu appears	12	17	0	5	focus	knowledge form
click on the close option on the context menu	12	17	4	5	solution	result of action
navigation back	12	19	3	5	history	data collection
click on the stop icon on the standard buttons	12	21	7	5	solution	result of action
click on the forward icon on the standard buttons	12	24	15	5	history	data collection
click on the compose mail message hyperlink	12	30	7	5	pop up	knowledge management
click on the browse button	12	40	4	5	pop up	knowledge management
click on the tutor list box	12	48	24	5	selection	knowledge build
click on the done button	12	50	7	5	solution	result of action
click on the message text area	12	52	17	5	focus	knowledge form
click on the subject text box	12	53	12	5	focus	knowledge form
written subject	12	57	15	5	process	knowledge build
click on the message text area	13	0	3	5	focus	knowledge form
written message	13	18	2	5	process	knowledge build
click on the send button	13	20	9	5	solution	result of action
click on the send button	13	23	5	5	solution	result of action

minimize the window	14	7	1	6	view	knowledge management
close the window	14	12	24	6	view	knowledge management
click on the right mouse button and the context menu appears	14	14	13	6	focus	knowledge form
click on the close option on the context menu	14	14	23	6	solution	result of action

Appendix 14

APPENDIX 14. User 14's categories of the model of learnability.

Concepts (concrete)	minutes	seconds	tenth	Assignments	Conceptual categories	Sub-categories
click on the log on hyperlink	0	6	1	1	solution	result of action
written user name	0	15	23	1	process	knowledge build
click on the password text box	0	19	18	1	focus	knowledge form
written password	0	23	22	1	process	knowledge build
click on the ok button	0	25	6	1	solution	result of action
system error (the page cannot be displayed)	0	26	11	1	error	result of action
navigation back	0	32	13	1	history	data collection
click on the log on hyperlink	0	34	7	1	solution	result of action
click on the information search course hyperlink	1	9	11	1	navigation	data collection
click on the information search course hyperlink	1	44	7	2	navigation	data collection
click on the WebCT instructions hyperlink	2	1	12	2	pop up	knowledge management
vertical scroll down with the mouse scroll button	2	15	6	2	examine	information search
vertical scroll up with the mouse scroll button	2	16	2	2	examine	information search
close the window	2	18	9	2	view	knowledge management
click on the information search course hyperlink	2	34	20	2	navigation	data collection
vertical scroll down with the mouse scroll button	2	40	23	2	examine	information search
vertical scroll up with the mouse scroll button	2	42	14	2	examine	information search
navigation back	2	47	9	2	history	data collection
navigation back	3	2	21	2	history	data collection
navigation back	3	6	7	2	history	data collection
click on the information search course hyperlink	3	21	11	2	navigation	data collection
click on the information search course hyperlink	4	0	0	2	navigation	data collection
click on the information search course instructions hyperlink	4	6	24	2	navigation	data collection
vertical scroll down with the mouse scroll button	4	11	0	2	examine	information search
vertical scroll up with the mouse scroll button	4	16	2	2	examine	information search
click on the menu bar file option	4	19	5	2	extra information	information search
click on the menu bar print option	4	21	11	2	solution	result of action
click on the print button	4	31	20	2	solution	result of action
navigation back	4	41	2	3	history	data collection
navigation back	4	44	2	3	history	data collection
navigation back	4	45	2	3	history	data collection

click on the calendar hyperlink	4	49	14	3	navigation	data collection
vertical scroll down with the mouse scroll button	4	57	15	3	examine	information search
click on the previous month hyperlink	5	26	15	3	navigation	data collection
navigation back	5	55	8	4	history	data collection
navigation back	5	55	22	4	history	data collection
click on the discussion forum hyperlink	5	59	4	4	navigation	data collection
click on the compose discussion message hyperlink	6	5	5	4	pop up	knowledge management
click on the subject text box	6	11	21	4	focus	knowledge form
written subject	6	16	5	4	process	knowledge build
click on the message text area	6	18	2	4	focus	knowledge form
written message	6	32	17	4	process	knowledge build
click on the post button	6	37	21	4	solution	result of action
navigation back	6	46	23	5	history	data collection
navigation back	6	49	12	5	history	data collection
click on the e-mail hyperlink	6	55	17	5	navigation	data collection
click on the compose mail message hyperlink	7	1	11	5	pop up	knowledge management
click on the browse button	7	7	18	5	pop up	knowledge management
vertical scroll down with the mouse scroll button	7	15	20	5	examine	information search
vertical scroll up with the mouse scroll button	7	16	19	5	examine	information search
close the window	7	19	19	5	view	knowledge management
close the window	7	24	14	5	view	knowledge management
navigation back	7	33	5	5	history	data collection
click on the information search course hyperlink	8	2	19	5	navigation	data collection
click on the stop icon on the standard buttons	8	55	23	5	solution	result of action
click on the e-mail hyperlink	8	57	22	5	navigation	data collection
navigation back	9	14	17	5	history	data collection
click on the information search course hyperlink	9	21	9	5	navigation	data collection
navigation back	9	52	12	5	history	data collection
click on the tutors contact information hyperlink	10	9	2	5	navigation	data collection
vertical scroll down with the mouse scroll button	10	16	4	5	examine	information search
vertical scroll up with the mouse scroll button	10	20	4	5	examine	information search
click on the Maija Koponen hyperlink	10	25	10	5	navigation	data collection
vertical scroll up with the mouse scroll button	10	28	0	5	examine	information search
click on the e-mail hyperlink	10	33	24	5	navigation	data collection
click on the compose mail message hyperlink	10	37	3	5	pop up	knowledge management
click on the browse button	10	39	10	5	pop up	knowledge management

vertical scroll down with the mouse scroll button	10	53	12	5	examine	information search
vertical scroll up with the mouse scroll button	11	12	6	5	examine	information search
vertical scroll down with the mouse scroll button	11	12	18	5	examine	information search
click on the tutor list box	11	19	4	5	selection	knowledge build
click on the done button	11	23	8	5	solution	result of action
click on the subject text box	11	25	13	5	focus	knowledge form
written subject	11	31	4	5	process	knowledge build
click on the message text area	11	32	14	5	focus	knowledge form
written message	11	43	7	5	process	knowledge build
click on the send button	11	47	10	5	solution	result of action
navigation back	11	57	15	6	history	data collection
navigation back	11	58	4	6	history	data collection
navigation back	11	59	21	6	history	data collection
navigation back	12	0	11	6	history	data collection
click on the menu bar file option	12	17	7	6	extra information	information search
click on the exit menu bar	12	18	21	6	solution	result of action

Appendix 15

APPENDIX 15. User 15’s categories of the model of learnability.

Concepts (concrete)	minutes	seconds	tenth	Assignments	Conceptual categories	Sub-categories
click on the log on hyperlink	0	2	12	1	solution	result of action
written user name	0	12	4	1	process	knowledge build
press on the backspace key on the keyboard	0	12	5	1	process	knowledge build
written user name	0	13	1	1	process	knowledge build
press on the tab key on the keyboard	0	13	14	1	process	knowledge build
written password	0	16	21	1	process	knowledge build
click on the ok button	0	18	0	1	solution	result of action
system error (the page cannot be displayed)	0	19	2	1	error	result of action
navigation back	0	22	6	1	history	data collection
click on the log on hyperlink	0	23	15	1	solution	result of action
vertical scroll down with the mouse scroll button	0	51	15	1	examine	information search
click on the information search course hyperlink	0	55	2	1	navigation	data collection
click on the information search course hyperlink	1	12	9	2	navigation	data collection
click on the quizzes hyperlink	1	22	4	2	navigation	data collection
vertical scroll down with the mouse scroll button	1	31	13	2	examine	information search
vertical scroll up with the mouse scroll button	1	32	11	2	examine	information search
navigation back	1	41	10	2	history	data collection
click on the WebCT instructions hyperlink	1	53	13	2	pop up	knowledge management
vertical scroll down with the mouse scroll button	1	59	14	2	examine	information search
vertical scroll up with the mouse scroll button	2	0	17	2	examine	information search
close the window	2	1	12	2	view	knowledge management
click on the information search course hyperlink	2	4	10	2	navigation	data collection
click on the quizzes hyperlink	2	12	2	2	navigation	data collection
click on the information search course hyperlink	2	32	6	2	navigation	data collection
click on the information search course hyperlink	2	47	15	2	navigation	data collection
navigation back	2	50	20	2	history	data collection
vertical scroll down with the mouse scroll button	2	56	6	2	examine	information search
click on the summary hyperlink	2	59	6	2	navigation	data collection
click on the information search course hyperlink	3	5	5	2	navigation	data collection
click on the WebCT instructions hyperlink	3	20	10	2	pop up	knowledge management
close the window	3	25	24	2	view	knowledge management
horizontal scroll right with the scroll bar	3	38	0	2	examine	information search

horizontal scroll left with the scroll bar	3	38	16	2	examine	information search
click on the homepage hyperlink	3	43	4	2	navigation	data collection
navigation back	4	20	12	2	history	data collection
navigation back	4	26	15	2	history	data collection
click on the information search course hyperlink	4	32	11	2	navigation	data collection
click on the information search course instructions hyperlink	4	38	9	2	navigation	data collection
vertical scroll down with the mouse scroll button	4	42	23	2	examine	information search
vertical scroll down with the mouse scroll button	4	44	5	2	examine	information search
vertical scroll up with the mouse scroll button	4	45	10	2	examine	information search
vertical scroll down with the mouse scroll button	4	45	15	2	examine	information search
vertical scroll up with the mouse scroll button	4	47	15	2	examine	information search
vertical scroll down with the mouse scroll button	4	48	16	2	examine	information search
vertical scroll up with the mouse scroll button	4	57	1	2	examine	information search
vertical scroll down with the mouse scroll button	5	2	4	2	examine	information search
starts to paint the information search course instructions	5	9	9	2	highlight	knowledge form
finish to paint the information search course instructions	5	17	15	2	highlight	knowledge form
click on the menu bar file option	5	19	3	2	extra information	information search
click on the menu bar print option	5	20	13	2	solution	result of action
click on the print button	5	30	24	2	solution	result of action
vertical scroll up with the mouse scroll button	5	44	22	3	examine	information search
click on the information search course hyperlink	5	55	19	3	navigation	data collection
click on the quizzes hyperlink	5	59	15	3	navigation	data collection
click on the calendar hyperlink	6	6	24	3	navigation	data collection
vertical scroll down with the mouse scroll button	6	11	11	3	examine	information search
vertical scroll up with the mouse scroll button	6	14	2	3	examine	information search
click on the previous month hyperlink	6	16	11	3	navigation	data collection
vertical scroll down with the mouse scroll button	6	22	16	3	examine	information search
vertical scroll up with the mouse scroll button	6	27	16	3	examine	information search
vertical scroll down with the mouse scroll button	6	28	12	3	examine	information search
vertical scroll up with the mouse scroll button	6	34	14	3	examine	information search
click on the right mouse button and the context menu appears	6	39	14	3	focus	knowledge form
click on the body element	6	40	0	4	focus	knowledge form
click on the discussion forum hyperlink	6	47	12	4	navigation	data collection
click on the topic all hyperlink	6	53	0	4	navigation	data collection
vertical scroll down with the mouse scroll button	6	58	0	4	examine	information search

click on the compose discussion message hyperlink	7	10	17	4	pop up	knowledge management
click on the subject text box	7	15	18	4	focus	knowledge form
written subject	7	18	24	4	process	knowledge build
press on the tab key on the keyboard	7	19	6	4	process	knowledge build
written subject	7	25	5	4	process	knowledge build
press on the backspace key on the keyboard	7	26	10	4	process	knowledge build
written subject	7	29	13	4	process	knowledge build
press on the backspace key on the keyboard	7	30	0	4	process	knowledge build
written subject	7	32	15	4	process	knowledge build
press on the backspace key on the keyboard	7	32	18	4	process	knowledge build
written subject	7	35	14	4	process	knowledge build
click on the post button	7	48	0	4	solution	result of action
click on the e-mail hyperlink	7	59	3	5	navigation	data collection
click on the compose mail message hyperlink	8	12	0	5	pop up	knowledge management
click on the browse button	8	15	20	5	pop up	knowledge management
vertical scroll down with the mouse scroll button	8	22	20	5	examine	information search
vertical scroll up with scroll bar	8	25	11	5	examine	information search
click on the tutor list box	9	6	16	5	selection	knowledge build
minimize the window	9	11	18	5	view	knowledge management
minimize the window	9	13	18	5	view	knowledge management
click on the homepage hyperlink	9	49	9	5	navigation	data collection
click on the tutors contact information hyperlink	9	54	23	5	navigation	data collection
vertical scroll down with the mouse scroll button	9	59	5	5	examine	information search
click on the mail message task bar	10	8	17	5	view	knowledge management
starts to move the window (south-east)	10	9	24	5	view	knowledge management
finish to move the window (south-east)	10	11	11	5	view	knowledge management
click on the send to text box	10	11	21	5	focus	knowledge form
written send to	10	18	3	5	process	knowledge build
starts to move the window (west)	10	18	5	5	view	knowledge management
finish to move the window (west)	10	19	0	5	view	knowledge management
click on the subject text box	10	19	8	5	focus	knowledge form
written subject	10	22	14	5	process	knowledge build
press on the tab key on the keyboard	10	23	3	5	process	knowledge build
written message	10	25	4	5	process	knowledge build
press on the backspace key on the keyboard	10	25	6	5	process	knowledge build
written message	10	35	2	5	process	knowledge build

press on the backspace key on the keyboard	10	35	4	5	process	knowledge build
written message	10	38	2	5	process	knowledge build
click on the send button	10	42	20	5	solution	result of action
alert window message (the following names were not found in the class)	10	42	21	5	error	result of action
click on the ok button	10	46	15	5	solution	result of action
written send to	10	48	0	5	process	knowledge build
starts to move the window (east)	10	48	17	5	view	knowledge management
finish to move the window (east)	10	49	2	5	view	knowledge management
starts to move the window (west)	10	49	4	5	view	knowledge management
finish to move the window (west)	10	50	7	5	view	knowledge management
Paints the e-mail address	10	55	12	5	highlight	knowledge form
press on the backspace key on the keyboard	10	58	4	5	process	knowledge build
written send to	10	59	10	5	process	knowledge build
press on the backspace key on the keyboard	10	59	12	5	process	knowledge build
written send to	11	2	0	5	process	knowledge build
click on the send button	11	5	23	5	solution	result of action
click on the tutors task bar	11	10	14	6	view	knowledge management
close the window	11	12	4	6	view	knowledge management
click on the tutors task bar	11	22	5	6	view	knowledge management
minimize the window	11	24	7	6	view	knowledge management
click on the tutors task bar	11	25	10	6	view	knowledge management
vertical scroll up with the mouse scroll button	11	26	4	6	examine	information search
navigation back	11	28	20	6	history	data collection
navigation back	11	31	13	6	history	data collection
close the window	11	46	23	6	view	knowledge management