ROLE OF ABDUCTIVE REASONING

IN DIGITAL INTERACTION

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DOCTORAL DISSERTATION

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Abstract

Along with geographical and technological barriers, the barriers created by local and parochial techno-social systems have to be taken into consideration in order to make us truly nomadic. A key question in the near future is how the user of advanced mobile technology could be empowered to have more control over the multiple spaces he or she inhabits and the numerous boundary crossings that he or she is forced to perform.

Information Society Technology (IST) has penetrated all walks of life, and is being applied, among other things, to enhance education. IST enhanced learning realizes some central ideals of constructivist pedagogy. Hermeneutic psychology and philosophical argumentation are applied to identify some potential or actual strengths and weaknesses in the chain of connections between constructivist pedagogical principles, psychological processes, supporting technologies and the actual application of IST in a learning environment. Ideally, mobile technology opens up new opportunities for (constructivistically oriented) learning. It conquers barriers of time and place; utilizes the physical and social context of learning; gives more room for individual learning styles as well as enables and intensifies collaboration and peer-to-peer communication.

Abduction goes a long way in describing and explaining the special epistemic circumstances of IST enhanced learning and digital interaction in general. A study of abductive reasoning will help us better understand IST enhanced learning and IST user behaviour as well as give us some valuable hints to the design of human-computer interaction. However, IST cuts out certain aspects of knowledge and reality, making abduction at some point inoperable. Aura and tacit knowledge, too, help in marking out the limits of discursive means via abduction (i.e. semiotic means).

Abduction, tacit knowledge and aura have some similarities which seem to justify treating them under the common denominator of low knowledge. Low knowledge is a personal yet democratic form of knowing that focuses on differences and details, treating individuals as whole universes. It is suggested that low knowledge may be a key to a

better understanding of the mobility and immobility of knowledge. Context-awareness, multisensority and virtual reality broaden the potential of abduction (i.e. the scope of semiotic knowledge) in cyberspace. They broaden it because they bring us (as users) a step closer to a real-world, situated face-to-face interaction, that is, a step closer to kicking the tires, feeling the fabric, casual chatting and taking a walk in the woods.

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Contents

List of figures and tables

List of publications

1. Patokorpi, E. 2006. Abductive Reasoning and ICT Enhanced Learning: Towards the Epistemology of Digital Nomads. In Zielinski, C., Duquenoy, P. and K. Kimppa (eds.), The Information Society: Emerging Landscapes. Springer: New York, pp. 101-117.

2. Patokorpi, E. and F. Tétard (in press). From Mobility to True Nomadicity and Ubiquity. In Huang, W., Wang, Y. L. and J. Day (eds.), Global Mobile Commerce: Strategies, Implementation and Case Studies. Idea Group Inc.

3. Patokorpi, E. 2006. Constructivist Instructional Principles, Learner Psychology and Technological Enablers of Learning. In Proceedings of the 8th International Conference on Enterprise Information Systems (ICEIS), Paphos, Cyprus, 23-27 May 2006, pp. 103-109.

4. Patokorpi, E., Tétard, F., Qiao, F. and N. Sjövall 2006. Mobile Learning Objects to Support Constructivist Learning. In Koohang, A. and K. Harman (eds.), Learning Objects: Applications, Implications, & Future Directions. Santa Rosa, California: Informing Science Press.

5. Patokorpi, E. 2006. Logic of Sherlock Holmes in Technology Enhanced Learning. Journal of Educational Technology & Society.

6. Patokorpi, E. 2006. Low Knowledge in Cyberspace: Abduction, Tacit Knowledge, Aura and the Mobility of Knowledge. Journal of Human Systems Management, Vol. 25, No. 3, pp. 211-220.

7. Patokorpi, E. 2006. Truly Nomadic Environments: Context-Awareness, Virtuality and Multisensority. Faculty of Technology, IAMSR Research Reports.

PART 1

RESEARCH SUMMARY

Introduction

Mobile and wireless technologies are the new cutting edge of modern Information and Communication Technology (ICT). Educators have embraced ICT and are trying to find ways of integrating it in the curriculum as well as in their day-to-day teaching. Concepts like mobile learning and edutainment challenge the old pedagogical principles and practices as educators combine modern ICT for instance with constructivist ideals of learning. Some visionaries claim that we are all turning into nomads (Keen and Mackintosh 2001; Carlsson and Walden 2002; Kleinrock 2001; Sørensen 2002; 2003). The technological development can be presented schematically as follows:

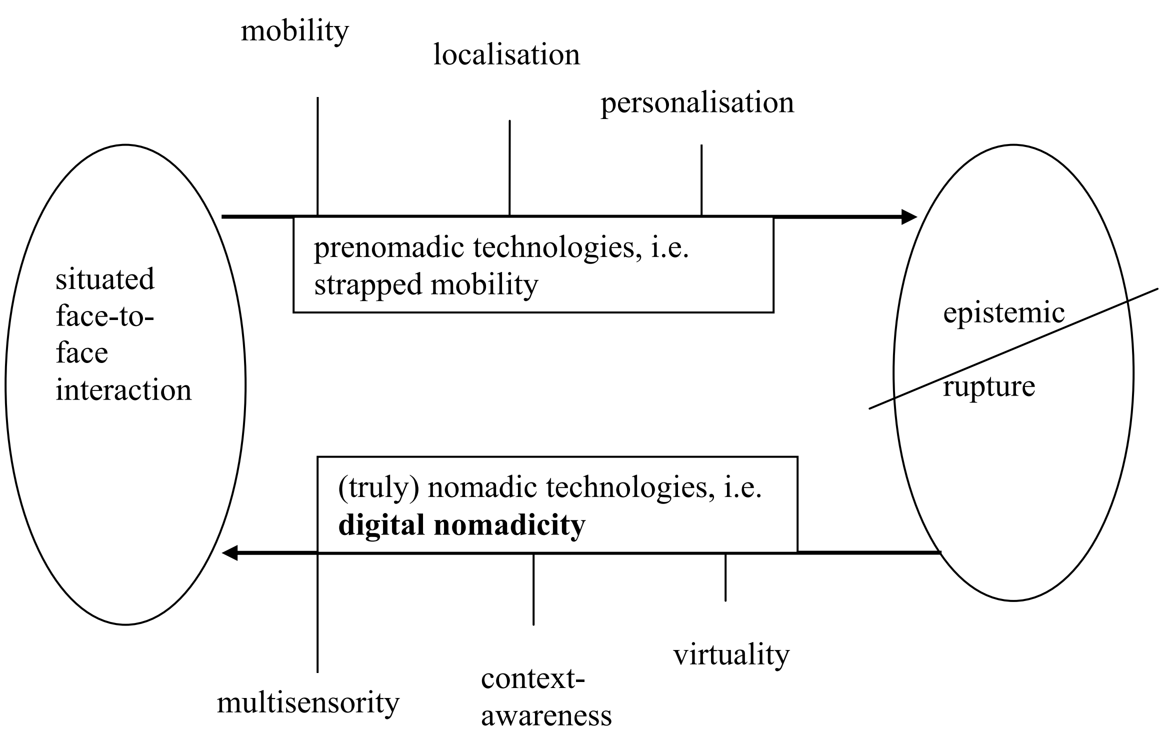

Figure 1: Technological development in terms of interaction

Figure 1 above shows how the technology first distances itself from situated face-to-face interaction by breaking loose from time and place (i.e. the early rhetoric of “anytime, anywhere”), and then with the development of truly nomadic technologies tries to imitate situated face-to-face interaction as closely as possible. Digital nomadicity refers to the part of technological development where technologies strive to imitate situated face-to-face interaction, illustrated by the arrow that points left. In a nomadic culture learning does not take place in the classroom but wherever one is in need of relevant information or new skills. Yet it is not clear how the new ICT will (if at all) change the ways we perceive the world around us, and how educators could or should use the new tools.

Alongside the term ICT also the term Information Society Technology (IST) is used in this dissertation. IST is a broader term than ICT, underlining the fact that new technologies have penetrated all walks of life. The term ICT will be used in contexts where more conventional technologies are discussed or when there is no pressing reason otherwise to deviate from the more established usage.

IST enhanced learning and digital interaction in general seem to favour the abductive form of reasoning. Abduction meets the demands of a mobile learner envisioned by constructivist pedagogues, and abduction is also the form of inference users seem to be compelled to use in cyberspace. Therefore one could perhaps call abduction the mobile or “pedestrian” form of reasoning *par excellence.* Abduction is here to be understood as everyday reasoning, that is, as a particular model of how people (sometimes in some situations) reason in real life. Abduction is also applied for instance in logic programming and the theory of science, but those interpretations of abductive logic usually differ from the one presented here and are not discussed in this work.

Knowledge by abduction has some inherent limitations. These limitations of abductive reasoning are therefore likely to shed some light on the limitations to human knowledge in cyberspace. In addition to abduction, tacit knowledge and aura are concepts that help exploring the limits of digital interaction. Tacit knowledge is notoriously difficult to convert to digital form, which makes knowledge flow in and between modern organisations unwieldy. The concept of aura has been used in aesthetics and philosophy to denote some features that unique objects (e.g. works of art) have or are supposed to have. Unlike many or most original works of art, digital objects are not unique but copies. In the case of digital objects, there is no original at all. Abduction, tacit knowledge and aura have similarities which seem to justify in treating them under a common denominator of low knowledge. Low knowledge is a personal yet democratic form of knowing that focuses on differences and details, treating individuals as whole universes.

On the other hand, there are certain key features connected to the emerging IST by which one may overcome some limitations of IST enhanced education, edutainment and interaction. These features are multisensority, context-awareness and virtuality. They expand the scope of low knowledge, making digital interaction more similar to human, situated face-to-face interaction.

The principal research question in this work is:

- What is the role of abductive reasoning in digital interaction?

In other words, what the research at hand wants to clarify are the epistemic conditions of emerging nomadic and ubiquitous computing environments. In order to even begin answering this principal question, one has to get some rationally grounded, and preferably also empirically corroborated, idea of human-to-human interaction, human-to-machine interaction, learning, human thought processes, the state of the art of available technologies for learning and interaction and the key features of the emerging ICT and IST. These minor, concomitant considerations give rise to the questions listed below:

- Does the emerging IST differ in terms of its epistemology from similar, previous technologies?
- How can ICT support constructivist learning?
- What should mobile learning objects be like from the user's point of view?
- What is abduction like as a pattern of everyday reasoning?

- What is the role of abduction as a particular thinking style in technology enhanced learning and digital interaction?
- What is low knowledge and what is its role in digital interaction?
- How do context-awareness, virtuality and multisensority affect the epistemic conditions of digital interaction?

The dissertation consists of seven chapters, based on six scientific papers published in international, refereed publications and one research report. Part 2 presents a copy of each publication. The topic of each chapter belongs to a well-established field of scientific research. These topical fields make up a motley crew whose mutual implications are hard to account for or verify. Abduction is the primary unit of analysis, tying these topics together.

The first chapter deals with method. The research at hand is theoretically oriented and cross-disciplinary, building both on a wealth of previous empirical research results and theoretical studies in a variety of scientific fields. The following fields are at one point or another touched upon: information systems (goes without saying), computer science, technology studies, logic, epistemology, pedagogy, psychology, semiotics, media studies and sociology. Abduction enables one to cross these disciplinary boundaries and at the same time to retain an acceptable level of scientific rigour. The task of abduction is twofold. Firstly, abduction is an analytical tool that will explain some key features of advanced IST. Secondly, abduction is probably the central inferential mechanism at work when users learn or interact in an IST context.

The second chapter discusses the claim, made by some influential computer science and information systems researchers, that we are on the threshold of a new paradigm of digital computing and communication – true digital nomadicity. Although we are still partly trapped in the old world of fixed computing platforms, accessed by users with the same (personal) device from the same IP address, the world of radical mobility – true nomadicity – is just round the corner (see esp. Kleinrock 2001). Peter Wegner (1997), Carsten Sørensen (2002; 2003) and Leonard Kleinrock (2001), among others, have aspired to describe and explain the workings of this paradigm shift from a strapped mobility to truly nomadic digital environments. Despite their efforts, we are still missing a common theoretical ground, by the help of which to make sense of the (allegedly) new paradigm. The paradigm shift, if true, implies that the epistemological conditions have changed or are changing, too, and abduction will presumably play a central role in the new world of digital nomads.

Chapter three presents the doctrine of constructivist pedagogy, and its relation to technology enhanced learning. The general opinion among constructivist pedagogues seems to be that ICT mediated learning and the constructivist educational doctrine is a match made in heaven. For instance Järvinen (2001) claims that technology enhanced learning supports "naturally" learning by manipulation, comparison and problem solving in a non-prescriptive real-world-like context that leaves room for creative thinking and innovation. And, at least on the surface, so it seems. Furthermore, it seems that the features associated with both constructivist learning and the new technologies used for supporting that learning – democratic, personal, skilled, creative and interactive – can also be used for describing knowledge by abduction.

Chapter four presents a mobile learning platform which is articulated around three main features derived from constructivist pedagogy: (i) problem orientation, (ii) individual learning strategies and (iii) situated collaboration. It focuses on the general design principles of learning objects specifically intended for mobile learning. It will be argued that learning objects must be revised if one wants to successfully apply them to mobile learning environments. The structure and dynamics of learning objects must be in line with the central features of mobile learning; they must promote learning experiences which are repeatable, expedient, personal, immediate and situated. Following these guidelines should result in mobile learning objects that are small, intelligible, object-like and interoperable (general qualities) as well as expedient, situated, immediate, persistent, reusable, personalized and manipulable (specific qualities).

The fifth chapter discusses abductive reasoning in greater detail, and argues that it is the most central inferential mechanism at work in interaction taking place in advanced IST environments in general and in mobile environments in particular. Abduction is the method used by Sherlock Holmes. It is the way in which people reason when making discoveries in the sense of coming up with new ideas. Hence abduction is considered a logic of discovery, and as such it is essentially a matter of finding and following clues (Peirce 2001; Wirth 1995; Peltonen 1999). Well over ten forms of abductive reasoning are presented and their role in technology enhanced education is discussed.

Chapter number 6 charts the limits of digital objects and interaction. In the same way as traditional classroom teaching sets boundaries to what and how learners can learn there seem to be some limitations to IST enhanced and mobile knowledge, that is, limitations or conditions set by eLearning and mLearning environments. How well knowledge in general can be mediated purely by ICT/IST without the subject (i.e. the user) being present in flesh and blood? It is common knowledge that for instance online customers have the urge to feel the fabric, smell the flowers and kick the tires in order to be persuaded to buy something. The limitations to human knowledge in cyberspace are examined with the help of three well-known philosophical concepts: abduction, aura and tacit knowledge.

Chapter seven examines some fundamental properties of digital interaction in advanced IST environments. The properties examined are: context-awareness, multisensority and virtuality. They seem to mark the beginning of a second era (a new paradigm) of very advanced IST in general and mobile technology in particular, transgressing the earlier limits of human knowledge. Although the current infrastructure does not support such advanced (esp. mobile) environments on any larger scale, it is possible to envision such an environment fully functional. It seems that context-aware systems, the Tangible User Interface (TUI), virtual reality, augmented reality and the so-called sentient objects significantly extend the possibilities of communication and flow of information between machines and humans. As a result, the scope of knowledge by abduction widens.

Finally, the concluding chapter (Conclusion, unnumbered) is a recapitulation of the main points, followed by a brief discussion of the key knowledge constructs and a glance at the future vistas opened up by this research.

Technologies that enhance normal day-to-day communication have been the most successful (e.g. e-mail and SMS), as they have been quickly and widely adopted by the man in the street. These sorts of technologies strive to imitate the natural flow of human communication, modelling interaction after situated face-to-face interaction. ICT and IST research and design have followed suit and are focusing more on the use of technology in everyday life. This so-called domestication approach tries – as the name indicates – to domesticate technologies so that they can be used not just by professional people for professional purposes but by all of us for edutainment, recreation, peer-to-peer communication and household tasks – anywhere and anytime (Punie et al. 2003; Punie 2003). Abduction, as a model for a particular form of informal reasoning and a thinking style, may help information systems researchers, computer scientists, designers and pedagogues interested in technology enhanced learning to better understand user behaviour in cyberspace. Low knowledge is a broader set of epistemic factors that is hoped to assist in making sense of digital interaction in general, irrespective of whether the interaction takes place in a learning, communication, collaboration or recreation context or situation. As the domestication approach calls for a holistic understanding of user behaviour, abduction and low knowledge seem like appropriate conceptual tools for both research and design of modern ICT and IST. The knowledge constructs of abduction and low knowledge are thus believed to contribute to the making of better, more easy-to-use and more natural technologies for education, work and leisure. Accordingly, the dissertation will focus on the man in the street as the primary user group, that is, focus on ordinary people as they go about their business in everyday life, doing everyday things like socializing, communicating, working, playing, learning and caring.

The research papers require little explaining as the dissertation chapters closely follow them in both order and content. Having read the chapter overviews above, the reader knows already what is in store for him or her in the research papers. Table 1 below presents how the thesis topics relate to the dissertation chapters and research papers.

Table 1: Overview of the thesis

Topic	Part I	Part II
Research questions and key concepts	Introduction	Paper 1
Method	Chapter 1	
State of the art of IST and the concept of nomadicity	Chapter 2	Paper 2
Constructivist learning and ICT	Chapter 3	Paper 3
Mobile learning and mobile learning objects	Chapter 4	Paper 4
Abductive reasoning	Chapter 5	Paper 5
Low knowledge and the mobility of knowledge	Chapter 6	Paper 6
Epistemic conditions of advanced nomadicity	Chapter 7	Paper 7
Summary of results	Conclusion	

The only exception is paper 1, which corresponds in content to the Introduction, instead of to Chapter 1. Thus Chapter 1 has no corresponding research paper. From the very beginning, the research papers were written as a tightly knit fabric, in spite of the numerous disciplines touched upon and the fairly frequent changes of perspective.

The chapters develop the same underlying themes, addressing the same fundamental questions concerning the epistemic conditions of ICT enhanced learning and digital interaction. Because in the course of the dissertation some basic concepts are developed further, the passage from one chapter to another may in some cases require prior clarification. The central conceptual construct in Chapter 2 is digital nomadicity, corresponding to advanced nomadic and ubiquitous computing environments. Constructivism is the focal, conceptual construct in Chapter 3, mobile learning and mobile learning objects in Chapter 4, abduction in Chapter 5, low knowledge in Chapters

6 and 7. Hence there are altogether six central conceptual constructs, whose interrelations, in terms of the layout, may be presented schematically, in the form of a conceptual map, as follows:

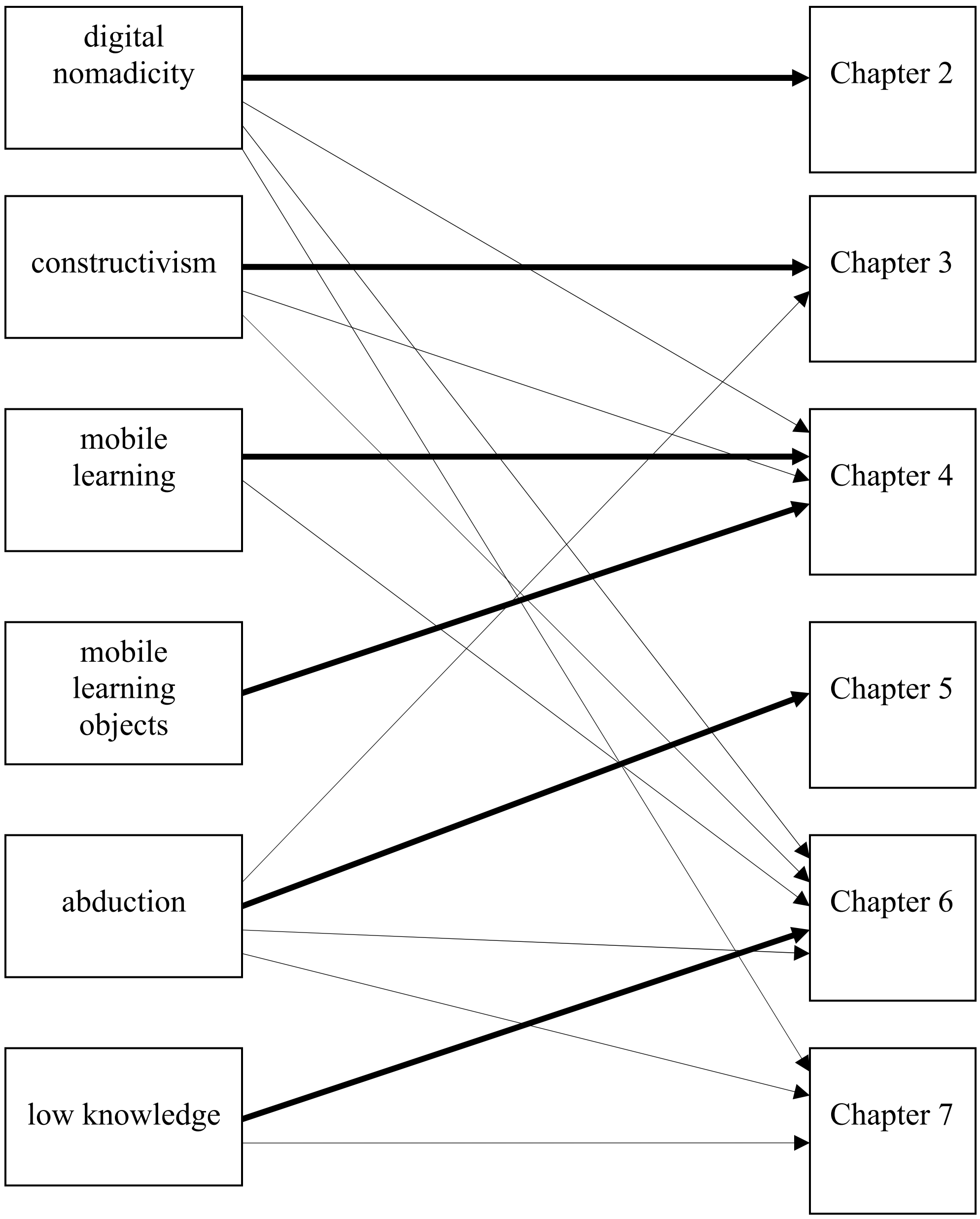

Figure 2: Interrelations between conceptual constructs and chapters

The bold arrow indicates in which chapter each conceptual construct or topic makes its first and primary appearance, whereas the thin arrows indicate which chapters build on or develop the same topic. For instance, digital nomadicity is central in Chapter 2 but also a relevant part of the theoretical background in Chapters 4, 6 and 7. The dissertation makes a modest claim of originality about the last three of the above conceptual constructs: mobile learning objects, abduction and low knowledge. It seems that they have not been applied to ICT enhanced learning and digital interaction in this manner and extent before.

1 Method

1.1 Call for methodological renewal

Consider these two appeals to Information Systems (IS) and computer science researchers:

> More specifically, we would highlight the absence of research considering the interactions of technology, instructional method, and the psychological processes of student learners (Alavi and Leidner 2001).

> Are the rapid developments in ICT outpacing our ability to judge their impact? (Jadad and Delamothe 2001)

The above quotations voice a growing concern among computer scientists and IS researchers over how little we still know about human-computer interaction in terms of psychological, social and cultural impact. Naturally opinions differ as to what exactly is wrong with IS research but the need for a methodological renewal is widely recognized. Before discussing the methodological tools in detail, the general methodological guidelines, which this particular research into digital interaction follows, are spelled out.

1.2 Three methodological guidelines

The methodological *credo* of this research can be expressed in the form of three guidelines:

- Apply a sophisticated conception of human knowledge

- Strive for a balanced treatment of both technology and the socio-cultural aspects of digital interaction and culture

- Picture the interaction between humans and technology as a constant struggle

It is perhaps fair to say that many IS researchers and computer scientists tend to have an unsophisticated conception of human knowledge. They often rest content with applying the so-called information processing view of the human psyche, which presents the user as an information processing system in analogy with the information processing system of the technology used (Kuutti 1995). This simplified view of human knowledge seems to have been sufficient for many short-term design projects. All the same, information systems science is not just about data and information but about knowledge, communication, collaboration and culture. Consequently, research into digital interaction needs to be based on a sophisticated conception of human knowledge. What is a sophisticated conception of knowledge is a matter of opinion. The Sociology of Knowledge (i.e. the Edinburgh school, e.g. David Bloor, Martin Kusch, Harry Collins, among others), the Structuration theory (Anthony Giddens) and the Activity Theory (e.g. Yrjö Engeström) spring to mind. Right or wrong, their understanding of human knowledge is sophisticated.

An unfortunate result of an unsophisticated or oversimplified view on human knowledge is that designers and researchers tend to ignore social and cultural factors. It leads to technology driven design and technological determinism. Sociological and cultural studies in turn are often guilty of an opposite fault: they tend to blackbox technology. They do not look into the technology itself in any significant detail.

Human interaction with technology is a constant struggle because technology changes us (as users) and we (as users) change technology. Technological artefacts are constantly modified, put to new uses, and given new meanings by the users (Punie et al. 2003). For instance, the designers could not predict that the users would use the Short Messaging System (SMS) in the way they nowadays do. Technology in turn changes how we humans behave, perceive and think; the SMS has changed how we make and keep appointments. To avoid both blackboxing and oversimplification of human cognition a balanced treatment of both technology and the socio-cultural aspects of digital interaction and culture is required. Human interaction with technology is a two-way street.

1.3 Abduction as a conceptual tool for studying digital interaction.

Abduction is a single unit of analysis, allowing the study of diverse phenomena with good scientific accuracy. In other words, it is a cross-disciplinary tool. Because it is a cross-disciplinary conceptual tool, both Information Technology (IT) people (e.g. computer scientists) and the Humanities people should accept it. Abduction is sharp and analytic but also broad and rich enough to enable research into digital interaction and culture in a way that does justice to both technological and socio-cultural factors in human-machine interaction. Secondly, by using abduction one can focus on the epistemological conditions of digital interaction, that is, focus on how the IST affects what we can know and how we know it. Finally, abduction can be made to conform to the aforementioned three methodological guidelines.

Abduction is not yet fully understood but it certainly seems a better conceptual tool than descriptive adjectives like "mobility" and "ubiquity" that are presently used especially in mobile technology research. It is better because: (i) abduction is a single (as well as rigorous and well-defined) unit of analysis, allowing one to analyze and compare diverse phenomena with good scientific accuracy; (ii) abduction catches the gist of how we humans reason under uncertainty in a context. It may be perplexing to see abduction serve a double role: as both a tool and an object of research. However, the existence of an inferential process called abduction is not in question but taken as given. As a methodological tool, abduction brings to mind fuzzy logic, which was at first an outcast but has by now proved its scientific worth and practical potential (see e.g. Zadeh 1975; Fuller and Carlsson 1996).

1.4 Three research traditions

The phenomenon of abductive reasoning has been discussed at some length in logic and rhetoric from Aristotle (Prior Analytics, 2nd Book, Ch. 25) to the early19th century. In the late 19th century, the study of abduction was taken up by the American philosopher Charles Sanders Peirce, whose interpretation and development of it has set the stage for all subsequent research. There are at the moment three distinct fields of application with their own issues and interpretational traditions: logic programming, scientific method and everyday reasoning. Abduction is thus interpreted as:

1. a method of scientific research or inquiry (logic of discovery)
2. a method of machine reasoning (logic programming)
3. a model of everyday reasoning (*logica utens*)

Perhaps the bulk of research into abduction has so far focused on the first one, that is, its role in scientific methodology.

Let us take a brief look at abduction as a method of scientific inquiry. Peirce maintains that there exist only three elementary forms of reasoning: deduction, induction and abduction (CP 8.209; Hoffman 1997; Rizzi 2004). Peirce's canonical examples of the three basic inferential forms are the following:

Deduction
Rule: All the beans from this bag are white.
Case: These beans are from this bag.
Result: These beans are white.

Induction
Case: These beans are from this bag.
Result: These beans are white.
Rule: All the beans from this bag are white.

Abduction
Rule: All the beans from this bag are white.
Result: These beans are white.
Case: These beans are from this bag (CP 2.623).

These three logical processes can be seen as complementary operations of human cognition (Rizzi 2004). Deduction infers a result (conclusion) that is certain. Induction produces a rule (conclusion) that is valid until a contrary instance is found. Abductive reasoning produces a case (conclusion) that is always uncertain (i.e. merely plausible). According to Peirce, deduction shows that something must be; induction shows that something in fact exists; and abduction shows that something may be. Hence, abduction is the starting point of the self-correcting empirical research process – the first step to reasoning and interpretation. In order to the scientific process of inquiry to become methodologically complete, abduction (whose job is to form hypotheses to explain an observation) needs to be followed by deduction (to logically derive the consequences of the hypothesis) and induction (to empirically test the predicted consequences of the hypothesis) (Pückler u/d; Pape u/d; Hoffmann 1997; Flach 1996). In Peirce's own words: "That which is to be done with the hypothesis is to trace out its consequences in deduction, to compare them with results of experiments in induction, and to discard the hypothesis, and try another, as soon as the first has been refuted" (CP 6.469; CP 7.220). The cycle of abduction, deduction and induction as well as the justification of inferences are not at issue here. Consequently, abduction as part of scientific method is excluded from this study.

The second perspective to abduction, abduction as a model for logic programming, has likewise interests and a research tradition of its own. Let a very brief characterization of it suffice. Abductive logic can make computing machines more intelligent, that is, make them think and act more like humans do. Josephson and Josephson (1994) have modelled computing after the abductive inference model. In syllogistic terms, abduction is a *modus ponens* turned backwards (Wirth 1993; Josephson and Josephson 1994). Logic programming belongs to the fields of machine intelligence and design science, and shall not be discussed here.

Both in the study of scientific inquiry and logic programming, abduction is usually interpreted as Inference to the Best Explanation (IBE), that is, in terms of the so-called IBE model. The IBE model deals with the generation and assessment of hypotheses, focusing more on the formal-logical accuracy than the actual mental process of reasoning. The IBE model is not discussed in this work at all.

In this work abduction is to be understood as a particular form of everyday reasoning. Why is everyday reasoning so important? Hoffmann (u/d) is not completely wrong when describing the role of abduction in the following, all-embracing manner: “The truth is that the whole fabric of our knowledge is one matted felt of pure hypothesis confirmed and refined by induction” (p. 9/21). Abduction is an intellectual tool, so to speak, especially suited for dealing with incomplete evidence under high uncertainty in complex real-life situations or in ill-structured disciplinary fields of knowledge (Spiro et al. 1988). Knowledge by abduction seems to have had a more dominant and widespread role earlier in history. According to the Italian microhistorian Carlo Ginzburg (1989), certain 19th-century sciences or disciplines typically allowed or called for interpretation and the searching of clues. Ginzburg calls them symptomatological sciences. Medicine, history, physical astronomy, geology, palaeontology, physical anthropology, ethnography, archaeology belong to the symptomatological sciences. These disciplines could also be called – at least in their 19th-century form – private detective sciences. They embraced the semiotic paradigm of knowledge based on the searching of clues or symptoms.

It appears that abduction suits admirably for describing and explaining the special epistemological circumstances of modern ICT mediated learning and digital interaction in general. (At this point it is underlined that the term digital interaction should be understood more broadly than has usually been done in Human-Computer Interaction (HCI) research. It includes also machine-to-machine interaction and human-to-computer-to-human interaction. It would be unwise to define digital interaction too restrictively as the nature of digital interaction is very much at issue in this work.) An advanced mobile computing situation calls for, or even compels to, the use of abductive reasoning. From a HCI design viewpoint, abduction as everyday reasoning is important because “Systems that do not mesh with natural social behaviour will fail or lead to unforeseen outcomes” (Grudin 2002, p. 78). It is material to be borne in mind that this work concentrates as good as exclusively on the last item of the above list, that is, on abduction as a model of everyday reasoning (*logica utens*).

1.5 Minor methodological considerations

Chapter 2 focuses on the recent developments in digital technologies, and will not discuss abduction. The chapter on mobile learning objects (Ch. 4) is the only other chapter in which abduction is not explicitly mentioned. Chapter 4 has been included in this study for three reasons. First, abduction seems especially applicable for mobile users. Therefore knowing the design requirements for mobile learning helps one to estimate the role of abduction in mobile learning. Second, it seems wise to have a more empirically oriented work included in the dissertation for the sake of balance and practical applicability. Third, mobile learning objects are a novelty, and discussing abduction simultaneously might be confusing. The chapter on mobile learning objects addresses the same cognitive and technological issues as the rest of the chapters. Leaving it out would have made the story less intelligible.

As a rule, learning is discussed from the viewpoint of constructivist pedagogy. Constructivist pedagogical theory has been chosen not because it would be the best theory around (although it might be) but rather for the sake of clarity. This point requires some explanation. To begin with, technologies designed or used to support learning abound. Technology embodies psychological claims of the user, thus suggesting and partly determining user behaviour. Designers, educationalists and learners may all have their own, mutually conflicting expectations or ideas of the particular technologies supporting learning. Some technologies are more malleable than others, submitting themselves to many different interpretations and uses. Some technologies are less flexible. Identifying a coherent set of pedagogical principles and expectations of learner (user) behaviour makes the assessment of particular technologies easier. For this reason alone, it seems wise to focus on a particular pedagogical view, which in this case is constructivism.

Constructivism is recognized to be one-sided, as presumably all other pedagogical theories. Let it be clear therefore that this study is in agreement with the critics of constructivism on certain central points of criticism. It goes almost without saying that not everything is a social construct but sometimes the material reality (e.g. quarks) offers resistance that cannot be "constructed" at will (against epistemological relativism) (Collin 2001). Knowledge is a human activity which is partly unconscious and tacit, involving tools – language as a tool included (against representationalism). Generally speaking, knowledge is built or created in collaboration with others (against mentalism) (Paavola et al. 2002; Lehtinen 2003). Knowledge and learning is not just what people think or say but also what they do as members of a community (against solipsism) (Kivinen and Ristelä 2003). On the other hand, this study attempts to avoid sociological reductionism – the idea that all can be explained by social factors – and defends the position that we do have mental processes. After all, we do have conceptual and logical means of making sense of these mental processes. Abductive inference is one such means.

1.6 Method in a nutshell

The research at hand is theoretically oriented and cross-disciplinary, building both on a wealth of previous empirical research results and theoretical studies in a variety of scientific fields. The following fields are at one point or another touched upon: information systems, computer science, technology studies, logic, epistemology, pedagogy, psychology, semiotics, media studies, economics and sociology. Abduction enables one to cross these disciplinary boundaries and at the same time to retain an acceptable level of scientific rigour. On the one hand, abduction is an analytical tool that will explain some key features of advanced IST, clarifying how the technology environment is constructed from an epistemic point of view. On the other hand, abduction is probably the central inferential mechanism at work when users learn or interact in an IST context, thus explaining (or modelling) what goes on inside the user's head.

2 From Mobility to True Nomadicity and Ubiquity

2.1 A paradigm shift in IST

Mobile technology has been characterized as mobile, interactive, ubiquitous, localized and personalized. It is becoming blatantly clear that these key concepts used in computer science and information systems literature – most notably those of nomadicity, mobility and interaction – cannot any more satisfactorily capture the present-day reality of advanced mobile technology environments (Keen and Mackintosh 2001; Carlsson and Walden 2002). More recently, concepts like context-aware, virtual and multisensory have been used in this context, but these features usually assume, among other things, a more advanced, fully working third generation (3G) network or other more advanced mobile technology environments that are not yet generally in place, and if in use, only tentatively so (Anckar et al. 2003). However, this state of affairs has not prevented some visionaries (esp. Peter Wegner, Carsten Sørensen and Leonard Kleinrock) from stealing a glance at things to come. These visionaries argue that we are entering a new world of digital nomadicity, transgressing the confines of a more static type of mobile communication and collaboration. Although we are still partly trapped in the old world of fixed computing platforms, accessed by users with the same (personal) device from the same IP address, the world of radical mobility – true nomadicity – is just round the corner (Kleinrock 2001).

The terms "paradigm" or "paradigmatic" have been used for instance by Carsten Sørensen (2002; 2003) to refer to the significant difference between the old idea of mobility and fluidity (fluid interaction); and by Leonard Kleinrock (2001) to refer to the shift from nomadicity in a disconnected world to a transparent, adaptive and integrated nomadicity. The word paradigm should not be understood in a strict Kuhnian sense, though. First, the new vision of true nomadicity is still without a sharp and systematic enough conceptual apparatus in order to seriously challenge the old paradigm. Second, and more importantly, we are here dealing with a technological entity, a construct that did not exist before. The construct has changed the world (reality), so the conceptual shift does not entail a sudden *Gestalt* switch while the research object stays the same, which is generally the case in Kuhn's examples (Kuhn 1962). Rather, in the case of digital nomadicity the concepts have ceased to describe reality in a satisfactory manner as technology has evolved. In this context, one would rather speak of an epistemic rupture, a breaking point in our conceptual arsenal and discourse.

In this chapter some central conceptual tools used by writers on advanced mobile technology (esp. nomadicity and mobility) are analyzed. In line with Peter Wegner, Leonard Kleinrock and Carsten Sørensen, it is maintained that these concepts are not any more satisfactory as tools of scientific research into advanced information and communication technology (ICT), or even as tools of popular understanding. To conclude with, the chapter presents and discusses some candidates for conceptual tools (fluidity, metaspace, micromobility and multiple-personalization) that might better catch the social and technological properties of true nomadicity and ubiquitous computing. Taking the advice of Orlikowski and Iacono (2001), an attempt is made to meaningfully combine both the technological and sociocultural aspects of the matter. It should be noted that the focus of interest is not so much in what kind of a new breed of man (Castells 2001) or new organizations (Järvenpää and Leidner 1999) our society is giving birth to but in the actual human-computer and machine-to-machine interaction and its epistemic conditions.

2.2 Nomadicity

"We are all nomads," says Leonard Kleinrock in an article that was published in 1996. And he continues: "but we lack the systems support to assist us in our various forms of mobility" (p. 351). For Kleinrock, nomadicity means two different things. First, nomadicity is used to describe a vision of a perfectly connected environment: "The essence of a nomadic environment is to automatically adjust all aspects of the user's computing, communications, and storage functionality in a transparent and integrated fashion" (*Ibid*). This sentence is presently widely used as a definition of nomadic computing. Being on the move, in transit, is here seen as a normal part of the life of digital nomads. However, Kleinrock also uses "nomadicity" to refer to a situation where a mobile user gets disconnected because the environment does not support perfect connectivity. The title of his paper underlines this second meaning of nomadicity:

"Nomadicity: Anytime, anywhere in a disconnected world". The second meaning has since been adopted by the mobile computing community so that by the phrase "go nomadic" is meant the phenomenon of a temporary disconnection: "It is desirable that mobile devices be able to cope with temporary disconnection (or "going nomadic") as it is known in the mobile computing literature" (Hawick and James 2003; Alanko et al. 1999).

In a more recent paper, Kleinrock (2001; see also 2004) starts off with the assumption that most users of computing, communication and services are people on the move, and that sudden changes in connectivity and bandwidth should be treated as the norm rather than exception. Here the word nomadicity is systematically used to refer to a phenomenon in which the state of being on the move is the normal state and not a break from the normal. And, when mobile devices get disconnected, they get disconnected rather than "go nomadic". Kleinrock underlines the need for a better infrastructure and a more advanced system support for nomadic users so that the computing environment adjusts itself to the user rather than the other way round. Computing should become as transparent and convenient a product as electricity (on the utility model see Rappa 2004). According to Kleinrock, we are on our way to a world of true nomadicity.

2.3 Old school of mobility, localization and personalization

Portable computing – in the form of laptops, mobile phones, PDAs and handheld computers – set the so-called knowledge workers free from the physical confines of the office. Along this line of thought, mobility has traditionally meant the ability of the user to move anywhere, anytime and yet stay connected, independently of the geographical constraints. For instance, Kopomaa (2000) talks about urban nomads and their "placeless use" of mobile devices. For Dahlbom and Ljungberg (1998), mobility implies that the user is away from his or her usual stationary point of activity (the office, for example), facing a changing and unpredictable context that deviates from the normal situation of use. Consequently, most of the research on mobility has dealt with technology issues such as limited battery life, unreliable network connections, volatile access points, risk of data loss, portability and location discovery (Wiberg and Ljungberg 2001). This sort of technologically oriented view on mobility has been aptly summarized by Messeter et al. (2004) as follows: “Even if connectivity and location-based services receive a lot of attention in the mobile technology industry, the dominating rhetoric still revolves around providing the functionality of the conventional office environment ‘anytime and anywhere’, regardless of contextual factors”. This kind of mobility Kakihara and Sørensen (2001; 2002) call spatial mobility: people in the post-industrial era are geographically independent “nomads” supported by various technologies.

Let us call it contextual mobility when context is, in some form, taken into account. Positioning (e.g. GPS, GLONASS and Galileo) is the single most important technology that makes contextual mobility possible. Apart from outdoor systems mentioned above there are indoors systems, which attain an accuracy of few centimetres, whereas outdoor systems usually have an accuracy ranging from one meter to hundreds of meters (Spriestersbach and Vogler 2002; Priyantha et al. 2001; Liljedal 2002). The most researched area in mobile context studies is the physical location of the mobile user. Examples include context-aware applications that enable users to discover resources in their physical proximity (Harter et al. 1999), active maps that automatically change as the user moves (Schilit et al. 1994), and applications whose user interface adapts to the user's location. Another aspect of context that is frequently discussed in research literature is related to the orientation of device position indoors (Bahl and Padmanabhan 2000). Dix et al. (2000), too, underline the importance of the physical locality and context in mobility: localization in mobile systems like mobile guides means that the interaction is based not on the device properties alone but on a device in a context – context includes the infrastructure context, the system context, the application domain context and the physical context. In other words, the location where the device is being used has an important impact on the nature of the information presented and on the whole interaction. All the same, this type of discussion focuses on the technological aspects of mobility. Some writers take a step further, trying for instance to make sense of both persons and devices moving in space (O´Hare 2000; Floch et al. 2001), and of the value that such technologically supported connectedness while moving creates in m-commerce or in work (Anckar and Eriksson 2003).

To sum up so far, in the early days of mobility, most mobile applications still sought to hide the location of use. Mobility meant first of all to be able to move anywhere, anytime and still stay connected – to be able to stay happily oblivious about location. In contrast, context-aware design, to name one example, tries to exploit location, making some aspects of it an integral part of the interaction between the user, the mobile system and the mobile device. Sørensen (2002; 2003) and his associates (Kakihara and Sørensen 2001; 2002; Pica and Kakihara 2003) have vigorously propagated for an even more expanded view on mobility, one which would better take into account the fact that not just devices and persons move but that also objects, spaces and symbols do so. This fact entails that over and above the spatial context, we consider the social and virtual contexts of use.

Personalization is a feature that is frequently connected to mobile devices. Compared to PCs, mobile devices like cellular phones and PDAs are very personalizable. Mobile devices are truly personal in the sense of being rarely shared by other people. They are also traceable, which makes it possible to link an individual with a particular device, and therefore tailor for instance services to suit the individual in question. By personalisation is also meant the malleability of the technology, allowing either the user himself to mould and adjust some of the device and interaction features or the technology learn about user preferences and automatically adapt to them (Lim et al. 2003; Smyth 2003). Research on personalization has been meagre and it has focused on personalization methods (computer science) and marketing applications. Personalization from the user's point of view has received little attention (Karat et al. 2003).

Researchers consistently stress the importance of personalization as the key to enhanced usability of mobile services. When machines universally talk to one another, personalized user interfaces seem to be the only way to reasonably well cater for individual information and service needs (Omojokun and Isbell 2003). As was mentioned earlier, the capability of accessing relevant information regardless of time and place was the main attraction for users just a few years ago: You could call or receive a call while lost in the woods but you could receive a call while paying your respects at a funeral. However, it does matter whether one is in the woods or at a funeral and one would like one's system to be able to tell those two apart. Time and place have not become less important but more important than ever, but our personalization techniques are not yet up to the challenge (Lyytinen and Yoo 2002a; Sørensen 2002).

2.4 Interactivity

Traditionally computability is seen in line with the algorithmic model. According to Peter Wegner (1997), equating computability with the behaviour that Turing machines are able to do (i.e. to compute mathematical functions), falls short of satisfactorily describing the behaviour of object-oriented and distributed or decentralized multiagent systems. Peter Wegner and Dina Goldin (1999; Goldin and Wegner 2004) say that the interaction of this sort of advanced computing systems is similar to dialog, question-answering and two-person games in the sense that inputs are dynamically dependent on prior outputs, whereas in a Turing machine the inputs are history-independent and reproducible. Keil and Goldin (2003) characterize decentralized multiagent systems as open systems that are constructed and constrained by the environment rather than designed. A termite colony is an example of a decentralized multiagent system in nature. Without design (i.e. an internal representation of a shared goal) as well as without a capacity for planning and coordination, the termites as a colony are capable of building a nest. If Wegner and Goldin are right, we have to revise our thinking not only of human-computer interaction but also of interaction within computers and computing systems.

Wegner and Goldin's claim that there is a new paradigm of interactive computation has not been accepted by all and sundry. Prasse and Rittgen (1998) dismiss Wegner's claim of interactive computing systems being open systems by saying that "if the external resources are integrated into the system, the system no longer interacts with the environment and we get a new closed system" (p. 359). It seems, however, that this is stretching the system theory too far; the line between two phenomena or systems may be fuzzy but that does not mean that the line (interpreted as a line between a system and the environment) would not be real but merely a mental construct. It is not in the eye of the beholder. Interestingly enough, some sociologists deny that human-computer interaction is really interaction. Stone (1996), for instance, says that interaction requires at least two conscious beings that are able to interpret, not just respond. However, in interaction between humans or two conscious beings, too, interaction entails that both parties play according to the rules (respond in a relevant manner), or act partial recursively, as Prasse and Rittgen (1998) put it. If I am engaged in a conversation and then run away, I am not engaged in a conversation any more. At least the definition of machine-to-machine and human-computer interaction should not be stronger than a hard-line sociological definition of interaction between humans.

2.5 Ubiquity

The term ubiquity (Lat. *ubique*, everywhere) conveys the idea that computing will be available everywhere and at all times. Ubiquitous computing and communication means intelligent environments in which various distributed computing units are linked together by heterogeneous communication links (Abowd and Mynatt 2000).

Ubiquitous mobile computing, in order to be really ubiquitous, entails that different networking technologies work seamlessly together (Chen and Petrie 2003). As a rule, coupling is made between cellular data networks and wireless local area networks (WLANs). WLANs are quicker, cheaper to maintain and operate than cellular networks. Cellular data networks again have wider coverage but are more expensive and slower. By combining the two, the user gets both high speed and anytime-anywhere mobility. The problem nowadays is that most integrated WLAN-cellular networks are parasitical annexes to cellular networks, without smooth and effortless connecting between different WLANs as the user moves from one place to another. Typically a WLAN-cellular network user needs to reconnect when he or she moves from a public WLAN to a private WLAN. There is no shortage of architectural models for integrating different networks. Logging in or signing in is both time-consuming and prone to errors. Consequently, a central problem in the integration is to manage connecting without having to login into several WLANs as the user moves about. When moving about the mobile device user can apply four principal strategies of reconnecting to a resource. The resource, say a news service, moves the resources with the mobile entity. This does not work with a database for instance. A copy is transferred with the moving mobile entity. This does not work when the copy is frequently modified. The reference instead of the resource is modified to refer to the remote host hosting the resource. Rebinding the mobile entity to an equivalent resource in the new locality. For instance a news service can be accessed in a new locality for up-to-date local news (Bellavista et al. 2003). Luo et al. (2003), to mention just one example, have presented a model in which the user needs to sign in and authenticate himself or herself just once. Kanter's (2003) Geobots service is another model, applying intelligent agents to automatically negotiate between competing local WLAN operators and GPRS access networks. Binding is not a simple matter, though context and location awareness help in choosing the suitable binding strategy. Notwithstanding, we are told that seamless network infrastructure is just round the corner.

The term nomadicity implies that the user carries the technology with him or her, whereas ubiquity implies that the world itself is computerized. Presently, these two lines of development are converging. Other terms related to ubiquitous and nomadic computing are for instance ambient intelligence, distributed and context-aware systems, tangible interaction, mobile informatics, pervasive computing and calm computing (Lyytinen and Yoo 2002b). In this work all the above mentioned things are considered to be slightly different perspectives to the same general phenomenon: very advanced mobile ICT environments.

2.6 Fluidity, metaspace and micromobility

This chapter seeks to make sense of the alleged new paradigm by presenting and discussing some candidates for conceptual tools. Carsten Sørensen, Daniele Pica and Masao Kakihara have borrowed the concept of fluidity from topology to describe the social patterns of interaction in advanced mobile ICT. They claim that fluidity describes better than the network metaphor the movement from one space to another. From a technological point of view, an integrated network of networks enables interactional stability, and interactional stability enables mobility regardless of the physical context as well as the continuous flow of virtual and real objects from one space to another across diverse networks, that is, fluidity. Pica and Kakihara (2003; Kakihara and Sørensen 2002) have characterized this feature of a nomadic environment as the duality of mobility: the dual possibility both to break loose from the physical (spatiotemporal) context and to enrich our contact with it by adding a virtual layer to it. From a sociological point of view, within a nomadic or ubiquitous environment – which by definition provides a transparent, integrated and convenient support for mobility – mobile devices synchronously bring real and virtual environments together, allowing us, the users, to be in both at the same time.

The cyberspace is a space of spaces. The study at hand suggests that there is a metaspace, a kind of a dominant (though transient) reference-point in the fluid topology. Someone or something is usually in some extent, some of the time in control of the relations between the different spaces of cyberspace. Someone or something configures or shuts out connections or in some other way steers the flow of interaction. For instance, different countries have different levels of access to the Internet (the digital divide); bandwidth varies at different locations; digital fences have been set up to prevent violations of copyright; private blocking software is blocking out sites; encryption and firewalls restrict access; different applications have built-in asymmetries or someone or something may control and configure applications so that the parties to an interaction are in an asymmetrical relation to one another (Bar 2001; Boyle 1997). It is a commonplace that we are not equal in cyberspace, and our models should be able to reflect this fact. It seems that there are distinguishable metaspaces that form the upper level of transient hierarchies of a fluid interaction. As the name indicates, these transient hierarchies change in the course of interaction, but most of the time there is a dominant space that somehow controls or overrides other spaces. A flat (egalitarian) space of spaces is rare. The transient hierarchies of the fluid interaction are presented graphically in Figure 2 below. One may of course change one's position *within* a transient hierarchy, for instance from a metaspace position to the bottom of the hierarchy. Fluidity is a metaphor or a regulative idea, which needs to be checked and balanced against the messy backdrop of reality. One could say that the concepts of metaspace and transient hierarchies function here also as such checks and balances. In other words, this chapter partly is an effort to pin down fluid interaction into something concrete, so that we do not lose sight of the technological limitations and the practical details of the situated, actual human-to-machine and machine-to-machine interaction.

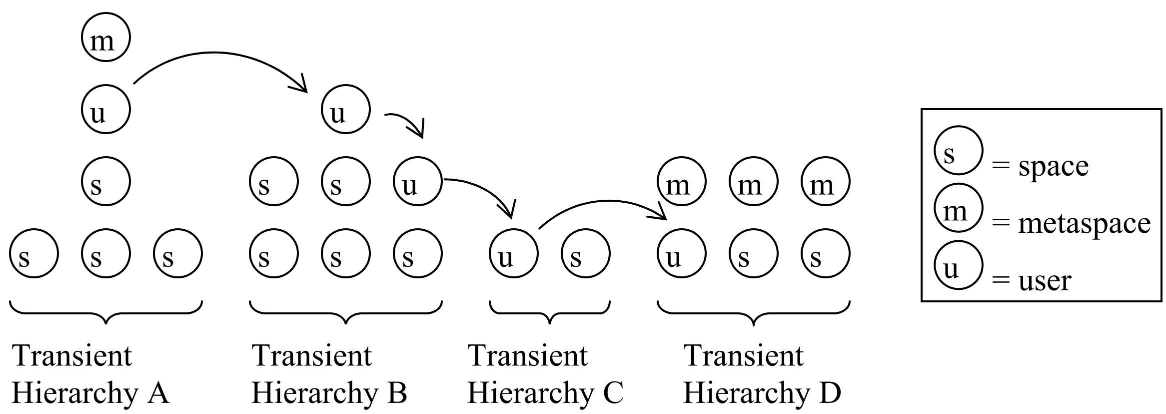

Figure 3: Transient hierarchies and metaspaces

Anyone who has taken part in a videoconference has got an intuitive understanding of metaspaces and transient hierarchies at work in a small scale.

One more thing delimiting digital interaction is micromobility. Luff and Heath (1998; see also Perry et al. 2001; Fagrell et al. 1999; Wiberg and Ljungberg 2001) have observed that distributed collaboration, i.e. mobile team work, runs into problems as the digital artefacts undergo small changes when transported from one space to another. The functional view on mobility (the rhetoric of "anytime, anywhere") generally turns a blind eye to micromobility, making all spaces equivalent. Unfortunately, in reality a paper document differs from its digital version on a PC screen, which in turn differs from a digital version of it on a mobile device screen. Consequently, the three manifestations of the same general object (document) often cannot perform a similar enough function in all three contexts of use to enable collaboration as intended. As Luff and Heath's (1998) observations indicate, complete fluidity is a distant and perhaps even an unrealizable dream. Even commonplace objects would need to be augmented by giving them virtual features or intelligence, and also the more mundane aspects of interaction would need to be successfully digitally enhanced and supported by ubiquitous computing. Lyytinen and Yoo (2002a) have addressed the same general issue when talking about the problems of digital convergence, calling for technical and managerial solutions to them. Hopefully, metaspaces, transient hierarchies and micromobility open up a field of empirical study into the conditions and practices of digital interaction (e.g. communication, collaboration and learning), capturing the mixture of social-technological and real-virtual aspects of interaction.

2.7 Multiple-profiling

Nomadic and ubiquitous environments are prone to be markedly intrusive and insensitive to the user's desires and intentions. Fluidity implies that the user, owing to the extreme flux or fluidity of multiple spaces or contexts, often is not in control of the terms of interaction. Personalisation technologies are supposed to level the way for better user control and usability in context. Unfortunately, many ambitious models of context – for instance within computer science – approach context mainly from the computing system perspective (Chen 2003). As a result, these models have a distinct element of the big brother. The same issues could be approached from a user perspective. In this way the big brother aspect could be tuned down. From the user's perspective the following aspects of context seem to be of fundamental importance:

1. Who am I?
2. What is this place?
3. Who are these people in this place?
4. What devices and artefacts are around or carried by these people?
5. Why are these people, artefacts and devices in the environment?

Despite appearances the first question is the most important of all. Nothing determines the suitability of a service or mode of interaction better than the role or identity of the user in a given context. The user should know or at least easily find out his or her own role in the situation, and also be able to change his or her role at will. Social roles, identity and anonymity are determinants of human behaviour and interaction over which the user needs to have some control. The transparency of the user's actions to the user himself or herself is a goal to be strived for but difficult to attain in design (Kramer et al. 2000; Purao and Krogstie 2004). In addition to the system context, the designer has to take into account the geographical, the (relative) locality, the temporal, the social and the virtual contexts (Junglas and Watson 2003; Avital et al. 2004; Prasopoulou et al. 2004; Lee and Sawyer 2002). Not even this suffices because, as Upkar Varshney (2004, p. 70) points out: "different users could act quite differently even in the same context".

Multiple-profiling (or multiple-personalization) might be of some assistance in meeting personalization requirements in a truly nomadic environment. Multiple Personality Disorder (MPD) is a codified psychopathological state in which an individual manifests many (multiple) personalities per body. Usually one (or several) of these alter-personalities may be conscious of some other alters residing in the same body (Allison 1998). Applied to cyberspace, multiple-profiling means that when moving from one space to another the user changes personality, i.e. profile, to fit the space he or she is in at that particular moment. The user can change profiles by modifying an old one or by purchasing or borrowing a new (ready-made) one, or the modification may take place automatically (i.e. to trump up a profile for the occasion). A ready-made profile is a software programme riding on the data stream, and its job is to configure (e.g. to decide what personal information to give, choose the level of user expertise) and personalize the systems, applications and networks encountered. The change of profile in a fluid cyberspace is a frequently recurring event, which needs to be negotiated. Negotiation is performed either automatically or by intelligent agents or by users or by a combination of these (see Figure 1 above: the arrows indicate a change of profile). One should observe that a change of profile usually means a change of hierarchical position, over and above the change in position that follows from a transition from one space to another.

2.8 Boundary crossing in everyday life

As Mark Weiser (1991) predicted, computing is disappearing to the background. The fact that it disappears from the centre of attention helps the user focus on what he or she really is doing, that is, focus on the real task at hand and not the tools. Foregrounding (i.e. deciding what the real task at hand is) is extremely difficult to master since background knowledge is largely tacit and increasingly embedded in the technological infrastructure. As we know from human interaction in general, keeping some knowledge at the background and uncodified is not something neutral but may be a significant exercise in discursive power (Duguid 2005). Therefore, the user and not the technology should be in charge of how, when and which things move from the background to the foreground or vice versa (Abowd and Mynatt 2000). As a rule, the user is unable to interpret the technical infrastructure underlying the interface. The user should be able to do so because technologies most likely have at least partly inherent values and consequences. In other words, technologies are not infinitely malleable locally (Winner 1986; Kallinikos 2002; Longford 2005; Brey, Forthcoming). It means that even if the user could make sense of the underlying technical layers, he or she has relatively few (physical or social) means of modifying them. Unfortunately, our digital media literacy in general is lacking not just in "reading" skills but much more so in "writing" (e.g. programming) skills, which prevents users from exploiting the already small potential for moulding technology. Gleason and Friedman (2005) argue that we should be able to predict the consequences of our use of information society technologies (ISTs) in the same way as we in the physical world are expected to predict the potential impact of our tools to others. In a nutshell, technology has to be domesticated (Punie et al. 2003). Rather than the technological and economic considerations, the user and his or her needs, capabilities and routines in the everyday life should inform design: "Ambient Intelligence will be aware of the specific characteristics of human presence and personality" (Punie 2003, p. 6). This sort of sociological everyday life approach, advocated by Yves Punie and his colleagues, starts from human concerns, trying to identify barriers for the use of ISTs in everyday life. Hence any attempts at helping the user cross all sorts of barriers and boundaries – however petty they may seem – in his or her everyday use of the ISTs are highly welcome.

In order to further illustrate some central concepts discussed so far, here are a few simple examples from several research projects (mobile learning project and mobile physicians) and the Finnish mobile telecommunications market (Multi-Sim and Dual-Sim).

The first example originates from a research project on mobile learning. In this project, several students used Personal Digital Assistants (PDAs) during several weeks in an Information Systems course given at the Åbo Akademi University. Students borrowed the devices during the project, and used the mobile system in parallel with their own mobile phones. The mobile system could be used to retrieve course materials, interactively discuss course matters and to check if other course participants were remotely available for interaction. The students reported that the use of the PDA in parallel with their own mobile phones appeared to be a problem because it was not possible to synchronize information (e.g. personal contacts) between the two devices (Patokorpi et al. 2006). The students had to juggle between two different information spaces, and to choose the information space they needed depending on the situation, while the devices did not support such transition from space to space.

The second example relates to a project where mobile physicians, who act in both civil and military medicine, use a mobile medical database, using the same mobile device. The mobile medical information system, used in this research, is designed by Duodecim Publication Ltd. It is a set of medical information and knowledge databases. It contains the Evidence Based Medicine Guidelines (EBMG) (available in both English and Finnish) with Cochrane abstracts, a pharmacology database, Pharmaca Fennica, with a wireless update service for a complete medicine price list, the international diagnosis code guide (ICD-10) in Finnish, a laboratory guide by the Helsinki University Hospital, an emergency care guide issued by the Meilahti Hospital, a medical dictionary of over 57,000 terms, and a comprehensive database over health-care related addresses and contact information (pharmacies, hospitals, health centres). The duties and information needs are different in civil and military medicine. In the project, physicians expressed the need for the possibility to customize the database according to the situation at hand. For example, the defence forces do not use the same drugs as in civil medicine (Tétard et al. 2006; Han 2005).

Multi-Sim is a service introduced by a major telecommunications company on the Finnish market in 2006. The service allows customers to use one mobile phone number on two phones, without the need to transfer the SIM card from one phone to another. In practice, the customer has two SIM cards (one main subscription and an additional card) that he or she can install in his or her phones. Additionally, the number is shown to the recipient of the call or text message as the same, regardless of whether the main subscription or the additional card is used (TeliaSonera 2006). The service is very handy for users who need to use different phones in different situations, but still want to be reached through the same number, regardless of which phone they use. This service illustrates the concept of multiple-profiling: the user has the choice to use a different device, according to his or her own needs, whereas the system is transparent for those recipients who choose not to know which device is used.

The Dual-Sim service is expected to be launched in the fall 2006. Several manufacturers have produced devices that allow the use of several SIM cards in the same phone; although not simultaneously. The innovation of the new Dual-Sim service will be that both SIM cards will be available at the same time. The service will be handy for people who want to use the same device in several situations, but need to use different connections (for example, one connection for leisure and one connection for work; or one connection including a special set of mobile services and the other including another set of features). This illustrates the concept of multi-profiling: using this service, the user could use the type of connection he or she needs without changing the device or the SIM card.

One promising advance, which can be observed on the telecommunications market, is the launch of new devices which integrate WLAN and 3G technologies (for example, Nokia mobile phones). Beyond the possibility that these devices offer to use different network access depending on the context and the preferences of the user, these new devices will offer seamless integration between different access technologies, so that the shift from one network to the other will be transparent to the user, for example, when a user moves between geographical areas with different network coverage and different network access technology.

The examples above illustrate how advances in mobile technologies (devices, networks, and software) will enable true nomadicity and extend our understanding of mobility. Although several problems remain, as illustrated in the first and the second examples, it appears that technology advances illustrated in examples 3, 4 and 5 will solve several problems by enabling fluidity between different information spaces, giving the user control over the transition from one information space to another, and allowing transparency about the different information spaces.

2.9 Future challenges

As technology has evolved, some key concepts widely used in information and communication technology (ICT) literature have adopted a confusing double meaning. For instance, nomadicity implies both the technological capability to deal with temporary disconnectedness, caused by movement from one connected place to another connected place, and the seamless technological support for nomads, for whom being on the move is the normal state of affairs. Mobility means both to be able to disregard context ("anywhere, anytime") and to enrich interaction by contextual factors. It is beginning to be a widely acknowledged fact that context has not become less important but more important than ever. Consequently, current research is focusing more and more on contextual issues. One decisive factor in contextual mobility is personalization, but, clearly, present personalization techniques are not yet up to the challenge.

Peter Wegner (1997) and his associates question whether the algorithmic model of computing can tell us what is happening for instance in distributed multiagent systems, which they call interactive systems. Indeed, we live in a largely man-made world, and there seems to be need for attempts – similar to Wegner's – to conceptually bridge the gap between humans and machines. It seems also clear that researchers and designers need to come to a better understanding of interactivity. Unfortunately, the term interaction is currently carrying excessive intellectual baggage.

Wegner, Kleinrock, Sørensen and their associates may be right in claiming that certain very advanced ICT or IST environments constitute an emerging paradigm, whose present-day manifestations include nomadic and ubiquitous computing. This chapter has sought to make sense of the alleged new paradigm by presenting and discussing some candidates for conceptual tools. Sørensen and his associates have proposed the metaphor of fluidity to describe the patterns of social interaction in advanced mobile ICT. The present chapter has presented and discussed the concepts of micromobility (borrowed from Luff and Heath 1998), metaspace and transient hierarchies. The objective has been to pin down fluid interaction into something concrete, so that we do not lose sight of the technological limitations and the practical details of the situated, actual human-computer and machine-to-machine interaction. Hopefully, the concepts of micromobility, metaspaces and transient hierarchies open up a field of empirical study into the conditions and practices of digital communication, collaboration and learning, capturing the mixture of social-technological and real-virtual aspects of interaction in cyberspace. Lastly, multiple-profiling is suggested as one potential means of meeting personalization requirements in a truly nomadic environment. A key question in the near future is how the user of advanced mobile technology could be made more aware of as well as empowered to have more control over the multiple spaces he or she inhabits and the numerous boundary crossings that he or she is forced to perform.

3 Constructivist Instructional Principles, Learner Psychology and Technological Enablers of Learning

3.1 Combining education, psychology and technology

As technology keeps evolving, things like mobile learning and edutainment become more commonplace, challenging the old pedagogical principles and practices. Yet it is not clear how the new Information and Communication Technology (ICT) will (if at all) change the ways we perceive the world around us, and how educators could or should use the new tools? In fact, we are still struggling to make sense of the impact of the more traditional forms of ICT, like PCs, on learning. Kuh and Vesper (1999) and Flowers et al. (2000) number among the very first major empirical studies on the cognitive effects on learning exerted by more traditional ICT.

Constructivist pedagogy has been here singled out for scrutiny because, in the happy phrase of Richard Fox (2001, p. 23), constructivism is “the uncritically accepted textbook account of learning". In constructivist learning theories, knowledge is seen essentially as a social construct. Because the learner builds on his prior knowledge and beliefs as well as on the knowledge and beliefs of others, learning needs to be scrutinized in its social, cultural and historical context (Piaget 1982; Piaget and Inhälder 1975; Vygotsky 1969; Leontjev 1977). According to Järvinen (2001), technology enhanced learning supports “naturally” learning by manipulation, comparison and problem solving in a non-prescriptive real-world-like context that leaves room for creative thinking and innovation. Consequently, one major reason for educationalists to embrace ICT is because ICT enhanced learning seems to tally with the central principles and objectives of constructivist pedagogy.

As was mentioned above, constructivists generally assume that the central principles and objectives of the constructivist pedagogy are realized by ICT enhanced learning. This chapter critically examines the grounds for this assumption in the light of available empirical and theoretical research literature. The inspiration for this chapter derives from

Alavi and Leidner (2001), who have called for research on how technology, learning theory/practice and the learners' psychological processes are related and influence one another. Methodologically, this is an exploratory study, building on hermeneutic psychology and philosophical argumentation. Hermeneutic psychology and philosophical argumentation are applied to identify some potential or actual weaknesses in the chain of connections between constructivist pedagogical principles, psychological processes, supporting technologies and the actual application of ICT in a learning environment. Pragmatism enters the picture as a ready source of criticism, bringing out a certain one-sidedness of the constructivist view of man and learning.

3.2 Constructivist instructional principles and the impact of ICT

Recent research literature indicates that there is a fairly clear consensus on a broad set of constructivist instructional strategies (Järvinen 2001; Ahtee and Pehkonen 1994; Jonassen 1994; Johansson 1999; Poikela 2002; Poikela and Nummenmaa 2002; Pehkonen 1994; Lehtonen 2002; Engeström 1987: Engeström et al. 2002; Leino 1994). First of all, constructivist pedagogues underline the importance of a larger goal that organizes smaller tasks into a sensible whole, giving an incentive to take care also of the less exciting intermediate routines. Learning is not focused on separate facts but on a problem. The learner needs to feel that the problem in some way concerns him (i.e. to own the problem) in order to be motivated to try to solve it. The problem should be close to a problem in the real world. Unlike in traditional teaching, in constructivist learning there is no one right answer but many possible solutions to a problem or at least if there is one right solution, there are many alternative routes to it.

It follows from what has been said above that it is the learner and not the teacher who needs to take in a significant degree the responsibility for gathering knowledge. The learning environment, too, should be in some sense similar to a real-world environment. This usually means going out from the traditional classroom, and learning things in their authentic environment. The learner's prior knowledge, experience and skills should be taken into account because the learner will better understand and remember new things if they are built on his prior knowledge and experience. People are different, with different experiences, skills, interests and goals. Constructivist education seeks to take this fact into account by leaving room for alternative individual learning strategies.

Constructivists underline the social aspect of learning; all forms of interaction are encouraged, and usually assignments involve teamwork or other forms of cooperation. The final feature stressed by constructivist pedagogues is guidance; the teacher's role is to facilitate learning by giving pieces of advice and guiding onto the right direction. Although teachers do not slavishly follow these strategies every time, their impact on educational practices is considerable.

A cursory look at what educationalists say about ICT in education indicates that ICT-mediated learning seems exceptionally well to tally with the constructivist instructional principles. According to Sotillo (2003), "New developments in wireless networking and computing will facilitate the implementation of pedagogical practices that are congruent with a constructivist educational philosophy. Such learning practices incorporate higher-order skills like problem-solving, reasoning, and reflection". It seems that the students cooperate more, work more intensively and are more motivated than in conventional classroom teaching. ICT enhanced teaching is an efficient equalizer, levelling regional and social inequalities (Puurula 2002; Hussain et al. 2003; Gruba and Sondergaard 2001). Langseth (2002) stresses creativity and the fact that the pupils take responsibility for their own work, and, instead of using their logical and linguistic faculties, use a "broader range of intelligences according to their personal preferences" (pp. 124-125). Langseth continues: "The web offers individuality in the sense that you can choose your own pace, your own source of information, and your own method; in a group or alone" (p. 125; Hawkey 2002; Kurzel et al. 2003). Furthermore, the focus is on collaborative work, not on the final product.

The above views are presumably quite representative of the enlightened popular idea of how ICT affects learning. All in all, ICT mediated learning is supposed to be more democratic, more personal, give broader skills, more creative, more interactive, and so forth. To cut a long story short one could say that both constructivist pedagogy and ICT enhanced knowledge and learning are supposed to be, by nature: cross-disciplinary, democratic, personal, collaborative, independent and practical (i.e. favour learning by doing). So, at least on the surface, it seems that ICT mediated learning and the constructivist educational doctrine is a match made in heaven.

3.3 Criticism of constructivism

Instructional principles should be based on an adequately correct understanding of the learning process. According to Kivinen and Ristelä (2003), cognitively oriented constructivists exaggerate the role of cognitive structures in learning. Contrary to what the constructivists say, what we humans do (i.e. construct) when we learn is not primarily cognitive structures but practical ways of doing things (habits of action), which we are not necessarily conscious of or able to articulate. Consequently, the role of deliberation in learning is not quite as central as cognitive constructivists tend to think. Constructivists also put too much emphasis on verbal knowledge (Fox 2001). For pragmatists, in turn, words and ideas are tools like any other man-made objects, and the creation of new knowledge is the creation of new ways of verbal and nonverbal action (Kivinen and Ristelä 2003). Likewise, as constructivists underline creativity and the active construction of personal meaning, they at the same time tend to ignore memorisation. Memorisation still serves an important function in everyday life and learning. Understanding without remembering would send us to endlessly repeating old errors (Fox 2001).

The human innate capacities and the maturation of the nervous system are not being sufficiently taken into account by constructivists. In context we passively absorb knowledge and adopt behavioural patterns. Fox (2001) implies that constructivism is to blame for the fact that nowadays teachers are unwilling to confront "the upsetting differences in innate ability or talent" (p. 33).

The role of training (drills) as part of learning is not acknowledged nor appreciated enough by constructivists. Training has its place in life because certain routines need to be performed quickly and correctly in order to enable us to direct our attention to matters of greater consequence. Richard Fox's (2001) example of training is a musician practising a musical piece. Fox says, "to the extent that a trial is an exact repetition of a previous trial, nothing has been learnt. The point of practice, in this sense, is to eliminate errors" (p. 32). Another favourite example that pragmatists typically present is driving a car (Kivinen and Ristelä 2003). The above examples nicely illuminate certain quite fundamental differences between the constructivist and the pragmatist views on learning. Consider the following example. One may practice writing one's signature, in which case an exact repetition implies that something has been learned. Golf training is another good example. Many golf players strive to train their swing so that it would be exactly the same every time. The difference in the trajectory of the ball is introduced by changing the club. Consequently, many cases of training have little or nothing to do with creativity but the overriding aim is to make the performance as machine-like and repeatable as possible (Collins and Kusch 1998). The traditional method of authority, applying the techniques of learning by rote, was used especially in the Middle Ages to ensure that the learners' performance adhered to and copied faithfully what the Church Fathers had written down. Army drills is another well-known example. Presumably, a more veiled or forced point in Fox's criticism is to imply that constructivism is poor at eliminating errors. Fox is perfectly right, but compared with the method of authority neither constructivism nor pragmatism succeeds very well in the elimination of errors.

Pragmatists recommend that learners concentrate on the subject matter, not on the learning process itself:

> Practices encouraging the observation of one's own learning as an end in itself can basically be seen as a mere rejustification of testing that has traditionally ruled school activities. Instead of the pupils being taught new skills and knowledge, they are trained to monitor their own studies. A gradual improvement in the ability to work independently is quite rightly an aim for education, but it is by no means self-evident that this can be achieved or promoted by intensive concentration on the operative aspects of one's own thinking (Kivinen and Ristelä 2003, p. 371).

Ignoring some obvious exaggerations, one could say that the most salient point of criticism in the above quotation is that too much introspection may be harmful. In defence of constructivism, one could say that it depends on what one is learning. Let us take foreign language pronunciation as an example. It stands to reason that a regular language learner should not consciously focus on the performance of the speech organs, unless there is a problem with the pronunciation. However, for a foreign language teacher trainee, who is learning to teach pronunciation, it makes sense to focus on the learning process itself (i.e. to consciously focus on how the speech organs work). Likewise, correcting speech impediments often requires conscious attention to the learning process itself. These two examples bring to light a genuine need for thinking about thinking retrospectively – as opposed to training in cases where there is no need to verbalise or make conscious the task or process itself. So, even student learners, not just university professors, may need to think about their thinking in retrospect for learning to be successful. In other words, to know what one knows is in some cases a valid learning goal by its own right.

3.4 Sherlock Holmes meets Forrest Gump

A certain kind of view of the learning process suggests a certain kind of (prototypical) learner profile. Constructivists strongly stress the element of active construction in human thinking and perception. A central inferential process behind the constructedness of human experience is abduction, which is also the principal method used by the famous literary figure, Sherlock Holmes. Abduction conveys the manner in which people reason when making discoveries in the sense of coming up with new ideas. Hence, abduction is considered a logic of discovery. As a logic of discovery, abduction is essentially a matter of finding and following clues. The observation of a clue is always in relation to the observer's background knowledge. The clues are there for all to see, which makes knowledge by abduction democratic by nature. However, all people do not detect these clues because the clues are qualitative and unique. This sets the stage for knowledge that is essentially personal. It is personal in the sense that individuals differ in their ability to detect clues, due to individual differences in their prior knowledge and experience as well as logical acumen (Peirce 2001; Ginzburg 1989; Peltonen 1999). As this very brief characterization of abductive reasoning indicates, knowledge by abduction is, by nature, personal, democratic, creative and based on prior knowledge. A Sherlock Holmes type of learner calls for laying out the learning materials as in a detective story. Pragmatists imply that more often than not deliberation is not worth the effort and one should not worry too much about the potential consequences of actions. The hero of the pragmatist learning ideology is Forrest Gump, and his slogan is: Just do it! The exhortation to go with one's gut feeling is seductive to many, but it smacks of irrationalism. Did Forrest Gump succeed because he did not reflect upon the tasks he was given or because he was dedicated, sympathetic and endowed with special innate talents? Human-computer interaction designers and researchers have noticed that some users are reluctant to read the manual, and rather resort to learning by doing (Carroll 1990). Forrest Gump, if anyone, seems to fall into this category of users. Unfortunately, the Sherlock Holmes of this world are no better themselves in this respect, prone as they are to figure things out on their own, hypothesize and overgeneralize. Hopefully there will be room for both Forrest Gump and Sherlock Holmes in each of us, although in some cases neither of them gets it right.

3.5 Link between technology and education

Gorard et al. 2003, claim that empirical evidence for the beneficial impact of ICT on learning is scarce. One reason for this alleged scarcity might be that we seem to lack the ability to estimate the influence of ICT, owing both to the complexity of ICT itself and disagreements among researchers concerning empirical methods or the interpretation of the findings (Jadad and Delamothe 2004). The brief and tentative discussion below is based on the available empirical and theoretical research literature, weighing the arguments pro and con presented there. Methodologically, the discussion applies the hermeneutic psychology of Carroll and Kellogg (1989; Carroll 1997); the idea is to interpret the psychological claims embodied in artefacts, or rather, in whole technologies. Equipped with a critical conception of the constructivist features of learning, one should be able to see clearer than before how well the constructivist pedagogy matches the most prominent features of ICT. Other important features of ICT enhanced learning of course exist – for instance time-to-performance (Wolpers 2004), cost efficiency, time savings

(Marcus 2000; Eales 2004; Judge 2004) and quality (Inman and Kerwin 1999) – but these features lack a clear connection to psychological processes. The table below lays out the interconnections between the constructivist pedagogy, psychology and technology, indicating the weakest link in each row by italics. A similar table with the pragmatist or, indeed, with the knowledge-creation movement's (Paavola et al. 2002) learning principles would look different.

Table 2: Links between constructivist pedagogy, psychology and technology

	Instructional theory: Constructivism	**Psychological processes**	**Technological enablers**	**Instructional practice: ICT enhanced learning**
Environment related factors	Problem-based, Close to real life, Many solutions	Abduction	Mobile technology, Virtual reality, Simulation	*Cross-disciplinary*
Personality related factors	Prior knowledge, Alternative learning strategies	Abduction, Induction, Deduction	*Personalisation technologies, End-user programming*	Personal, Cognitively flexible, Democratic
Action related factors	*Learning by doing or by manipulation*	Trial and error	Simulation technologies, e.g. computer games	Practical
Cognitive factors	Learner responsible for searching information	*Motivation*	Information retrieving technologies, e.g. the Internet	Independent, Democratic
Interactional factors	Interactive	Communicative and team work skills	Interactive technologies, e.g. hypertext and email	*Collaborative, Democratic*

The four columns mark out instructional theory, psychology, technology and instructional practice. Each column is divided into five rows. The rows are constructed on the basis of instructional theory (i.e. constructivist pedagogy) whose principles seem to fall fairly naturally into the five sets of factors: environmental, personality, action, cognitive and interactional. The general idea is that in an ideal case all the columns support each other. Thus in the first row (i.e. environment related factors) the principles of problem oriented learning can be best realized through abductive reasoning, supported by mobile technology, virtual reality and simulation, taking place in a real-world-like (cross-disciplinary) setting. As was mentioned above, the italics indicate the element which is the least supportive. The most pivotal interrelations are discussed in some detail below.

It is generally assumed that both constructivism and ICT provide ample leeway for integrating many disciplines into a meaningful storyline, for instance thanks to simulation technologies. Mobile technologies, too, expand the potential of problem-based learning environments, but to the direction of the real world, as they enable the learner to go outside of the traditional classroom. The weakest link in the first row (environmental factors) is cross-disciplinarity because therein the instructional design is difficult to arrange, owing to a compartmentalization of teaching subjects, inflexible curricula, a lack of ICT skills and a lack of teacher cooperation (cf. Spector 2000). In other words, attempts at cross-disciplinarity are riddled with the practical problems of daily teaching arrangements rather than with any fundamental problems in technological support, pedagogical theory or learner psychology.

Personalisation does not mean just accommodating materials to fit the learners' expectations, skills and experience but it also allows students "to break away from the expert view and follow personalised goals" (Kurzel et al. 2003). Personalisation is a central enabler for ICT enhanced learning, especially if and when learning breaks free from the desktop environment and becomes mobile and ubiquitous. Mobile devices are personal in the sense of being rarely shared by other people. They are also traceable, which makes it possible to link an individual with a particular device, and therefore tailor for instance services to suit the individual in question. By personalisation is also meant the malleability of the technology, allowing either the user himself to mould and adjust some of the device and interaction features or the technology to learn about user preferences, and automatically adapt to them (Lim et al. 2003; Smyth 2003). Unfortunately, we are still very much trapped in the old world of fixed computing platforms, accessed by users with the same (personal) device from the same IP address. The creation of personal knowledge is also hampered by barriers (e.g. copyright) to end-user computing. Personalisation technology just is not yet mature enough to support the creation of truly personal knowledge (Dolog et al. 2004; Kurzel et al. 2003).

There are various advanced simulation technologies that make simulated practice possible. Learning by doing has not been challenged directly by empirical research on ICT enhanced learning, although there must be differences owing to whether one is practical in the real world or in a virtual world. Owing to the conceptual vagueness of the term ‘practical,’ a closer scrutiny of the mental and behavioural processes at work in these environments seems to be called for.

The weakest link in the row of cognitive factors is motivation because in case the learner does not accept responsibility for seeking information, the constructivist pedagogy seems to have no ready remedy to it. How to motivate a learner to take responsibility if he or she refuses to own the problem? Moreover, information technologies per se do not give the user information seeking skills.

In an ICT enhanced learning environment the constructivist principle of interactivity translates into technology-enabled collaboration. There seem to be no major problems in terms of supporting technologies but collaborativeness partly undermines or interferes with certain other constructivist learning objectives. Constructivist learning methods generally require more guidance and feedback (Björkqvist 1994; Ahtee 1994). On the other hand, ICT is supposed to free the teacher’s time for just those activities. The dilemma here is that ICT enhanced learning seems to take more, not less, of the teacher’s time than traditional teaching (Eales 2004; Judge 2004). There is also a danger of too efficient guidance or instruction, which means that the facilitator ends up doing the learner’s work. A suggested remedy is the maximization of peer dialogue by means of interactive technologies (Mayes 2000; Saunders 2002). However, when the work is done independently in groups, i.e. away from under the watchful eye of the teacher, it may lead to free rider problems (Tétard and Patokorpi 2005). Hence the problems with collaboration are mainly in the area of instructional practice, as teachers have trouble in handling collaborative learning environments (Wielenga 2002)

It is generally claimed by constructivists that ICT enhanced learning makes learning more democratic. Interaction is more democratic between the knowledge source and the learner (Hussain et al. 2003). It is also democratic in the equally narrow sense of making the learner relatively independent of others in the seeking of information, and in building on the individual's own prior knowledge and skills. However, according to Gorard et al. (2003), ICT cannot solve the social problems of inequality and non-participation because it does not help to give access to ICT when the reasons for non-participation stem from prior long-term economic, educational and social factors.

3.6 Grievances and expectations

Artefacts as well as whole technologies embody social, psychological and aesthetic preconceptions, directing and moulding the way we learn and live. The designers as well as professional users of ICT (e.g. teachers) should be aware of these preconceptions. We should also become aware of the blind spots that all learning theories have. Then, having avoided these two above-mentioned pitfalls, the teacher applying ICT in educational settings has still to accommodate it into the real-life conditions of the actual learning environment.

In order to critically examine the constructivists' sweeping claim of the perfect match of constructivist pedagogy and ICT, this chapter has attempted to unearth the central grievances related to the interconnections of the constructivist instructional method, psychological processes, technology and the practical application of ICT in learning in the hope that the match could be improved in the future. The overall picture attained is sketchy and tentative as it is based on whole technological domains, an individual-psychological view of man and does not focus on any clearly defined level of education or group of learners. Nonetheless, a bird's eye view may be helpful in putting scattered empirical observations into perspective.

Some general observations seem worth underlining. Constructivists put much weight on the learners' own initiative and personal interests, which per se seems commendable, but when the learner lacks motivation the technology may be used for mindless copying (plagiarism). The technology itself can to a certain degree give guidance to the user, but the skills in using for instance the information retrieving technologies do not equal knowledge seeking skills. Constructivists shun certain cognitive processes, like memorisation, although suitable supporting technologies abound. Lastly, it seems that ICT enhanced cross-disciplinary and collaborative learning are difficult to arrange in most schools today mainly for practical reasons related to the learning environment, rather than for theoretical or technological reasons (Lehtinen 2003).

In terms of technology, the biggest hindrance to a further development of constructivistically oriented ICT enhanced learning seems to be immature personalisation technologies, whereas the biggest promise seems to be the mobile technologies. Mobile technologies may be turning us all into nomads, as has been claimed by some visionaries (Keen and Mackintosh 2001; Carlsson and Walden 2002). In a nomadic culture learning does not take place in the classroom but wherever one is in need of relevant information or new skills.

4 Mobile Learning Objects to Support Constructivist Learning

4.1 From eLearning to mobile learning

Information and communication technologies have helped making learners less dependent on the educational institution in terms of time and place. E-learning is already a real alternative especially for working people because knowledge changes rapidly over time and people need continuously to enhance their knowledge and skills in order to remain competitive on the job market (Zhang et al. 2004; Dolence and Norris 1995). Mobile learning brings yet a new dimension to technology enhanced education by giving learners expedient, immediate, reusable, persistent, personalized and situated learning experiences anchored in their real surroundings. Compared to eLearning, mobile learning goes a step further in enabling learners to learn practices and activities required in the real world. Also, it appears that mobile learning lends itself remarkably well to the realization of constructivist pedagogical ideals. Whereas traditional education is often accused of teaching things in a way that students find it difficult to apply their knowledge to the complex problems of everyday life, constructivist learning theories seek to create learning environments that come closer to real life environments. In particular, personalization, localization, and communication features of mobile technologies can help attain the central objectives of constructivist pedagogy.

The design of a mobile learning platform presented and discussed in this chapter is articulated around three main features derived from constructivist pedagogy: (i) problem orientation, (ii) individual learning strategies and (iii) situated collaboration. In this chapter, the design principles of learning objects for mobile learning are investigated. It will be argued that learning objects must be revised if one wants to successfully apply them to mobile learning environments. The structure and dynamics of learning objects must be in line with the central features of mobile learning; they must promote learning experiences which are repeatable, expedient, personal, immediate and situated.

An empirical account of a mobile learning experiment is presented. Ten students, enrolled on a university-level course in information systems, used a mobile learning environment for a period of six weeks. The findings about the utility and the usability of the learning objects retrieved by the students through mobile devices from a specially designed mobile learning platform will be reported. A longitudinal study of the experiment focuses on the learning experience of the course participants, giving an insight into the applicability of learning objects in mobile learning.

4.2 M-learning implementations and previous research

In 2000, the foremost obstacles to the applying of mobile devices for learning were poor connectivity, slow processing, limited storage capacity and a small screen (Quinn 2000). Knut Lundby (2002), two years later, reports on a large mobile learning project, concluding that the technology available "is still at a very early stage". The obstacles for an effective use of mobile devices (PDAs in this case) were not just technological but social and organizational. Furthermore, the learning environment was not designed with a mobile learner in mind. Consequently, the handhelds were often left unused by the learners even in situations where their utility seemed obvious to an outsider. In addition to the still persistent bandwidth limitations and a small screen, the learners' work habits and conventions created a further barrier to the use of handhelds. Lundby squarely admits that the learning environment and the infrastructure issues had not been sufficiently taken into consideration. He suggests that a handheld as a learning tool should be seen more as enabling communication in collaborative learning, that is, as a gateway for a group of learners, rather than a personal (individual) digital assistant. Lundby's observation on the importance of mobile or wireless devices as enabling communication and collaboration is seconded by Sotillo (2003). Sotillo (2003) applied a wireless laptop computer (with real-time audio, document sharing, a keyboard chat and a whiteboard) for collaborative writing of scientific texts. Situated at different locations the students worked together on texts, and the clear advantages of this work form include, among other things, quick access and verification of online sources as well as efficient transfer of skills and knowledge from more advanced students and instructors to less advanced students. The foremost advantage discovered in this experiment was the enhancement of collaborative work. The intention is not to discuss wireless laptop computers in this chapter but Sotillo's case study is interesting because it sets aside the problems of bandwidth, screen size and storage capacity. In the near future we should have handhelds with a nearly equal level and quality of performance and ergonomics than today's laptops (Mitchell 2002).

More recent mobile learning experiments include LIVE, Uniwap and Mobilearn. The purpose of the LIVE project (Rönkä and Sariola 2003) was to examine and develop networking models for a virtual school environment for teacher training. These models formed the basis for cooperative learning in mobile environments. The Uniwap project aimed at using mobile technology to support project learning with WAP-enabled devices (Tuononen 2003). Among the experiences reported by the users, it is important to note that reading messages and short memos seemed to be practical and easy with a WAP-enabled phone. Also the feeling of being part of a learning environment independent of time and place was perceived as an important factor. Mobility also brought added value to certain phases of the learning process. Rieger and Gay (1997) have developed and studied the experiential aspects of mobile learning. They show that mobile devices allow users to experience and personalize a visit to a nature park or a museum by taking notes, pictures and video clips. The users can later return to the material captured. Hujala et al. (2003) give an account of two projects conducted at the University of Helsinki. One of them was a forest resource management project. The authors conclude in reference to this project that the meaningfulness of using mobile devices may be lost if mobility and contextuality aspects are not seriously taken into consideration. The students using the forest resource mLearning system found that convenience is one of the most positive factors when using the mobile device for learning because it made it easy for them to incorporate studying into their personal life (the students can study anytime, anywhere). Hujala *et alia* also point out that authenticity was not achieved, which taxed the expediency of the learning experience. Immediacy was apparent as the students could use their devices to take notes or browse for relevant information. In the Mobilearn project, mobile technologies were used to develop approaches to informal, problem-based and workplace learning.

An account of a course held using only mobile devices as a medium for learning is presented by Ahonen et al. (2003). The results of the follow-up study show that less than 20 % of the course participants found the device useful and that the majority of students found the task of reading course materials on the device to be very difficult. Consequently, any educator planning a course using technology-mediated learning should carefully consider whether the use of mobile devices will match the context where the learner will use the device and the task at hand, and whether learning will be enhanced as a consequence. Other mobile learning projects or experiments include the pan-European m-Learning project, which aimed at attracting especially young adults back to education (Mitchell 2002), and a pilot study of SMS and digital pictures used in supporting teacher training (Seppälä and Alamäki 2002).

4.3 Definition and theoretical grounds of mLearning

There are many definitions of mLearning. Popular business and technology literature defines mLearning as "e-learning through mobile computational devices" (Quinn 2000; see also Trifonova and Ronchetti 2003), or as "the point at which mobile computing and e-learning intersect to produce an anytime, anywhere learning experience" (Harris 2001). These two definitions tend to oversimplify the concept of mLearning and its implications. First, mLearning is more than replacing the *e* of e-learning by an *m*, although it is true that mLearning borrows some features of eLearning so that mLearning enables education to be provided independently of time and place. Second, mLearning is not only about providing location and context dependent knowledge, as will be shown in the course of this chapter. An alternative approach to defining mLearning would be to start from two propositions. First, communication plays a major role in all human activity (including learning). Second, one cannot stop people from being mobile. Today, we have technology that allows us to interact socially independently of time and place: communication has become strongly ubiquitous. This approach to mLearning is explicated in greater detail in Nyíri (2002). Nyíri defines mLearning as learning taking place in the course of person-to-person ubiquitous or mobile communication. In a similar line of argument, Tella (2003) refers to mLearning as studying and communication in which different tools or mobile technologies are used. More precisely, we should speak of the *process* of learning, as introduced by Uljens (1997). The process of learning is decomposed in teaching-studying-learning, according to which "*teaching indirectly affects the learning process through the student's way of studying*". These components will be kept in mind, as mobile learning does not only enhance learning: it also enables teachers to interact with their students, and the students to study in a mobile manner (Tella 2002). As the concept of mobile learning is currently poorly defined (Tirri 2003), one needs to consider what are the benefits to bring about by mobility in learning environments, and what principles should be applied to implement mLearning and reap its benefits.

According to Ahonen et al. (2003), mobile learning is seldom the sole strategy utilized for learning: it is often used as an aid for formal and traditional learning. This approach is known as blended learning. Blended learning is usually seen as a combination of classroom and online learning (Eales 2004). The advantage of blended learning is that the learners have more freedoms in choosing the time and place of learning without loosing the opportunity for face-to-face contact. Evidently, mobile learning extends these freedoms further (Rovai 2004; Forsblom and Silius 2004).

However, rather than see mobile technology and mobile learning as a means to learning irrespective of geographical location (Kopomaa 2000; Dahlbom and Ljungberg 1998), it should be seen as a means to situated learning. By situated learning is meant learning in a context in which the learning substance is to be put into use (Brown et al. 1989). With mobile devices being potentially found in the pocket of any employee, the ideas of work-related learning and mobile knowledge management are gaining ground. While knowledge management projects appeared still some time ago doomed to be costly and relatively unsuccessful (Dibella and Kelly 2000), mobile learning promises to put training and learning into a context of meaningful job activities in the real world. Mobile knowledge management is thus closely related to constructivist learning and lifelong learning (Sharples 2000; Pasanen 2003).

The definition of mLearning, which defines it as an extension of eLearning, was criticized above. In view of the more immediate benefits and pedagogical (in this case constructivist) principles, one could give mLearning a narrow, normative definition. Mobile learning is here defined as *situated, collaborative and guided teaching, studying and learning, supported by mobile devices that utilise symmetric mobile communications channels by which the learners and the facilitator may use and mould specially designed learning objects for work, hobby or citizenship -related purposes or as an aid to traditional education.*

The understanding of mLearning presented here builds on two pillars: the constructivist instructional strategies and the key features of the state of the art mobile technology. Consequently, mobile learning objects should meet two conditions in order to be realizable and effective. First, mobile learning objects should meet the objectives that the constructivist pedagogues set to learning. Second, mobile learning objects should be designed so that the mobile technologies in actual fact manage to handle them as they are supposed to.

4.4 Constructivist instructional principles

The pedagogical issues need to be taken into account as much as technological issues in the design of the learning environment and materials (Seppälä 2002a; Lorentsen 2001). Therefore, this section presents the pedagogical theory that guides the design of mobile learning objects. The pedagogical theory applied here is constructivism. Constructivist instructional principles may be summarized as follows:

- learning should be *problem oriented*
- there should be room for *individual learning strategies*
- learning should encourage and support *situated collaboration*

For a more detailed presentation of constructivist instructional principles see Chapter 2.2 above.

4.5 Enabling mobile technologies

"Mobile technologies include any system or device that allows a learner to access information or to communicate without the limitations of power cables or network wires" (Karran 2003). It appears that the early visions of mobile technology enhanced learning lend themselves remarkably well to the realization of the pedagogical ideals of constructivism (Tella 2003; Sharples 2000; Mitchell 2002; Leino et al. 2002). In particular, personalization, localization and communication features of mobile technologies can help attain the central objectives of constructivist pedagogy. In this section the role of mobile technology as an enabler of mobile learning will be discussed. A number of key enabling mobile technology features have been selected, and it will be briefly explained how they support or fail to support constructivist learning on the move.

The possibility to access the information source in a wireless manner anywhere, anytime represents an important opportunity for mobile learning. Unfortunately, most mobile applications still seek to hide the location of use. *Mobility* means first of all to be able to move anywhere, anytime and still stay connected – to be able to stay happily oblivious about location. In contrast, *context-aware* design tries to exploit location, making some aspects of it an integral part of the interaction between the user, the mobile system and the mobile device. *Positioning* (e.g. GPS, GLONASS, Galileo) is the single most important technology that makes contextual mobility possible (Spriestersbach and Vogler 2002; Priyantha et al. 2001; Liljedal 2002). Sørensen (2002) and his associates (Kakihara and Sørensen 2001; 2002; Pica and Kakihara 2003) have advocated an even more expanded view on mobility, one which would better take into account that in addition to devices and persons also objects, spaces and symbols move. In this respect, the mobile Internet – to give just one example – holds great promise for learning on the move. As the mobile Internet develops, traditional broadcasting may move onto the mobile channel, thus turning it into an on-demand digital broadcast channel, provided that the question of costs (related for instance to UMTS) will be solved (Engström 2000).

Ubiquity means not just "anytime, anywhere" but that the surroundings have built-in intelligence, and that the devices talk with one another and with the surroundings

(Lyytinen and Yoo 2002a; Abowd and Mynatt 2000). Ambient intelligence and various context-aware systems enable learners to converse with their immediate surroundings, that is, to make real-life and digital objects give information of themselves and the surroundings via the mobile device (Harter et al. 1999). According to some visionaries, mobile technologies are turning us all into digital nomads with a ready access to all kinds of digital content (Keen and Mackintosh 2001; Carlsson and Walden 2002).

In very simple terms, *personalization* means that the user preferences and needs are taken into account when displaying the information (Riecken 2000). An overriding problem for mLearning is how to represent information in a resource constrained mobile device. User interface research has widely studied the issues related to the representation of information (Quintana et al. 2004), but personalization technologies are still largely at a very early stage of development (Karat et al. 2003; Omojokun and Isbell 2003). Yet, compared to PCs, mobile devices like cellular phones and PDAs are fairly personalizable. All the same, we have no reason to believe that mLearning environments would any time soon be more flexible than eLearning environments, whose interactivity and user control features are generally known to be poor (Zhang et al. 2004). In order to make mobile devices in any deeper sense personalizable, the user would have to be allowed to reprogram software through the regular interface. At the present moment, intellectual property rights and the expertise usually required in programming (even of open source software) prevent the user from adapting the device and the content in any significant degree.

E-learning, with its e-mail and discussion boards, expanded the potential for *interactivity,* collaboration and peer-to-peer (P2P) communication (Saunders 2002; Trifonova and Ronchetti 2003). Mobile network access further expands the possibility to share information with peers, thus enhancing the social learning process. At present, it is possible to share text, images, audio and video content through mobile devices almost independently of the users' location. This sort of media rich learning materials requires broader bandwidth than before because the learners do not just download diverse learning materials but create and share it with others. As Alice Mitchell (2002) has observed, "symmetry is a key component of a broadband learning environment as learners put in and contribute rather than simply download and interact" (p. 3/11). Broader bandwidth and the increased symmetry of communication will potentially level way for new learning practices such as situated problem-based learning, mobile cooperative learning and asynchronous learning (Tirri 2003). Unfortunately, mobile technology is not likely to completely avoid the problems experienced in distant learning in general. One of the most critical points in distant and eLearning are unclear instructions and the lack of timely (instructor or peer) feedback (Chin and Kon 2004; Tétard and Patokorpi 2005). Kristóf Nyíri (2002) has suggested that in mLearning person-to-person communication *per se* constitutes learning. This is a strong statement, illustrating the central role that constructivistically oriented scholars give to communication in mobile learning.

Early mobile devices were severely limited in terms of input and output capabilities, using almost exclusively alphanumeric characters. Alphanumeric input and output are not necessarily the best solution, considering the variety of situations of use that users find themselves in. These situations of use may vary in relation to the level of attention demanded from the user, physical capability to operate with the device, context conditions (e.g. noise, light), and so forth. To deal with these issues, new mobile devices are designed with *multimodal* features, giving the users the freedom to interact with the device in a manner that is convenient to them. So far, it is possible to use keypad input, handwriting and speech as input data, but, sooner or later, it will be possible to input data using for example haptics (e.g. fingerprint recognition, touchpad). Output features are perhaps more advanced, as it is possible to use sounds, text, video and haptics to communicate with the user. For mLearning, multimodality is believed to be important as it will let the users use their devices in a manner that they think is appropriate to the situation at hand, thus providing them with a richer learning experience.

To sum up, the enabling mobile technology features are the following:

- mobility (technological artefacts can be used while on the move)
- positioning (the user's physical position can be localized and used to provide location-based services and content)

- context-awareness (the technology can adapt to the conditions of the immediate environment in order to enhance the user experience)
- ubiquity (the technology is not only portable and mobile but also an integral part of the user environment)
- personalization (the user or the technological system itself can tailor the operating settings according to user preferences)
- interactivity (the user and the technological system can talk with one another and this talk is not only user-driven, it can also be initiated by the technology)
- multimodality (user-technology interaction can take place in many modes, giving the user the freedom to interact with technology in a way that is convenient to him or her)

As the above list of features indicates, mobile technology opens up new opportunities for (constructivistically oriented) learning. It conquers barriers of time and place; utilizes the physical and social context of learning; gives more room for individual learning styles as well as enables collaboration and P2P communication.

4.6 Design of mLearning objects

Ahonen et al. (2003) point out that mobile devices can be useful in formal learning situations, where the learning content can easily be divided into small, meaningful pieces and when one part is learned, the learner can easily connect it to other parts (on language courses see Regan 2000). Perhaps more importantly, demand for just-in-time learning is increasing, and this form of learning should offer smaller and more malleable content because the workers´ needs are specific as well as tied to a certain place and time frame. A large part of the knowledge required by employees is usually tacit knowledge, which means that the knowledge should be in a form that is context-based and easy and quick to interpret (e.g. story-based) (Quinn 2002; Mulholland et al. 2004; Castells 2001, p. 91). The learner being mobile also sets constraints to learning because his or her attention is usually divided or distracted by other things happening in the environment (Seppälä 2002a; Bae et al. 2005). Mobile learning objects should also be like building blocks (discrete objects) that can be easily combined. The object-likeness derives from both the constructivist view on knowledge (as constructing) and object-oriented programming (as digital building blocks). Related to this object-likeness is the requirement of functional compatibility. In other words, the learner should be able to put the building blocks together regardless of where they come from (Harper et al. 2005; Navarro et al. 2005). Consequently, mobile learning objects should be *small*, *intelligible* (i.e. easy to understand), *interoperable* and *object-like*. One could call these four qualities the general (or intrinsic) requirements for mobile learning objects.

Mobile technology enables the learner to choose rationally a suitable time and place to perform his or her educational activities (Kynäslahti 2003). Mobile learning is *expedient* in the sense that it should support solving real-life or real-life-like problems in a context. Learning should be *situated*; e.g. there is an incentive to travel to a certain place because knowledge can be gained from this particular place, or because our knowledge can become relevant at this particular place (Brown et al. 1989; Seppälä 2002a; Lai et al. 2005; Tsai et al. 2005). *Immediacy*, in turn, means that learners can perform educational acts regardless of the time and location; also, knowledge can be potentially exploited at the time it is created. In the modern society knowledge and skills soon get outdated, creating pressure for *persistent* learning solutions. By persistent is meant learning materials that can be made (e.g. by updates) to support the learning and mastery of skills and knowledge throughout the learner's lifetime.

Because much of the learning materials are the same, it makes sense to share them. Learning objects should therefore be *reusable* and easy to update. Instead of producing the materials anew every time, teachers and learners may select, update and reuse individual learning objects. This obviously saves time, effort and money (Leeder et al. 2002; Muzio et al. 2002; Sierra et al. 2005), as well as serves the constructivist requirement that the learners constantly should (or need to) retrace their steps and revise their knowledge and skills in interaction with their environment (Björkqvist 1994).

In order to give room for individual learning strategies, designers have generally attempted to take into account different user groups with distinctly different patterns of technology use (Oosterholt et al. 1996). This is not enough any more but the learner (or the facilitator) needs to be able to mould the technology itself in order to make the learning content and its representations truly *personalizable* (Smith and Whiteley 2002; Sharples 2000; Hadzilacos and Tryfona 2005).

Mobile learning objects should be *manipulable*. Manipulability is a slightly different matter from personalizability. Manipulability refers to the functionality of the learning objects rather than to their representational qualities alone. By manipulable mobile learning objects is meant both purely digital objects and real objects with embedded intelligence that are to be found in the physical environment, and can be accessed through the mobile device. These objects can be manipulated in the sense that the learner can change or mould them, after which they function differently (Resnick et al. 2000).

Consequently, mobile learning object qualities can be divided in the following two categories:

General (or intrinsic) mobile learning object qualities

- small (enabling it to be quickly accessed and processed by the mobile device and the learner)
- intelligible (simple and easy to understand even on its own)
- object-like (can be used as a building block)
- interoperable (can be made to function interactively with other learning objects)

Specific (or extrinsic) mobile learning object qualities:

- expedient (suited to problem solving and everyday learning situations)
- situated (supports learning in a real-life or real-life-like situation or context)
- immediate (can be used at once)
- persistent (enhances learning through the learner’s lifetime)
- reusable (can be used repeatedly)
- personalized or personalizable (adapts to the user’s skills, experience and learning strategy)
- manipulable (can be moulded by the user)

Mobile learning objects have simultaneously a technological and an educational dimension. “Small” means both that it does not consist of too many bytes to make it cumbersome to download (or upload) and that the learning content is not too large to make it impractical for situated learning. Presently, a gigabyte is too much, whereas 100 kilobytes seems small enough. A mobile learning object presenting 20th-century art is too large, whereas one presenting Picasso’s Guernica seems small enough. It goes without saying that a mobile learning object may be in the form of an image, a text, moving images, sounds, a hypertext or a combination of these.

The table below maps the constructivist instructional principles supported by the respective enabling mobile technology features and mLearning requirements.

Table 3: Constructivist, mobile technology and learning features

	Problem orientation	**Learning strategies**	**Collaboration**
Constructivist learning objectives	real-life-like context and problem, many possible solutions	room for learning styles, e.g. abduction	calls for P2P communication and situated collaboration
Enabling mobile technology features	mobility, positioning, context-awareness	personalization, multimodality	interactivity, ubiquity, context-awareness
Mobile learning object requirements	expedient, situated, manipulable	personalized, reusable, persistent	immediate, reusable, manipulable

The table above should be read column-wise, from top to bottom. The design principles presented in the bottom row build on the three main pedagogical principles of constructivist learning: (i) problem-orientation, (ii) individual or personalized learning strategies and (iii) situated collaboration (and communication). The enabling mobile technology features presented in the middle row are features which should support the constructivist objectives. The mobile learning object requirements (i.e. the design principles) realize (in an ideal case) the constructivist objectives by the help of mobile technology. Both the pedagogy and technology have to be in line with each other for the design principles to become realizable. It should be born in mind that the state of the art mobile technology is not yet generally advanced enough to support in any significant degree the interoperability, personalizability and manipulability of mobile learning objects (see Ch. 3). Hopefully we see development especially in this area of mobile technology in the near future.

4.7 M-learning environment experiment: MobyL

This section presents the mobile learning environment that was constructed in Turku for the purpose of supporting mobile learning by information systems graduate students taking a course in mobile commerce. First, the mobile learning environment in terms of the technology and tools used is described. Second, the way how the learning environment has been taken into use in a learning context is presented.

MobyL m-learning environment

When developing the mobile learning environment, the main principle of design was that the environment should be open. An open environment is not constrained to the use of one particular technology. The mobile technology sector is evolving rapidly and any given technology may fall into disuse in a very short time. An open environment, although more complex to manage, gives one the opportunity to adopt alternative technologies, tools and features. One aspect of the mobile technology sector is that there is a wide variety of end-user devices which have different properties: for example, mobile phones are designed mainly for voice communication and connectivity, whereas personal digital assistants (PDAs) are designed mainly for information management. Of course, advances in technology tend to blur the borders between the different types of devices; technology convergence is taking place, resulting in PDAs having phone capabilities and mobile phones having information management capabilities. In this respect, one benefit of an open environment is that one is not bound to a given type of end-user device.

Another factor determining our technical choices was the existence of a support infrastructure for wireless connectivity on the campus area where the pilot project was intended to take place. The campus area is equipped with OpenSpark/SparkNet wireless stations, enabling users to access remotely the Internet and the university's computing resources. OpenSpark/SparkNet is the widest wireless net in Finland. It utilizes existing networks, which makes it inexpensive and fast growing. The wireless net services are available not just in the office but in parks and restaurants in the city area. This support infrastructure is presently being extended to the most frequented areas of the city.

The mobile learning environment comprises three categories of tools: (i) device-specific tools, (ii) specifically designed tools and (iii) publicly available tools. *Device-specific tools* are tools embedded into the device; for example, video streaming applications, a calendar, note-taking applications, a voice recorder, a web browser and information management applications. *Specifically designed tools* are tools that were built especially for this particular project. The main tool designed is called the MobyL mLearning platform. MobyL, optimised for small interfaces, includes the following functionalities:

- m-diary is one of the main tools. It is a group web log optimised for mobile devices. With the m-diary, a group can input their own comments, reflections and ideas about the assignment. This application is designed to be used in a group setting so that interaction and dialogue between the group members take place remotely.
- presence notification will alert users if there are several users online simultaneously.
- group management: groups can manage their own settings and accept new group members.
- messaging functions: besides the m-diary, users can use other messaging tools (e.g. mobile e-mail) to communicate exclusively with one other group member or the instructor. The instructor also has access to messaging functions to communicate with one user, one group or the whole class.

Publicly available tools can be downloaded and installed into the device or used remotely through the Internet. In the experiment, the participants were asked to use a news service, which would broadcast pieces of information relevant to the task at hand. The news service had customization of content and update frequency features (see figure 2 below).

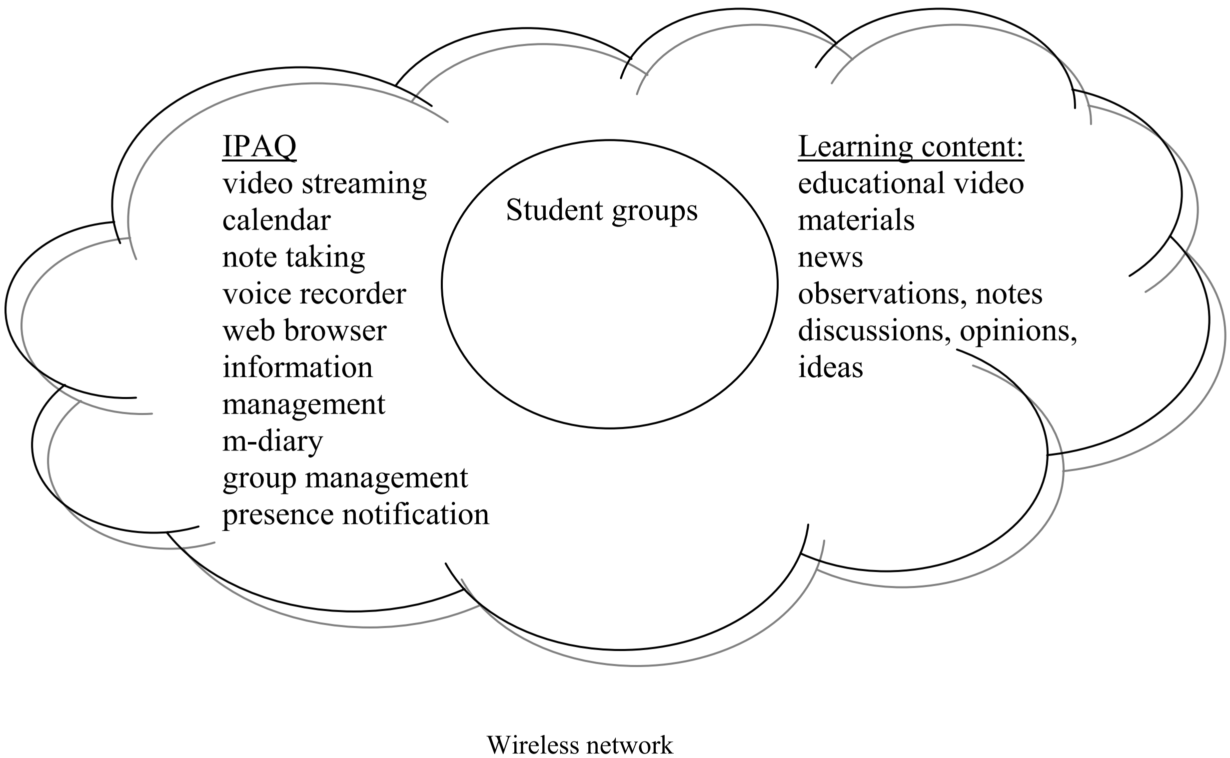

Figure 4: M-learning environment schematically

MobyL mLearning experiment

The mLearning environment was used by information systems graduate students taking an advanced course in mobile commerce. The participants were given PDAs (Ipaq), equipped with a wireless network card, for use for a period of two months during the course. The participants' main task was to produce a thorough business plan for a mobile service; the business plan would include an analysis of user needs, an investigation of a technological infrastructure needed and a description of the service in technological terms, and a description of a business model for exploiting the service (see Appendix 1). As a part of this main assignment, participants were assigned smaller tasks which would help them collect and analyse background information regarding user needs, technology and business models. These smaller tasks were formulated and structured so that it would be possible to perform them within the mLearning environment with the help of online video materials, business news services, the m-diary and discussion features as well as other features of the mobile device (note taking, messaging applications, voice recording, etc.).

A longitudinal study was conducted in order to collect and analyze the students' attitudes towards the mobile learning system. In the study, questionnaires and interviews were used as instruments to collect information. Three questionnaires were sent to the participants at regular intervals during the experiment (the experiment's duration was about 6 weeks), in order to monitor changes in attitudes and opinions regarding the use of the system. The first questionnaire, sent early in the beginning of the experiment, was intended to collect mostly personal information about the participants including background, knowledge and skills in using mobile devices and e-learning environments. The longitudinal questionnaires were sent to the participants in order to acquire individual information about their expectations, user experience, communication behaviour as well as their thoughts about the ease of use and their future adoption behaviour. After the experiment, a round of group interviews was conducted in order to collect information on the use of the learning system from a group perspective. Participants were also asked to freely report on their own usage of the system.

The experiment took place as part of an assignment to be completed within an advanced course in an information systems study programme. Altogether, 10 students joined the experiment. They were divided into three groups. The students are majoring either in information systems, computer science or accounting, their age varying between 21 and 25. Most of them had not used an mLearning system before.

4.8 Findings from the mLearning experiment

Expectations

When asked about their expectations of using a mobile system for learning purposes, the interviewees seemed to have different expectations depending on their previous experiences with eLearning. The students who had previous experience of eLearning systems mentioned that eLearning systems were quite complex and fully-featured from a functionality point of view, but they expected an mLearning system would be much more simple to use and adapt to the circumstances of mobility, including the possibility to access content "anytime, anywhere".

User experience

In relation to user experience, the interviewees were asked to comment on the various components used in the learning environment: communication features, the video materials, and the news delivery service. They were also asked to comment on the general use of the learning environment with mobile devices.

All groups thought that the layout of the system was simple and nice, and that such a system could be used anytime, anywhere. They thought that the PDA was an appropriate device to access and use the system, compared to the mobile phone which is not a device optimized for the use of such systems. Students deplored that the use of the system was limited by the existing network coverage, including only the campus area and a few other hot spots in the city area. Some students with experience with eLearning systems mentioned that the system did not have very many functions. In particular, features like mailing, downloading and other communication features would have been appreciated. Most participants agreed that the ability to check assignments, deadlines and discussion anywhere, anytime are the most distinct characteristics of mobile learning. They also said that mLearning works well as a complement to the more traditional learning strategies used during the course. One student thought that the system supports "group coordination and collaboration at any time" and "the distant and distributed provision of education and training anytime and anywhere you want".

The video materials were used quite extensively. The course participants assessed that these were relevant and necessary for the completion of their assignments, although launch time was long in some cases. Some users experienced problems with buffering and the small screen size of the PDA. The problems were solved over time. The contents of video materials were said to be overlapping sometimes. Overall, the participants said that they like using this “function”: as one student put it “watching the video sparks my mind to create our business plan”.

The use of the news delivery service remained limited in the beginning of the experiment due to network limitations and inconvenient input. After some time, most participants thought that the news service was useful, and tailored to be used through the PDA: “It is interesting to access the news channels through the service and have them formatted for the Ipaq screen”. However, opinions diverged as some students said that they would trust more information sources they were familiar with: “Unfortunately it is not useful. Maybe I am not yet accustomed to using it. I preferred sites that I am familiar with”.

Communication behaviour

When asked how communication occurred through the system, the students said that although they prefer self-study, they think that the possibility to communicate with their peers is a necessary complement to their study. However, they mentioned that the limited coverage of the WLAN network was a barrier to extensive communication during the experiment. They usually agreed beforehand on a time when they would interact face-to-face or virtually, rather than interact asynchronously: “Because of other assignments, there is little time. So, we communicate mostly while meeting before and after the lectures”.

Some groups also downloaded some other application to their PDAs in order to facilitate communication. They also appreciated the presence notification functionality: one group reported that once they exchanged ideas about the assignment when two group members were simultaneously online.

Ease of use

The students were asked about the ease of use of the system, that is, whether they think the system is easy to use, and whether they can find the information they need when using the system. All students thought that the system was simple and easy to use and that it meets their basic needs. However, one participant said that there was no function he benefits from.

The students encountered no technical difficulties, and thought that it was unnecessary to provide online instructions on how to use the system. However, nearly all students encountered difficulties in getting the wireless network cards to work. One student said that he preferred using a traditional keyboard rather than a stylus to input text. Two groups agreed that the m-diary's discussion function is a useful feature.

Future adoption behaviour

The interviewees thought that the future adoption of mLearning will depend on the spread of WLAN coverage. In their opinion, the system can complement eLearning and traditional learning. Nevertheless, classroom teaching and lecturers cannot be replaced by an electronic system. One student said that the lack of instructor guidance during the experiment was a problem: "I think that the biggest barrier seems to be the freedom it (the mobile learning system) offers. It can be a good thing, but the negative effect is that there is no supervision and therefore it is up to individuals to learn by themselves". In other words, there was some concern among the students whether the lack of supervision would affect the incentive to learn.

Learning styles seem to have an important impact on how useful the students find the mLearning environment. All Finnish students (6 out of 10) preferred self-learning. Therefore they felt that they got less benefit from the group interaction and communication functions than the rest of the students. The international students (4 out of 10) preferred group discussion, and think that the mLearning system can better facilitate their study, and that they benefit from discussions between the groups. It was a general observation made by the students that the small screen size, the lack of a multi-tasking feature as well as the fact that people have less time to concentrate on things will impede the development of the mLearning system.

Further comments

All groups expressed a need for a function to attach and upload files. Videoconferencing was also suggested. One group would like to have more interactivity in the system, and they thought that the network connectivity urgently needed to be improved. In addition, they thought that the system should also add a function which enables group discussion with the whole class. Another group felt like adding chat and classification of the topics (making the content public or private) functions to the m-diary.

Lessons learned

In section 4.6 (see esp. Table 3) the qualities required of mobile learning objects were defined. The findings from the mLearning experiment can be used to evaluate whether the learning objects successfully meet the requirements for mobile learning objects and whether there are obstacles to implementing them. It should be taken into account, though, that only ten students took part in the experiment. Therefore the results are not readily generalizable. Nonetheless, the pilot test should give valuable insights into the use and design of mobile learning objects.

- Small: The functionality of the learning objects was tested with mobile devices. The students mentioned at several occasions that they were surprised to see that even videos function very nicely on mobile devices through a wireless network. The size of the objects did not seem to be an obstacle to their use.
- Intelligible: The students said that they could easily make sense of the materials, although they complained about the redundancy across various objects. It would make sense in future experiments to avoid such redundancy.
- Object-like and interoperable: Dealing with the objects in a learning context seemed to be very difficult. One obstacle was the limited functionalities of the devices in some areas. For example, editing a video and even text materials did not happen very smoothly. Another obstacle was to be found in the lack of

support from the MobyL system; the students expressed their need for attachment, appendage, classification and linkage features to support their use of the m-diary.

- Personalized: Personalization is one of the areas where a lot of work remains to be done. The personalization features of PDAs remain very limited. However, the students never expressed a need for the personalization of the objects *per se*.
- Persistent: The students stated that they could see a system like MobyL to be in use continuously during their studies, jointly with traditional teaching and eLearning.
- Expedient: It was appreciated by the students that the materials selected fitted the learning situations.
- Immediate: In the students´ opinion, the system could be used anytime, anywhere, despite problems encountered with the wireless network coverage. These problems are likely to be solved in the near future.
- Situated: A couple of times the students had the occasion to interact remotely and simultaneously through the system. While these kinds of situations were appreciated, the students thought that the use of the devices was not in all situations as natural and convenient as for instance the use of a desktop computer. In this respect, some of the limitations of mobile technology are being met, as it is not possible to make the most out of a given learning situation because of insufficient technology support.
- Interoperable and manipulable: As for interoperability, the students found that it was difficult at times to manipulate the objects in the desired manner.

4.9 Summing up

Compared to eLearning, mobile learning goes a step further in enabling learners to learn practices and activities required in the real world. Also, it appears that mobile learning lends itself remarkably well to the realization of constructivist pedagogical ideals. Mobile learning is here defined as *situated, collaborative and guided teaching, studying and learning, supported by mobile devices that utilise symmetric mobile communications channels by which the learners and the facilitator may use and mould specially designed learning objects for work, hobby, or citizenship –related purposes or as an aid to* *traditional education.* Hence, mobile learning objects enhance education by giving learners expedient, immediate, reusable, persistent, personalized and situated learning experiences anchored in their real surroundings.

In the design of mobile learning objects two major guidelines were relied on. First, mobile learning objects should meet the objectives that the constructivist pedagogues set to learning. Mobile learning objects may of course be designed in accordance with any pedagogical theory or principles but in order to make the design work more focused the insights and objectives provided by constructivist learning theories were followed. Second, mobile learning objects should be designed so that the mobile technologies in actual fact manage to handle them as they are supposed to. Ideally, mobile technology opens up new opportunities for (constructivistically oriented) learning. It conquers barriers of time and place; utilizes the physical and social context of learning; gives more room for individual learning styles as well as enables and intensifies collaboration and P2P communication.

Consequently, the design guidelines for mobile learning objects presented in this chapter are based on an understanding of how learning takes place (i.e. constructivistically) and what are the supporting technologies for learning on the move. Following these guidelines should result in mobile learning objects that are small, intelligible, object-like and interoperable (general qualities) as well as expedient, situated, immediate, persistent, reusable, personalized and manipulable (specific qualities). Today’s mobile technology does not cater equally well for all of these requirements or desirable qualities. In particular, the state of the art of mobile technology is not yet generally advanced enough to support in any significant degree the interoperability, personalizability and manipulability of mobile learning objects. One hopes to see development especially in this area of mobile technology in the near future.

5 Logic of Sherlock Holmes in Technology Enhanced Learning

5.1 Linking constructivist pedagogy with a thinking style

In this chapter, a thinking style is connected to a pedagogical approach. The thinking style in question is abductive reasoning and the pedagogical approach is constructivism. Generally speaking, the analysis of reasoning styles can be used to develop new educational strategies. Hence, constructivist pedagogy could give some directions for building educational programmes around IST and the abductive form of reasoning. However, as has been argued in Chapters 3 and 4, there are some mismatches between the available technology and the constructivist learning theory and practice. Especially the personalisation technologies are still too immature to provide good support for constructivistically oriented IST enhanced learning. Abduction also requires backing up by deduction (to trace the consequences of hypotheses) and induction (to test hypotheses) to make the hypotheses (guesses) not just plausible but accurate as well. The cyberspace can in principle be made to support also deductive and inductive reasoning, but it seems that presently the cyberspace does not favour these patterns of reasoning.

5.2 Sherlock Holmes and his method

Sherlock Holmes, the hero of Arthur Conan Doyle’s novels, often amazed his loyal friend Dr. Watson by drawing a correct conclusion from an array of seemingly disparate and unconnected facts and observations. The method of reasoning used by Sherlock Holmes is abduction. As will be argued in this chapter, an advanced information society technology (IST) environment – a mobile computing environment in particular – calls for, or even compels to, the use of abductive reasoning. Abduction is not yet fully understood but it is a better conceptual tool than descriptive adjectives like “interactivity,” “mobility” and “ubiquity” that are presently used in IST research. It is better because: First, abduction is a single, rigorous and well-defined unit of analysis, allowing one to analyze and compare diverse phenomena with good scientific accuracy. In the words of Uwe Wirth, research on abduction provides the unique opportunity of approaching interdisciplinarity under a single aspect (1995, p. 405). Second, abduction catches the gist of how we humans reason under uncertainty in a context. Consequently, abduction illuminates the special epistemological circumstances of IST enhanced learning, especially when the learning materials and the environment have been arranged in concord with constructivist educational principles. If it is true that abduction is a central element of everyday thought, and especially significant and ubiquitous in advanced IST environments, it follows that a study of abductive reasoning will help us better understand IST enhanced learning and IST user behaviour as well as give us some valuable hints to the design of human-computer interaction in general.

The chapter at hand will focus on abduction as a central process of everyday human reasoning and on its role in human-computer interaction, especially on its role in IST enhanced learning. As Ahn and Kalish (2000) have pointed out, abduction has so far been little studied in cognitive psychology, and therefore what are in fact forms of abductive reasoning have usually been misinterpreted as induction. Thanks to portable and ubiquitous technology, education increasingly takes place in authentic real-life contexts instead of in the confines of a classroom. Consequently, the learner is most likely to resort to abductive reasoning more than before. Abduction is of course a central element in traditional education, too, but the new IST lends it a heightened importance. Constructivist pedagogy enters the picture as the currently predominant theory of learning. Constructivist pedagogues have embraced the new IST because it in their opinion naturally supports, or can be made to support, the fundamental constructivist instructional strategies and learning objectives (Tétard and Patokorpi 2005). Abduction clarifies how learning takes place especially on the level of individuals in and out of cyberspace.

5. 3 Abduction as an inferential process

The canonical example of abductive reasoning comes from Charles Sanders Peirce:

> Rule: All the beans from this bag are white.
> Result: These beans are white.
> Case: Therefore, these beans are from this bag (CP 2.623 [CP refers to Peirce 1934-63]).

The inference is not deductively or analytically valid – because the beans could come from somewhere else – but this form of reasoning conveys the manner in which people reason when making discoveries in the sense of coming up with new ideas. Abduction is the only inferential process that gives birth to new ideas, thus expanding our knowledge (CP 2.777; CP 5.171; Wirth 1995; Pückler u/d). Abduction is a retroductive process of finding or forming hypotheses or theories that might explain a (surprising) fact or an (unexpected) observation. Contrary to a widespread misconception, the fact or facts observed do not necessarily have to be surprising. Abductive reasoning may be used for opening up a new perspective into things even when there is nothing out of the ordinary in them (e.g. humour) (Hoffmann u/d). Abduction comes to its own in the face of incomplete evidence and high uncertainty that are usually related to very rare or nonrepeatable events and to the realm of the unique in general (Flach 1996; Yu 2004; Leake 1995; Shanahan 1989).

Abduction has both a psychological (synthetic) and a logical (analytic) dimension closely intertwined (Pückler u/d; Hoffman u/d). To borrow Roesler's (u/d) illuminative example: (P1) a surprising object (fact) is observed which is round, orange coloured and porous. (P2) Oranges are round, orange coloured and porous. If this object were an orange, the object would make sense to us and thus cease being surprising. (C) Ergo: it is plausible that this object is an orange. The premises, containing perceptive judgments, and the conclusion, containing an abductive inference, cannot be sharply separated from one another. Floyd Merrell explains the matter as follows: "since all seeing is at bottom level interpreting, there is no hard and fast line of demarcation between perception and knowledge (CP 5.184). There is, however, a distinction between abductive judgments and perceptual judgments: the former are usually subject to some degree of control, though they can also shade into the latter, which are by and large uncontrollable" (Merrell u/d, p. 8/20; see also Merrell 2004).

By producing hypotheses abduction simplifies the complexity of reality, making it intelligible to us. When abduction, as a form of synthetic and qualitative thought, is given a central place in knowing, the hypothetical and provisional nature of human knowledge is underlined (Wirth 1995; Bertilsson and Christiansen in Peirce 2001).

5.4 Some forms of abductive inference

For the purposes of this essay abduction will be divided into four basic forms: selective, creative, non-sentential and manipulative (Magnani 1998; Magnani et al. 2002). Selective and creative abduction may be further divided in two distinct types (see Figure 1 below). The non-sentential form, in turn, may be divided into five and the manipulative into three subcategories. Finally, the quasi-automatic abduction is here further divided into species-specific and doxatic modes, and all of the five non-sentential modes as well as the man-made manipulative mode may be further divided into two subcategories: creative and selective.

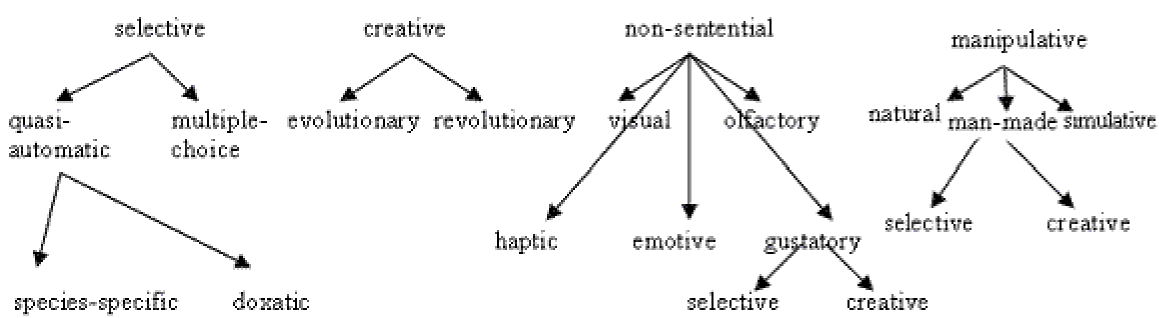

Figure 5: Some forms of abductive inference

Selective abduction, as the name indicates, selects among existing bags (alternative rules, antecedents) the bag that these particular beans (result, clues, consequent) come from. There are two forms of selective abduction: quasi-automatic (Eco's overcoded abduction) and multiple-choice (Eco's undercoded abduction). Abduction may happen almost automatically (quasi-automatically) when there is just one bag (i.e. a singular cause or a general rule or law) to choose from.

Figure 6: Quasi-automatic abduction

Umberto Eco (1983) gives the example that upon seeing a portion of tuna fish on a plate on the table and next to it an opened tin of tuna, one without any conscious effort concludes that the tuna on the plate comes from the tin. In quasi-automatic abduction there is no need to search for a rule as one already exists in the mind. The inference thus proceeds from the result to the case. The principles of proximity, similarity, an objective set, closure, completion and pregnancy could be seen to number among the quasi-automatic abductive processes of human perception (see Wertheimer 1923). The last-mentioned abductive processes could be said to be common to the human species, whereas some abductions are rather based on culture. Stopping at red lights in traffic is an example of a culturally or conventionally embedded abductive inference. In this case the power of the sign is more due to convention (i.e. the social institution of the sign) instead of to shared psychological principles or propensities of human perception. The 'traffic light' abduction could be called doxatic and the other one (the gestalt-psychological) could be called species-specific abduction (Bertilsson 2004).

In a multiple-choice abduction there are two or more rules to choose from. Thus the mind proceeds from the result to the rule (Wirth 1995).

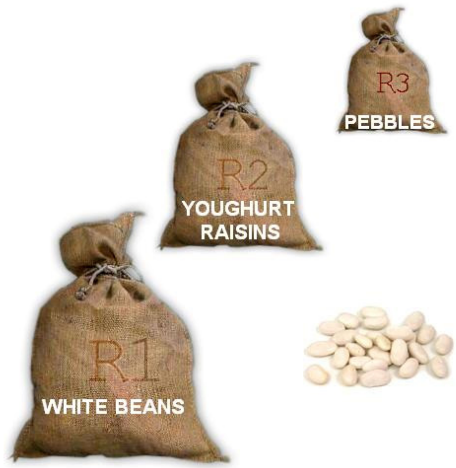

Figure 7: Multiple-choice abduction

An example of a multiple-choice abduction is to be found in Peirce (CP 2.707; quoted in Eco 1983). The data that Kepler had about the longitudes and latitudes of Mars' revolutions around the sun suggested a finite number of geometrical curves from which to choose. Kepler's hypothesis was that the orbit is elliptical, which he then corroborated against the available evidence.

Creative abduction creates a new bag of beans (i.e. rule) from which the particular beans come from. In other words, the immediately existing (present to the reasoner's mind) bag or bags (contexts) do not fit the result (these beans are white) or there does not exist any general rule, so the reasoner needs to find or create a new one. Generally speaking, by abduction we come up with rules, reasons or laws that explain the case. Insofar as we stick to our prior experience as a ready repertoire of hypotheses, we are not properly engaged in a creative abduction. To infer that a patient has hepatitis because he or she has jaundice (Josephson and Josephson 1994, p. 13) is a multiple-choice abduction. If one explains some (in this case the same above-mentioned plus some) symptoms by abducing a new disease (e.g. AIDS when there was no such disease in medical records), it is a case of an evolutionary creative abduction.

Figure 8: Evolutionary abduction

"Here the *only* premise of an abduction is the result, and *both* the rule and the case are consequences of it" (Reid 2003; see also Hoffman 1997). In other words, these beans are white (result); All the same, not all white beans (rule) come from this bag (case: hepatitis); Instead, they probably come from this bag (case: AIDS).

The creative revolutionary abduction (Eco's meta-abduction) is a further abduction based on earlier ones. It assesses whether the potential universe created by earlier abductions corresponds to our experiences (Roesler u/d).

Figure 9: Revolutionary abduction

Galileo's hypothesis of the earth circling the sun, leading to a heliocentric worldview, is an example of revolutionary creative abduction. A revolutionary abduction replaces existing sets of rules by new sets of rules, thus challenging our beliefs in a wholesale manner.

Observation is a central factor in abduction. All or any of the five senses may provide the required clues for abductive reasoning (Pierpaolo u/d). Especially medicine is known for exploiting all the five senses in the finding of clues (symptoms) when diagnosing an illness. Consequently, there is reason to think that there are other forms of non-sentential abduction, involving vision, touch, smell, taste and feelings. For instance, instead of verbal representations of things and events, we can form pictorial representations. These pictorial representations can be used as vehicles of inferences and explanations, that is, as tools of thought (Thagard and Shelley 1997). Visual abduction is a form of inference that is based on signs which resemble the thing they represent (i.e. the signs used are icons). This pictorial form of thinking is usually instantaneous, uncontrolled and automatic, thus verging on perception. Visual abduction retrieves from the mind a previously stored piece of (pictorial) knowledge by which a result (these white beans) is referred to a familiar rule (a bag of white beans) (Magnani 1998). Visual abduction can be either selective or creative. Here is an example of creative visual abduction from Thagard and Shelley (1997). An archaeologist finds two notches on the skullcap of a hominid that probably have led to its death. Is this a case of cannibalism? By picturing the hominid in the jaws of a leopard, the archaeologist can abduct (by creative, visual abduction) to an alternative explanation. The first explanation that comes to the archaeologist's mind, namely that the hominid has fallen a victim to cannibalism, is a selective visual abduction because the rule is part of the furniture of the reasoner's mind. Creative visual abduction involves the introduction of a new or additional element (diagram or icon) into the reasoning process.

The manipulative abduction could be said to be based on action rather than perception. The reasoner acts non-verbally upon reality, changing the object of observation and then uses the resultant tacit knowledge (which may be embodied in an external or externalised object) as an auxiliary element of the reasoning process. An example of manipulative abduction is the use of auxiliary figures by hand in geometry (Magnani et al. 2002). These few examples of some forms of abductive reasoning should suffice for the purposes of this work.

5.5 Semiotic paradigm of knowledge

In the late 20th century, epistemology has taken an abductive turn. It means among other things that the earlier division into hermeneutic understanding and natural-scientific explanation gives way to abductive educated guessing, that is, to the semiotic paradigm of knowledge (Wirth 2000). It means also that it is increasingly difficult to keep up strict borders between fields of knowledge as phenomena spill over from one discipline into another (e.g. biophysics). Presumably, the bulk of human knowledge in everyday life is based on hypothetical (abductive) thinking.

According to Peirce, consciousness is always mediated by signs. What we know is signs. Signs get their meaning in relation to other signs through an interpretative process. Thought is thus an infinite chain of signs (CP 5.262; Spina u/d). Then, why should we think that our signs have close enough affinity with the outside world to make guessing worthwhile? Peirce says that we succeed in our abductive reasoning, that is, in guessing, because the mind has a natural affinity with nature. Consequently, our guessing is not blind but guided by *lumen naturale* (CP 5.591; CP 5.581; Wirth 1993; Schulz u/d; CP 8.238). Unfortunately, Peirce ignores differing sign-object relations in different cultures, thus playing down the role of culture (i.e. the cultural development of man) in semiosis (Uslucan 2004). The affinity between the human mind and nature is partly innate (an outcome of our biological evolution) and partly an outcome of cultural development (Wirth 2000). According to Luis Radford (2004, p. 12/16), "In actual fact, Secondness (the realm of what exists, the realm of indexicality), and Firstness (i.e. the realm of suchness, the realm of 'potential being', of what 'may-be' or of uninterpreted iconicity) are already cultural through and through". Hence the semiotic experience should be seen as creation, re-creation and renewal of meaning and culture by a linguistic (semiotic) community.

Abduction is essentially a matter of finding and following clues. However, as Matti Peltonen (1999) points out, a clue alone is not enough. A clue merely leads the reasoner to something that he or she already knows. Abduction, in contrast to the mere following of clues, aims at eliciting new knowledge. One cannot become an adept detective, that is, skilful in finding clues, by merely following rules. The observation of a clue is in relation to the observer's background knowledge, consisting of more or less rough models or theories. Clues without models or theories are useless.

The semiotic paradigm (i.e. the science dealing with signs, symbols and clues) of knowledge does not deal with a disciplined regulation of coded knowledge, yet the clues are there for all to see. As Matti Peltonen says (1999, p. 61), clues are not something hidden deep in the things themselves and that they would have to be dug out from their hiding place. The knowledge found by abduction is out in the open for all to see. Rather than rediscovering knowledge or things that were forgotten or covered from sight, we constantly create things or knowledge anew by interpretation. By actively interpreting, that is, by giving meanings to things, the observer produces new knowledge. Culture is public and the meanings are recognized by other members of the same culture although they do not always share them. Consequently, the knowledge based on abduction is not esoteric but something that can be communicated to others. It can be communicated to others precisely because it is, among other things, based on (public) signs and reasonings.

Abduction is first of all a reasoning pattern with strong claims to being democratic. All the relevant knowledge (clues) is in principle "out there," that is, laid out in the open for all to see. Historians (Ginzburg 1989; Peltonen 1999) sometimes talk of this sort of semiotic interpretation and knowledge as low or shallow knowledge, the knowledge of the poor, and the oppressed or otherwise marginalized groups in society. Low knowledge may be contrasted with high knowledge like for instance the Greek *mythos*. Myth is hidden knowledge, knowledge for the chosen few, not accessible to all. However, low knowledge should not be understood as sheer, unadulterated observation. Abduction, rather than observation alone, is for instance required to tear down theoretical constructions or social agreements: the Emperor has no clothes. In Hans Christian Andersen's story of the Emperor's new clothes, it is not enough to see (observe) that the Emperor has no clothes because we still believe that he has. A process of abductive reasoning is required: the hypothesis that the Emperor does not have any clothes is a better explanation of the facts of the case. In this way abduction opens up a new perspective. It is material to notice how easy it is to communicate knowledge by abduction; the clues are not hidden but public and the reasoning process is easily repeatable by others.

The clues that are there for all to see are qualitative and unique. They cannot be measured and regulated. This sets the stage for knowledge that is essentially personal. It is personal in the sense that individuals differ in their ability to detect clues, due to individual differences in their prior knowledge and experience as well as logical acumen (Ginzburg 1989, pp. 8-39; Peltonen 1999, p. 61). Despite the apparent paradox, knowledge by abduction is simultaneously both personal and democratic.

5.6 Art of abductive reasoning

Because thinking is an endless chain of signs, thought is essentially a temporal phenomenon (CP 1.444; CP 2.229; Uslucan 2004; Bergman 2002; 2000). Abduction especially is best understood as a pattern of temporal reasoning. The process of abductive reasoning may not come to a conclusion for a very long time but may be suspended until all the relevant or adequate information is in (Josephson and Josephson 1994; Paavola 2004b). Abductions stretching over a long period of time are typically complex. An example of a prolonged complex abduction is Darwin's theory of evolution by natural selection.

As Thagard and Shelley (1997; see also Roesler u/d) have pointed out, complex abductions are layered. Layeredness means that each abductive conclusion may become the premise of the next abduction:

> The hypothesis is that the suspect is the murderer, and a higher level hypothesis might be that the suspect hated the victim because of some previous altercation. The plausibility of the lower-level hypothesis comes not only from what it explains, but also from it itself being explained. This kind of hierarchical explanation in which hypotheses explain other hypotheses that explain data is also found in science and medicine … (Thagard and Shelley 1997, p. 417).

In complex abductions in particular the steps of the reasoning process may break out from the confines of a single mind. Reasoning and argumentation may thus be seen not only as internal dialogue or suspended reasoning over time but also as a process involving two or more participants (Wirth 2000; Pape u/d). The following example derives from Richard Whately's Elements of Logic (1st edn. 1826):

> Let us suppose that a group of labourers has dug up a fossil animal with horns on the skull. In other words, the labourers know the minor premise: "This animal has horns on the skull." Let us further suppose that there is a distant naturalist who knows that all horned animals are ruminants. The naturalist knows the major premise: "All horned animals are ruminants." As the labourers are ignorant of that all horned animals are ruminants and as the distant naturalist to whom the fossil is described is ignorant of that it has horns, they are both unable to draw the conclusion that it was a ruminant. This is clearly a case in which to reach the conclusion both premises are required (Whately 1882, pp. 156-165; elaborated in Patokorpi 1996, pp. 107-109).

The above example nicely brings out the dialogical nature of thought.

Peirce (CP 5.181) pictures the generation of a hypothesis as a sudden flash of insight. According to Paavola (2004b), this view of hypothesis generation is unsatisfactory. It is possible to trump up hypotheses that meet the formal requirements of abduction but are too far-fetched to be taken seriously. Achinstein's ([1970, p. 92]; quoted in Paavola

2004a; see also CP 2.662; Wirth 1999) example is that he is happy because he has won the Nobel Prize. There are certainly other reasons for a person to be happy, although winning the Nobel Prize would explain why one is happy. Something else is clearly needed for making abduction a useful mode of inference. What is needed are strategic rules or principles whose job is to guide the reasoner in fitting the hypothesis with the background information and other relevant clues related to the subject matter, the situation and the reasoner's goal. From a strategic viewpoint, it may become necessary to resort to further explanations to show how the hypothesis fits the context in question, and that potential counter-arguments can be warded off (Paavola 2004a; CP 5.181; Hoffman 1997). A surprising phenomenon is stressed as a starting point because of strategic or methodological considerations. It is a good strategy to start one's explanation from anomalous phenomena because one has to start from somewhere, and it would most likely be impossible to explain everything (Paavola 2004a; 2004b).

5.7 Constructedness of human cognition

Constructivist pedagogues strongly stress the element of active construction in human thinking and perception (Piaget 1982; Vygotsky 1969; Leontjev 1977). A central inferential process behind the constructedness of human experience is abduction. Abduction thus enables one to posit learning between the rationalist and the empiricist viewpoints, and *a fortiori*, to strike a balance between constructivist, pragmatist and behaviourist learning theories. The existence of several different forms of abductive reasoning may throw light on some disagreements between the constructivists and the proponents of other learning theories, the pragmatists and the behaviourists in particular. Accordingly, the purpose of this section is to illuminate the constructedness of human cognition with the help of the abductive mode of inference.

A central piece of criticism levelled at constructivist theories of learning is that they stress deliberation too much. In terms of abductive inferences it means that constructivists exaggerate the role of creative abduction. As learning in the sense of training familiar things and skills seems to belong to quasi-automatic abduction, learning as expansion of knowledge seems to be based on creative abduction and multiple-choice abduction (Wirth 1993). Fox (2001), who numbers among the recent critics of constructivist learning theories, presents the following figure that illustrates visual illusions:

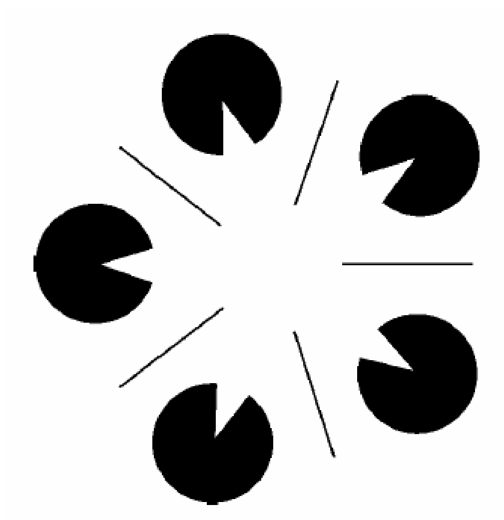

Figure 10: White star illusion

Figures like this give support to the idea of constructedness of human perception. However, according to Fox (2001), virtually all humans "construct" the figure in the same way, and they do it without any conscious effort or deliberation, and they may at will resist the illusion: "Thus, as well as being impressive examples of the 'constructed' nature of our perceptions, such figures can also be read as examples of the objectivity of human perception, of its deep innate roots and of the way in which we can, up to a point, resist various features of our own initial view" (p. 31). Now, all these three observations made by Fox may be explained by applying different forms of abduction in a layered manner: a selective (quasi-automatic or multiple-choice) abduction followed by a creative evolutionary or revolutionary abduction. Insofar as the reasoner has only one figure present to his or her mind, it is a case of quasi-automatic abduction. Gestalt switches and Necker cubes are good examples of figures in which by training one learns to keep two figures (i.e. two general rules) present to the mind consecutively so that one jumps from one figure to the other more or less at will (Merrell u/d). If there are two figures (two alternative bags of beans) to choose from, it is a case of multiple-choice abduction. The ability to resist the illusion takes us to the so-called metacognitive level of human mental processes. To make our perceptual and thought processes an object of thought (i.e. reflection in some form) comes to us as naturally as the initial illusionary vision of the figure. Revolutionary abduction is a way of, purposefully, to see things different from what they appear at first. As Wenyan Zhou says, “identifying the abductive object entails comparing one’s existing beliefs and evidences revealed in the current situation, becoming aware of the incongruence between them, and discovering the anomalies” (2004, p. 132). Reasoning in its expansive and creative mode is by nature temporal and layered (Roesler u/d), involving a varying degree of reflection (Leontjev 1977).

Kivinen and Ristelä (2003) criticize the idea of metacognition. They ascribe to constructivists a picture of metacognition as a higher level of consciousness that monitors and evaluates the lower levels. Nevertheless, if metacognition is not seen as two simultaneous levels of cognition but as a temporal process where knowledge-in-action and reflection take turns, the problem vanishes. Some pragmatists seem to have trouble in admitting reflection any clear place in human action. Kivinen and Ristelä’s example of an experienced driver and a novice driver misses the point. It is clear that a novice driver makes a worse job of driving than an experienced driver but the main reason for it hardly is because the novice tries to be careful while driving. One of these drivers does not yet know how to drive whereas for the other driving is a routine task. Moreover, reflection and action take turns even when one does something in which one is experienced; reflection merely shows that one is still learning something. Cases of training in which no or very little reflection occur are relatively rare. Much of the conceptual muddle in the case at hand derives from a too elevated picture of reflection. As Bengt Molander (1996) has convincingly argued, reflection allows many forms and degrees. “Just do it!” is a good advice for a timid and ponderous learner learning some very practical skill. On the other hand, it does not validate the conclusion that taking, from time to time, back a step from what one is doing would be a bad thing even in more practical learning tasks. By verbalising, visualising, in a word, externalising learning, it can be made more easily accessible to others as well as to the individual learner himself or herself. Social or collaborative learning is a powerful reason for making learning explicit by reflection and externalisation (Kankkunen 2004).

5.8 IST enhanced learning

As the section on semiotic knowledge above indicates, knowledge by abduction is, by nature, personal, democratic, creative and based on prior knowledge. This is almost exactly the way that many constructivist pedagogues describe learning (Sotillo 2003; Puurula 2002; Hussain et al. 2003; Langseth 2002; Hawkey 2002; Kurzel et al. 2003). It is not difficult to become convinced of the resemblances between knowledge by abduction and constructivist learning. Furthermore, Information and Communication Technology (ICT) enhanced learning in general and mobile learning in particular seem to favour the abductive form of reasoning (Nyíri 2002; Patokorpi et al. 2006).

Abduction is a tool for low knowledge with a tendency to (over)simplification. Therefore, resorting to abductive reasoning has its pitfalls. The construction of a personal meaning goes at times against the objectives of more traditional educational principles, which include the dissemination of uniform knowledge and eradication of false conceptions. Especially due to the immense increase in information, the eradication of erroneous conceptions has become one of the most important and most difficult tasks of today's teachers. In abductive reasoning there is a tendency to resort to guessing before all the facts are in, which leads to over-generalisation and error. Sticking to prior knowledge and experience when the guesswork ends in error may send the reasoner to prolonged attempts at second-guessing the cause (rule) of the error and thereby to error recovery (Carroll 1990; 1997). A real-life example of this kind of behaviour is when a computer user ignores the manual and proceeds guessing, and when it ends up in error, resorts to some more guessing. Umberto Eco (1983) refers to a similar problem when saying that detectives tend uncritically to rely on their abductions whereas scientists meticulously put their hypotheses to test. By modelling learning after scientific discourse, the knowledge creation movement (Bereiter 1994; Scardamalia and Bereiter 1994) aims to get the best of both worlds. In epistemic terms, when the learners start with their own questions, the adoption of knowledge produced by others is, as a process, analogous to that of creating knowledge (Bereiter 1994). The remedy they prescribe to the pitfalls of abductive reasoning is added reflexivity. Added reflexivity translates into increased layeredness of abduction, more attention to logical strategies, more thinking about thinking and intensified dialogue and collaboration between the members of a knowledge community.

According to Hussain et al. (2003): "Edutainment offers children a way to wander through stories, information or games at their own pace and in their own way. They can connect ideas in paths they choose or investigate one particular idea among many" (p. 1077). This is the hypertextual property of the content on the Web. Hypertext is a web of links that sends the reader onto a quest from one piece of text to another. In every act of reading, one piece of text can in principle be connected with any other piece of text. Thereby a text on the Internet loses its book quality (Wirth 1999). In the words of Spiro et al. (1988):

> The computer is ideally suited, by virtue of the flexibility it can provide, for fostering cognitive flexibility. In particular, multidimensional and nonlinear hypertext systems … have the power to convey ill-structured aspects of knowledge domains and to promote features of cognitive flexibility in ways that traditional learning environments (textbooks, lectures, computer-based drill) could not […] (pp. 2-3/20).

So, on the Web the materials (ideas, objects) may be arranged as one pleases. The endless semiosis thus seems to find full vent in the digital media. The user or reader on the Internet may either follow aimlessly the links that he or she comes across or seek clues (meaning) as a detective (Wirth 1999). We no longer seem to need so much as before a memorized and often visual path to pieces of information or knowledge (e.g. be able to trace a certain passage in Hegel's *oeuvre*). Admittedly, there are technological solutions to tracking paths in a computing environment – bookmarks, track changes and 'go back to the previous page' – but to date, owing to technological limitations, these memory traces are mostly our own personal creations. The point is that it is easier to avoid listening to other points of view (other universes of discourse, world-views) as one may pick up a passage and ignore the rest of the work. As a result, hypertextuality gives more room for our abductive competence and strengthens our personal knowledge structures – sometimes at the expense of not understanding other points of view.

A Sherlock Holmes type of learner calls for laying out the learning materials as in a detective story. In actual fact, often in the new learning media, at least so far, the learning materials have been arranged in a rather strict hermeneutical path of the master. The learner, just like the reader of Internet texts, is supposed to follow the links (clues) so that he or she eventually goes through the same path as the author of the text and links. On the Internet, texts may lose their book quality, but they still need to be read as books, or rather, as detective stories, in order to make sense. Texts, in general, need to be inherently coherent to enable us to interpret them instead of just utilizing them (Wirth 1999). We still have to see the text as a contribution coming from another conscious mind because human thought is by nature dialogic. This comes close to the idea of a hermeneutic cycle. In the footsteps of Karl-Otto Apel (1973), abduction is here interpreted as an inherent part of the hermeneutic cycle. At the very least, knowledge building, hermeneutics and abductive reasoning could be seen as complimentary perspectives to the temporal and dialogical process of knowledge creation and renewal in a shared culture.

Along with the new media (TV, video, PC games, virtual reality etc.) images have become a more pivotal vehicle of meaning and communication in all walks of life. Pictorial knowledge has always had its defenders, although they seem to be in the minority. Peirce is a case in point: "For Peirce, the human mind is not a calculating engine, but it is a mind which draws figures," says Leila Haaparanta (2001, p. 9/11; CP 3.363). Pictures are more concrete and simpler than meanings mediated by verbal language but they are often also clearer and easier to understand. In the words of Kristóf Nyíri: "Due mainly to advances in cognitive science, philosophers today increasingly recognize that we do indeed have the capacity of thinking *directly* with images, without verbal mediation. And, due mainly to advances in computer software, pictures are today becoming a convenient vehicle for communicating ideas" (Nyíri 2002, p. 3/4). Especially moving images are important because they have the capacity to be self-interpreting.

Pictorial knowledge is essentially interdisciplinary and less hierarchical than verbal knowledge. However, language and communication have their anthropological basis in all of the five senses, not just in vision. With this cognitive species-specific makeup in mind, Nyíri (2002) argues for the natural suitability of modern ubiquitous and multimodal IST to human communication and learning. Today, learning takes increasingly place not in the school but out there in the world, and it is supported by the same tools with which most communication and work is done, namely the ICTs. If and when mobile learning gets properly under way within and outside the educational system, abduction seems like a good candidate for an interdisciplinary conceptual tool for both educational and technological research.

Finally, the recent systemically oriented research on ICT enhanced learning, particularly under the label of computer supported collaborative learning, is all well and good as it often gives a sophisticated picture of the process of learning and of the dialogical unity of knowledge and action. However, there is need for research which analyses the learning process more from the concrete viewpoint of individuals – without covering from sight other minds, action and artefacts. Abduction could have an important role in this kind of research.

6. Low Knowledge in Cyberspace: Abduction, Tacit Knowledge, Aura, and the Mobility of Knowledge

6.1 From abduction to low knowledge

The previous chapter examined various forms of abductive reasoning, trying to shed some light on their role in learning from the constructivist point of view. The chapter at hand expands the idea of abduction as a pattern of everyday reasoning and a thinking style towards a broader set of epistemic factors, which is here called low knowledge. This broad set of epistemic factors is applied to clarify some general mechanisms of digital interaction rather than the epistemic conditions of ICT enhanced learning alone.

6.2 Plato in cyberspace

In Phaedrus (1988), Plato attacked writing, claiming that writing is further removed from the things themselves, and therefore less truthful than oral discourse. The development and adoption of new technologies of communication and interaction raise questions of their social and cultural impact. In the same way as traditional classroom teaching sets boundaries or special conditions to what and how learners can learn there seem to be some limitations to Information and Communication Technology (ICT) enhanced and mobile learning, that is, limitations or constraints set by the special epistemological conditions of digital interaction and culture. The chapter at hand will focus on the limitations not only to online learning but to digital interaction in general. It does so with the help of three well-known philosophical concepts: abduction, tacit knowledge and aura. If it is true that abduction is a central process in cyberspace and especially in online learning (Cunningham and Shank u/d; Cunningham 1998; Patokorpi 2006; Lundberg 2000), it follows that the inherent limitations of abductive reasoning will clarify the limitations to human knowledge in cyberspace in general. Tacit knowledge in turn has long been an object of diligent study for instance in information systems science and economics because it resists conversion to digital form and makes knowledge flow in and between organisations cumbersome. Aura is a concept used in aesthetics and philosophy to denote some features that unique objects (e.g. works of art) have or are supposed to have. Digital objects are anything but unique, that is, they are all copies, which opens up an interesting perspective to the differences between real (physical and mental) and digital objects. Abduction, tacit knowledge and aura have some similarities which seem to justify in treating them under a common denominator of low knowledge. Low knowledge is a personal yet democratic form of knowing that focuses on differences and details, treating individuals as whole universes. It is suggested in this chapter that low knowledge may be a key to a better understanding of the mobility of knowledge.

6.3 Abduction – the cornerstone of low knowledge

Thomas Huxley (on Huxley see Catellin 2003) claims that because abduction is an innate ability in all humans, it should be valid in all sciences. Nevertheless, one should bear in mind that knowledge by abduction (i.e. the semiotic paradigm of knowledge) is only part of human knowledge. This may be illustrated by comparing knowledge by abduction with knowledge by deduction, induction and simulation. Abduction does not involve systematic observations and experiments, like scientific knowledge by induction does. There are no systematic observations alone for the reason that one never knows what might become a clue. Abduction does not aim at system building like the bulk of deductive knowledge (e.g. Euclidean geometry). On the contrary, in abduction one starts afresh, with a clean slate every time. Abduction is not based on rules like simulation is. In simulation there are rules and a starting state. The programme is started and then one just sees what happens. In abduction there are no rules. Abduction is a way of rewriting rules. In this sense, abduction is a shared human capability of constructing plausible conjectures or theories of how things are. Therefore, abduction does not work in all cases but has its limitations. Some avenues of investigation require systematic observations and induction; or deduction; or experiments, using expensive special machinery or other equipment; special skills, and so forth.

According to Charles Sanders Peirce, “abduction is, after all, nothing but guessing” (CP 7.219). As was mentioned earlier, in abductive reasoning there is a tendency to resort to guessing before all the facts are in, which leads to over-generalisation and error, which again leads to prolonged attempts at second-guessing the cause of the error (Carroll 1990;

1997). Abduction has also a tendency to oversimplification and the construction of a personal meaning, which go at times against the more traditional educational principles of the dissemination of uniform knowledge and eradication of false conceptions. Some postmodernists (see e.g. Giroux 1988) recommend media literacy, i.e. the teaching of critical analysis skills of modes of representation, as a means to dealing with the problems caused by what they call multiple rationalities and narratives. In a modest and not quite as optimistic way this chapter is partly an exercise in media literacy.

The Internet is a web of webs, whose materials (ideas, objects) may be arranged as one pleases. This structure and functionality of the Internet give birth to its hypertextual quality. Hypertextuality allows for meanings to get connected to meanings in an endless chain. An unfortunate and likely drawback of hypertextuality is that it is easier to avoid listening to other points of view as one may pick up a piece of information from here and another piece of information from there, ignoring the rest. Hypertextuality gives more room for our abductive competence and strengthens our personal knowledge structures but with the unwelcome consequence of potentially ignoring other points of view.

Abduction is an intellectual tool, especially suited for dealing with incomplete evidence under high uncertainty in complex real-life situations or in ill-structured disciplinary fields of knowledge like medicine, psychoanalysis, the history of art and literary criticism (Apel 1973; Ginzburg 1989). Essential for both of these knowledge domains is the application of prior knowledge and experience into individual cases. The cases typically involve many kinds of conceptual complexity and even cases of the same type vary significantly from one another (Spiro et al. 1988). The mastery of conceptual complexity and the skill in applying knowledge from one case to another are very demanding. Normally they are regarded as tasks belonging to a higher-level learning within ill-structured knowledge domains. However, here the cyberspace seems to have changed things. In an online environment it is easier for a novice to go straight to a professional level without first mastering basic skills. Because we do not have sufficient means for testing our (abductive) conclusions in cyberspace, people have a hard time in telling a lucky hunch from a well-grounded and tested opinion. According to Cunningham and

Shank, "Abduction alone, of course, is not sufficient. Ideas must be linked by reason to other ideas and tested. In its current form the WWW may be less well suited for induction and deduction … but there is nothing inherent in the web that prevents it from serving those modes" (u/d, p. 8/10). Great scientists seem to have considerable perseverance in keeping guessing and testing, guessing and testing (Sebeok and Sebeok 1980, p. 40). According to Bereiter (1994; see also Scardamalia and Bereiter 1994), when knowledge gets more complex, even subsequent testing by induction and deduction is not enough but abduction needs to be complemented with intensified dialogue and collaboration. Unfortunately, dialogue and collaboration in cyberspace is undermined by the lack of pedigree criteria. Pedigree criteria are criteria concerning the reliability of the source of information: Who says what, to whom, when, where and why (Vedder and Wachbroit 2003).

6.4 Tacit knowledge

All human knowledge is at least partly tacit, i.e. knowledge that usually cannot be articulated or communicated verbally: we know more than we are able to tell. Hermann Helmholtz was perhaps the first modern writer to discuss at length the phenomenon of silent or tacit knowledge, but Michael Polanyi's writings on the matter are currently better known and more influential. According to Michael Polanyí (1964; 1967), knowledge is a human construction, and although it is public, it is at the same time to a great extent personal. Knowledge is personal in the sense that our emotions and experiences are an important and inescapable part of it. On the other hand, the language, the concepts and the intellectual tools we use when processing our experiences come from the social and linguistic community whose members we are (i.e. from other people and previous generations). The concepts we inherit and use always have a tacit dimension. Some knowledge, like practical skills, has a large proportion of tacit knowledge.

Tacit knowledge may be silent in three principal ways. First, we are sometimes not conscious of the cognitive processes that go through our mind. These processes take place so quickly or are so intricate that one cannot afterwards give a satisfactory account of them. For instance, some people with a talent for mathematics may be unable to describe verbally how they came to a solution to a mathematical problem. Second, the processes that are constitutive of knowledge may not be properly speaking cognitive, although they may become cognitive and we may become cognitively conscious of them later. For instance, manipulative abduction involves thinking through doing that is not fully conscious but we may come to an awareness of the cognitive process later, even years later (Magnani 2004a: 2004b). A more standard example would be riding the bicycle. We know how to do it, but would be at a loss when pressed for an explanation or description. Third, certain basic beliefs, generally shared by all people, about what the world is like and how things normally work are tacit. Such background beliefs are for instance that objects are rigid. When sitting down we assume that the chair will hold instead of inflating like a wet sponge underneath our body. Generally speaking, tacit knowledge forms the cognitive background for our more focal knowledge. The difference between the focus of attention and the background knowledge is fundamental to the concept of tacit knowledge.

Tacit knowledge may also be categorised into different types according to in which degree it is communicable (Molander 1996). First, some tacit knowledge is codifiable to verbal or propositional form. Using the if-then-because scenarios Tschannen-Moran and Nestor-Baker (2004), in their empirical study, dig up practical, professional knowledge from educational scholars' interviews. This type of knowledge is street smarts, practical intelligence, knowing the ropes, which is not usually verbalized but verbalisable. Second, some knowledge – especially professional manual skills – may not be expressed in verbal form but can be mediated by other means, for instance by showing how something is done (Johannessen 1999). Both the codifiable and the uncodifiable (but showable) form of tacit knowledge may be further divided into three subcategories: a) things which are not said or shown because everybody knows or are supposed to know them; b) things which are not said or shown because the cost of saying or showing is too high (Molander 1996; Styhre 2004; Boisot 1998); c) things which are not said or shown because they are not allowed to be said or shown or are not recognized or heard. Molander (1996, p. 44) calls the last-mentioned type of tacit knowledge “silenced” knowledge. On this view, things which cannot be communicated in any way do not qualify as knowledge at all.

Nonaka and Takeuchi (1995) have studied the mechanisms of the communication of tacit knowledge to others. It is this communication aspect of tacit knowledge that the chapter at hand focuses on. Shapin and Schaffer (1989) as well as Collins and Kusch (1998) have illuminated the immense difficulties distant researchers have in repeating a scientific experiment that involves more or less complicated equipment. To mediate this sort of knowledge verbal communication does not suffice but practical or physical interaction with people, machines and objects in time and place are required. Online shopping is another well-known example. Consumers generally have an urge to feel the fabric, smell the flowers and kick the tires in order to be persuaded to buy something. In the online world the customer cannot toy with the product in his or her hands, try on a pair of shoes, see if a sweater fits or get a second opinion from the salesperson (Breite et al. 1999; Breite et al. 2000).

Especially by virtue of its collaborative possibilities the ISTs in general and IST mediated learning especially enhance the mediation of skills (and thus the transference of tacit knowledge) whenever the user or learner gets practical guidance by a human collaborator (via a computation element) or built-in machine guidance. All the same, it seems plausible that there is a limit (which can be approached but never quite reached) to how well tacit knowledge can be mediated purely by IST without the real objects and without the people involved being on the spot in flesh and blood.

6.5 Aura

Aura gives expression to the intuition that a copy (even a perfect copy) of Leonardo Da Vinci’s Mona Lisa is not the same thing as the original. The concept of aura is Walter Benjamin’s attempt to put a finger on the inimitable qualities that an original object has or is supposed to have. Benjamin’s defence of the unique was a reaction to the expansion of the reproductive industries into art in the early 20th century. He tried to find the unique features of a work of art in photography, too, so that photography could enter the realm of the unique. According to Benjamin, to have an aura is to be unique. Reproduction, or copying, destroys the unique in things, that is, it destroys their aura. Aura conveys the idea that an object has a history and a patina. Patina is a number of physical traces which can be detected for instance by chemical analysis. A history of an object consists for instance of a known record of the people that have owned it and the places it has been in. Unique traces guarantee an object's authenticity. With technical reproduction like photography authenticity cannot be ascertained (Benjamin 1991, pp. 63-67).

Benjamin's concept of aura rests on the presumption that there is something hidden, a shadow or darkness in which meanings lure (Benjamin 1991, pp. 54-55). This view is related to Benjamin's habit of positing aura in the things themselves. This is difficult to accept. Matti Peltonen (1999) is perfectly right in rejecting Benjamin's habit of positing meanings in objects themselves. It is rather human beings that posit meanings into objects. Hence, by actively interpreting, that is, by giving meanings to things, the observer produces new knowledge rather than recovers pieces of old knowledge. According to Clifford Geertz (cited in Peltonen, 1999, p. 61), culture is public, and other members of the same culture recognize the meanings, although they do not always share them. Meanings are not something hidden deep in the things themselves but out in the open for all to see.

The romantic idea of the uniqueness of artefacts and the uniqueness of individual artists and their genius lies at the bottom of the concept of aura. The heydays of this romantic idea have been especially the Renaissance and the modern era. Aura is rather a historical construction; an idea, an attitude, and a practice that has a historical origin, and therefore an end as well. This historical construction rests largely on the well-known social and economic structures of the art market. Quite as easily the unique features (aura) may lose their value in the eyes of the beholder and in the social and economic system in general. Nowadays, objects in the real world get all the time more "digital". For instance an identifier tag may become in the near future so common (Downes 2003) that people may stop trusting (real or virtual or mixed) objects which do not have built-in information about their origin, authenticity, make-up, author, and so forth (Patokorpi and Kimppa

2006). Consequently, authenticity does not have to be anchored in uniqueness. Photography, Andy Warhol's reproductive art, digital artefacts which can be copied and reproduced perfectly have been steps towards a different way of seeing works of art and other "unique" objects. The young generations may well constitute a public with a different sensibility. Jean-Francois Lyotard (1993), who has analysed the so-called post-modern condition of human knowledge, goes a step further, arguing that attempts at anchoring meaning into so-called real objects are doomed to fail.

6.6 Low knowledge

Abduction, tacit knowledge and aura bring forward aspects of human knowledge that are difficult or in some cases impossible to convert to propositional form. The commonalities between these three concepts should not be exaggerated, because their mutual differences in philosophical starting points, perspective and focus are significant. However, the similarities seem to justify treating these three phenomena under the common denominator of low knowledge. The idea of low or shallow knowledge has been borrowed from Ginzburg (1989) and Peltonen (1999). What abduction, tacit knowledge and aura have in common is the focusing on the unique: individuals and particulars. The fixing of attention to unique features is in a dialectic relation to seeing totalities (i.e. wholes). It means that after having recognized something as a whole, one has to focus on the differences and details to tell this whole (this individual as a whole) apart from other wholes (other individuals). Knowledge by abduction, aura and most of the tacit knowledge are democratic because the stuff (signs) that they use as their vehicle of meaning is out in the open for all to see. Silenced knowledge is an exception. Furthermore, abduction, tacit knowledge and aura are personal yet democratic processes of knowledge, involving the senses, personal experience and action. Some functional links between the three phenomena can be found as well. One could say that bridging the gap between the background awareness and focal awareness is an abductive process as it leads to making sense of something. For instance, by tapping with a stick in a pitch dark room the object in front of you to find out that it is a chair (Mooradian 2005), requires an abductive inference. Both tacit knowledge and abduction deal with phenomena and processes that cross (erase) the borderline between sense perception and thought. Since the concept of aura seems, at least on the surface, to have the least in common with the idea of low knowledge, the following paragraphs amplify especially on it.

In spite of some problems Benjamin's aura is fascinating from an epistemological point of view. Namely, a fundamental part of human knowledge revolves round individuals and particulars, in a word, round the unique. The word unique should be understood here in a very simple, down-to-earth way. For instance, an apple – a real, physical apple – is unique, in spite of whether we perceive it to be so or not. It is unique in the sense that it can only be in one place at one time and, if we look close enough, it differs from all other apples in the basically same way as every individual human being is different from all other individual human beings. Digital objects like for instance Word documents do not have this sort of unique existence but every time one accesses the document, the computer produces a copy, a perfectly similar string of zeros and ones. This is simply how a computer works.

Benjamin (1991) claims that the less we have (real) unique objects in our proximity, the less will we become accustomed to have an eye for the unique in the world. The phrase "to have an eye for detail" reveals something essential about human perception and knowledge. Benjamin (1991, pp. 66-67) claims that the middle class people of the industrial age were tuned to see, hear and taste similarities, that is, to detect the same in things. In his opinion, the taste of the "masses" for the same – i.e. for that which stays the same in things – is the reason for the increased importance of statistics in contemporary science. However, the idea that the observer should regard all objects (of knowledge) as unique is a rather extreme epistemological tenet. It derives from the fact that Benjamin studied objects from an aesthetic point of view, that is, as works of art. Works of art are supposed to be highly unique and what we are supposed to see in them is precisely their unique, inimitable features that only can be fully experienced first hand on the spot with all the five (or at least all the relevant) senses.

Here Johannessen's (1999, esp. pp. 60-61) analysis of aesthetic knowledge and perception, which he presents in his book on tacit knowledge, may be of assistance to deepening our understanding of low knowledge. Johannessen says that when visiting an art exhibition displaying Edward Munch's paintings, we do not look at the Cry primarily to find out what it has in common with other paintings. Instead, we concentrate on the special individual features of this particular painting. In other words, we focus mostly on differences and try to see this particular painting in its individuality. Johannessen's analysis of aesthetic sensemaking builds on Wittgenstein's later philosophy, and he points out the resemblances between aesthetics as a form of knowledge and Wittgenstein's later philosophy. The most we can do in both in order to convince those we are talking to is by descriptions, gestures, insinuations, analogies and metaphors ('look at it in this way') to make them "see with their own eyes or draw their own conclusions" (p. 64). Because the interlocutor sees in principle what we see, the point is to ensure that he or she really sees what we see and make him or her experience what we have experienced. If objects are seen as individual (unique) meaningful universes by their own right, persuasive language with its metaphors and analogies is the only way to drive home this sort of knowledge. It will succeed only if the dialogue takes place in the same context in which the objects (of knowledge) are situated because the interlocutors have to simultaneously perceive the objects or at the very least the interlocutors have to have first-hand experience of the objects and the relevant context beforehand.

6.7 Digitisation of low knowledge

The near future holds a great promise in enriching the abductive means of sensemaking in cyberspace as virtual, ubiquitous and ambient intelligence technologies develop. One important question is: To what extent do the ICTs give us a means of manipulating objects of knowledge? Manipulative abduction is based on action rather than perception. The reasoner acts non-verbally upon reality, changing the object of observation and then uses the resultant tacit knowledge (which may be embodied in an external or externalised object) as an auxiliary element of the reasoning process. As was mentioned above, an example of manipulative abduction is the use of auxiliary figures by hand in geometry (Magnani et al. 2002; Magnani 2004a: Magnani 2004b). The digital media provide in principle ample opportunities for manipulating digital objects but this type of functionality is not yet widely available to the general public (Patokorpi et al. 2006). As will be argued in the next chapter, low knowledge is important for understanding the future epistemological challenges facing virtual environments, ubiquitous computing environments, ambient intelligence and so forth.

In order to become an efficient educational tool, hypertextuality requires support. Many interesting systems of digital support to online information and digital artefacts have been developed for instance in various heritage institutions and projects around the world (e.g. CHIMER, CIPHER). It is not possible to go into detail as to their design and functionality but it seems that many of them follow the guidelines of constructivist learning, underlining the active learner (Mulholland et al. 2004), and thereby building on man's natural abductive competence.

The amount of tacit knowledge in objects can be diminished by digital means. For instance, the customer may get information about the product via text, sound or video files, recommendation systems, virtual communities and so forth (Bhatt 2005). The development in mixed reality and virtual environments may force us to rethink the epistemology of unique real objects, which means reopening questions that Benjamin raised in relation to the industrial society.

Western science strives for complete articulation and representation of knowledge (von Wright 1987). This *ethos* of western science informed among other things the design of early expert systems. Although some development has taken place in expert systems in recent years in terms of logic programming and attention to the tacit dimension of knowledge, the key elements of problem solving of human experts still seem to resist conversion into propositional form and into the binary code (Hackley 1999). It has become clear by now that the model of human knowledge that informed expert systems in the 1980s was far too simplified. Attempts to "drain human brains" of their knowledge often failed and conversion to a computer-supported system led to an erosion of expert skills in the organization (Molander 1996, p. 29). Science is the domain of knowledge which comes closest to the ideal of propositional knowledge. Notwithstanding, one quintessential point made in Shapin and Schaffer's (1989) book is that in real life even scientific inquiry is a unified process of knowledge and situated collaborative action which can never be fully articulated. Moreover, conversion to propositional knowledge may not always be the most expedient way to handle the situation. Fuzzy logic, neural networks and swarm intelligence succeed in operationalising non-propositional knowledge without having to convert this knowledge into linear, step-by-step rules, which normally entails conversion into propositional knowledge.

6.8 Low knowledge mobilised and immobilised

Fairly recently, the research in computer-supported collaborative learning (Seitamaa-Hakkarainen et al. 2004; Bereiter and Scardamalia 1993; Paavola et al. 2002; Lehtinen 2003) and studies related to knowledge management and the competitive enterprise (Johannessen et al. 2001; Hackley 1999) have focused on socially shared practices that are called communities of practice, innovative learning communities or knowledge building communities. Instead of seeing tacit knowledge as "wholly embodied in the individual" (Fleck 1996, p. 119), they regard knowledge as something that is created in complex interaction with other people and external objects. The concepts of networked intelligence and distributed cognition are used in this context. Accordingly, this systemic view on knowledge recognizes that artefacts and groups of human agents, who create, gather and use information or knowledge for some purpose, are key elements of human knowledge in general.

As a result of the change of focus to communities of practice, technologies enhancing interaction and communication have gained a heightened importance (Johannessen et al. 2001). Expert knowledge and experience may at least partly be made visible and socialized by the means of ICT and distributed within a community (Lehtinen 2003). When knowledge is distributed among community members, the individuals do not have to know everything (Stapleton et al. 2005). It seems that this type of advanced knowledge building processes is not simple to implement in schools or companies, despite the heavy support by ICT (Engeström et al. 2002). Sometimes the costs for conversion by digital or other means are too high or no conversion is actually even required. As Paul Duguid (2005) has observed, sometimes it is most expedient to leave "as much as possible unsaid" (p. 112). Along the same line of thinking, Nonaka and Takeuchi (1995) point out that sometimes it is best to convert tacit knowledge into tacit knowledge. Conversion from tacit to tacit entails working together in a team, sharing experiences and interacting in many ways. Big international companies routinely mobilise tacit knowledge by moving people from one local community of practice to another (Sole and Huysman 2002; Cooper 2001; Madsen et al. 2002; Song et al. 2003).

The relative immobility of low knowledge may also be turned into an advantage in ways that are not immediately obvious. Ali Yakhlef (2005) describes how some companies nowadays move innovation activities to the customers. It is the customers who possess the tacit knowledge of their own desires and needs, making them experts in design. This sort of outsourcing to the customers would not be possible without advanced IST; the (unpaid) design work is done on the Internet. Because we have here novices – relying on their abductive competence – doing the work of professionals, Yakhlef's example could also be seen as a sign of the growing importance of low knowledge in society today.

6.9 Discussion

In the online world the pecking order that reigned in the traditional academic and professional work and company environments is crumbling down. Cunningham and Shank (u/d) explain the change brought about by the cyberspace in the following manner: "Mastering a subject matter becomes the exception rather than the rule. Clear communication about a domain of knowledge or set of skills in anticipation of future application becomes less important than connecting with resources as they are needed to solve a contemporaneous problem" (p. 6/10). Older, established members of the community cannot act as gatekeepers to relevant knowledge in the same fashion as before and the newcomers also often have ICT skills that the more established members do not have (Bereiter and Scardamalia 1993; Paavola et al. 2002). Low knowledge is spreading to new walks of life and taking a more central role in society. It is understandable because the pace of modern life is hectic and we have to act quick and dirty. Unfortunately, we largely lack the technological, social, cultural and political means of supporting low knowledge, where the use of low knowledge would be expedient, as well as the means of providing alternatives or tests to low knowledge, where its use would be inexpedient. Understanding both the limitations and advantages of low knowledge may help us towards better problem solving, communication, decision-making and collaboration in the digital age.

The chapter at hand concentrates on the limitations of digital interaction. Nevertheless, it does not share the pessimistic air of paradise lost that is evident in Plato’s and Benjamin’s attitude towards new technology. Contrary to what Plato proclaimed in Phaedrus (1988), writing has not had such devastating consequences to education and to the human condition as he feared. The medium has not replaced the message as Marshall McLuhan (1968) argued with reference to the radio and television. We do not live in a world of mirrors (simulacrum) where real objects and the hard core of reality have as good as disappeared as Jean-Francois Lyotard (1993) argued. Why not? Because the new technologies and the ensuing new practices do not replace old ones completely and overnight. The old technologies and practices usually continue their parallel although diminished existence in some form or other indefinitely or at least for some time. In time, digital interaction will blend with other forms of interaction and culture. More importantly, new technologies do not take over completely because they get anchored into our life-world (i.e. the material and social reality we live in) through social practices. Put differently, the technologies of digital media and writing are not just external containers of knowledge but involve a range of complicated social practices that partake in knowledge creation. The point is (once more) that human knowledge is a complicated thing whose creation and communication requires a complex interaction between people, ideas and artefacts (read: technologies).

Finally, the digital media surely is different from writing or anything we have seen before. We should not stultify the potential of the digital media by subjecting it to or imitating other forms of interaction and culture. Knowing how the cyberspace is different from other media should help us in utilising its full potential as well as perhaps avoiding some unwelcome consequences.

7 Technology Enhanced Nomadicity Supports Low Knowledge

7.1 Nomadicity and low knowledge revisited

Abduction, as an art of guessing (see Ch. 5), is a central conceptual tool as users try to make sense of things on the Internet. Users are compelled to using abduction despite the fact that the digital world of the Internet is largely decontextualized and the interaction is riddled with sensory deprivation as well as subject to a lack of pedigree criteria of knowledge. Paradoxically, the users on the Internet are forced to resort to clues but these clues lack many of the qualities of natural, situated interaction in the real world. Simultaneously then, and as the previous chapter (Ch. 6) attempted to show, the digital media are fairly ineffective in storing and mediating forms of knowing that anthropologists call the poor people's knowledge and historians call low knowledge. This trend is bending as context-awareness, multisensority and virtuality expand the scope of low knowledge in cyberspace, transgressing the earlier limits – examined in Chapters 3, 5 and 6 – to technology enhanced knowledge. Consequently, this chapter is partly futuristic in nature, focusing on the epistemic impact of the emerging computing environments that enable truly nomadic and ubiquitous digital interaction. The question is: How will this sort of advanced technology environment change the conditions of human knowledge?

The concepts of true nomadicity and ubiquity were introduced and explicated in Chapter 2. Therefore a very brief reminder of their meaning should suffice. In the wake of Kakihara and Sørensen (2002), technology enhanced nomadicity is here understood to mean that being on the move is an essential and normal part of the life of digital nomads, not a break from the normal. According to Leonard Kleinrock (2004), we are on the road to a world of true nomadicity. Another essential element belonging to true nomadicity is ubiquity, which implies that the world around us is computerized. Ubiquity makes computing available everywhere and at all times. The term technology enhanced nomadicity is here used for covering both of these aspects of advanced support for mobile users of IST.

As was explained in the previous chapter (Ch. 6), a fundamental part of human knowledge revolves round individuals and particulars, in a word, round the unique. Works of art in particular are supposed to be unique and what we are supposed to see in them is precisely their one-of-a-kind, inimitable features that only can be fully experienced first hand on the spot with all the five senses. If objects are seen as individual, meaningful universes by their own right, persuasive language with its metaphors and analogies would seem to be the only way to drive home this kind of knowledge. Communication will succeed only if the dialogue takes place in the same context in which the objects (of knowledge) are situated because the interlocutors have to simultaneously perceive the objects or at the very least the interlocutors have to have first-hand experience of the objects and the relevant context beforehand (Johannessen 1999). The fixing of attention to unique features is in a dialectic relation to seeing totalities (i.e. wholes). It means that after having recognized something as a whole, one has to focus on the differences and details to tell this whole (this individual as a whole) apart from other wholes (other individuals).

7.2 Context-awareness

Context-aware systems are systems in which the devices are to some extent aware of their own status, the user status, the surroundings and other devices in the surroundings. The physical or geographical location is only a part of context-aware systems, and should be understood in reference to some positioning technology and some particular context-aware system (Bellavista et al. 2003). Context-aware mobile applications, which adapt their behaviour to environmental context, are an important class of applications in emerging mobile systems. Examples include context-aware applications that enable users to discover resources in their physical proximity (Harter et al. 1999), active maps that automatically change as the user moves (Schilit et al. 1994), and applications which adapt to the device position indoors (Bahl and Padmanabhan 2000), outdoors (Priyantha et al. 2001) or both (Nord et al. 2002). Mobile context-aware systems for tourists have been around for a long time, e.g. the Cyberguide (Abowd et al. 1997), REAL (Baus et al. 2001) and CRUMPET (Schmidt-Belz et al. 2001).

Context is a central term in research on location-based services and context-aware applications and systems. Intuitively the demands of context are not too difficult to grasp. Robert Filman in his editorial in *IEEE Internet Computing* puts it nicely:

> If someone approaches you in Times Square and asks if you know how to get to Carnegie Hall, for example, you don't answer, "Yes." Rather, you take account of the question's context. You might consider the weather or seek information (or infer from age and dress) on whether the questioner prefers the subway, a taxi, or walking. People are context-aware in their service responses – and more concerned with intent than literal interpretation (Filman 2003, p. 4/5).

The implication is that future systems will need to be able to engage in situated humanlike conversation with the user (Kleinrock 2003; Punie 2003). In a similar vein of thought, Leonard Kleinrock (2004) claims that what draws people *en masse* to using new technology is the potential for improved or expanded Human-to-Human (H2H) communication (e.g. e-mail, SMS). Situated human conversation involves elements like gestures, facial expressions and the use of physical artefacts. At least some researchers (e.g. Abowd and Mynatt 2000) believe that these natural language conversation elements could be utilized as explicit or implicit input to ubiquitous systems. In this fashion H2M interaction could be made "as refreshing as taking a walk in the woods" (Weiser 1991, p. 11/11). The pressure to make systems increasingly open-ended and human-like is particularly felt in context-aware mobile systems.

Context involves numerous heterogeneous things: the physical (absolute, relative, symbolic) location, the physical conditions (e.g. light, noise), the technical infrastructure (e.g. network, bandwidth), the application domain, the system, the user (e.g. identity, gender), the user's task (e.g. acting as a secretary), other users, symbols, symbolic positions (e.g. social capital), virtual settings (e.g. the desktop metaphor), socio-economic positions (e.g. class) and social settings (e.g. a meeting) (Dix et al. 2000; Punie 2003; Floch et al. 2001). Pica and Kakihara (2003) suggest that interaction today could be described being as fluid as water. People, devices, applications, symbols and virtual spaces move and intermingle, and there seem to be no clear boundaries. However, the fluidity of interaction does not mean that there would not be asymmetries, inequalities and all sorts of clashing structures and processes in cyberspace.

Perhaps the best way to illuminate the severity of the challenge facing a context-aware systems designer in the world of fluid interaction is through examples. For starters, the device may be technologically unable to access the information. For instance, the file attachment is too large. Accessing the information is technologically possible but the physical (task) context makes it impossible or dangerous to access it: reading an email or a document while driving a car (Perry et al. 2001). It is often difficult to combine virtual space with a physical space not so much because of technological limitations but because of social norms. In other words, the behaviour expected of the user in the physical space (a social space with a set of social codes) may be in conflict with the expected behaviour in the virtual space (another social space with another set of social codes) (Palen et al. 2000). For instance, answering a mobile phone in a funeral. The virtual space may be in the metaphorical shape of an office desktop while the physical environment where the mobile user finds him- or herself makes it difficult to utilize the incoming data effectively (Cousins and Robey 2003). In the same context users may be prevented from having equal access to the same information space: when Bob is leaving Carol's office a privacy system deletes the data owned by Carol on Bob's laptop (Jiang and Landay 2002). Things take place not only in a context but in a situation within a context. The same context may give rise to many very different situations: a meeting may change into a more relaxed social gathering (Lueg 2001, p. 4/6). Different individuals act differently not only in the same context but in the same situation. Finally, the same individual may act differently than before in the same situation.

7.3 Virtuality

Virtual Reality (VR) is "a computer generated interactive, three-dimensional environment in which a person is immersed" (Aukstakalnis and Blatner 1992). Especially early on virtual reality research strived to completely immerse the user into an artificial environment, blocking out the real world (Vallino 1998). Virtuality systems or environments that extend parts of the real world with virtual elements are called augmented realities or augmented reality systems. Advances in mobile computing naturally direct VR systems towards Augmented Reality (AR) environments. Mobile devices like a PDA can be fairly easily used to complement the real world with virtual elements. Examples of this kind of mobile augmented reality systems include 3D AR prototype for a mobile system (Feiner et al. 1997), handheld AR tracking systems (Wagner and Schmalstieg 2003) and active AR systems based on mobile code (Kangas and Röning 2002).

Some applications, like intelligent agents, have an existence only in virtual space (Dix et al. 2000). As a rule, people and computational devices should be seen as simultaneously inhabiting both the real world (i.e. one physical space) and multiple virtual spaces or worlds. The virtual and the real may be mapped onto one another so that the user moves seamlessly from one to the other (Dix et al. 2005). For instance, in emergency training systems the virtual world is built upon a model of the real world. Activities in this sort of virtual worlds have their (realistic) counterparts in the real world. The outcome is an imaginary real world which enables the user to construct a mental model of real emergency situations (Kristensen et al. 2003). Mobile devices likewise give access to multiple virtual spaces although the user is less immersed in them compared to a full-scale VR. Because the virtual space has a reference to a real space or to a metaphorical setting (i.e. another virtual space modelling reality), Pica and Kakihara (2003) talk about the duality or dialectic of mobility. Hence mobile devices "exist in that they bring about a virtual reality that affects the way in which we act in disparate physical environments" (p. 9/12).

Virtuality should perhaps be seen as subjective and gradual because the sense of presence in virtual worlds differs from case to case. Video games can be highly engaging although the player is only partly immersed in them. We are surrounded by writing, TVs, radios, telephones, photographs and so forth, which are all virtual or makers of the virtual. A greater and greater part of the artefacts we deal with in our everyday life are immaterial things not located in the physical space. Our lifeworld is becoming increasingly virtual

(Brey 2005). On the other hand, Timo Airaksinen (2005) argues that in the last analysis virtual worlds are places to visit. Sooner or later we have to return to the real physical world. Or do we?

Manuel Castells (2001) says that the virtual is real to us because we deal with real ideas, feelings and conceptions. It means that objects of thought and even feelings are only virtually present to the mind. If one were to follow this terminology consistently, our normal everyday life would in no way differ from virtual reality as we in both deal with real ideas, feelings and conceptions. Finer terminological distinctions are clearly called for. The virtual can be real but also unreal (Orliaguet 2001): (i) a virtual unreal object is a new, original idea in an individual mind, not shared by the rest of the semiotic community. It is unreal because it exists only in the individual mind; (ii) a virtual real object is an idea shared by a semiotic community; (iii) a virtual unreal object (but a real image) is a virtual object with no correspondence to reality; (iv) a virtual real object is a virtual object with a correspondence to reality. The first and third (i and iii) are fictive or imaginary objects.

Charles Sanders Peirce discerns between actual, habitual and virtual capacities of the mind to contemplate an object or idea. Actual content or meaning consists of a particular object in its concreteness being thought by an individual mind. Habitual content consists of a sum of particular experiences of the same or similar objects being thought by an individual mind. Virtual content corresponds to the form (the eidetic structure) of an object shared by the semiotic community (Esposito u/d). As Seitamaa-Hakkarainen et al. (2004) have pointed out, virtual collaborative environments have the capacity to "provide new resources for transforming individual insights and accomplishments into externalized and public form so that they may become items of collective property" (p. 28). In this way unreal, imaginary objects or ideas can in some cases be made into real ones. On the other hand, it is possible to create virtual environments that are based on completely imaginary objects and ideas or metaphors without any backing from scientific theories or models of reality. These virtual models can be realized in the computer environment without any need to verify them against the physical reality (Turoff 1997).

The ability to opportunistically and at will to mould virtual environments is seen as the most valuable function of virtuality in computing systems (O'Hare 2000). Thus VR environments have the capacity to create alternative realities as well as representing existing reality.

7.4 Multisensority

Presently, the Graphical User Interface (GUI) dominates HCI design, making visual input/output the main medium at the expense of other senses, such as touch. Nomadic systems require developing novel ways of interaction that reduce the amount of user attention to the computing system. The demand for visual attention in particular should be reduced (Myers et al. 2000). The use of non-speech sounds in mobile computing is one way of improving GUI-based interaction (Brewster et al. 1998). The AudioGPS created by Holland and Morse (2001), to present just one example, is an audio interface coupled with the Global Positioning System. The system relies on non-speech sounds (i.e. spatial audio), informing the user of distance and direction. The direction is mediated by stereophonic, simple, repeated panning.

The Tangible User Interface (TUI) represents a wholesale solution to the problems that users face when using GUI. TUI combines physical objects and physical space with virtual elements. The so-called Tangible Bits allow haptic (i.e. grasp and manipulate) interaction with physical objects as well as exploit the mediation of information by versatile sensory input from the background. Examples of haptic interaction include such display media as light, sound and airflow, which exert their impact on the more peripheral senses. Tangible Bits copies the rich potential of the division between foreground and background of awareness in regular human activity in the real world. Here one could talk about ambient intelligence which makes the environment intelligent by augmenting space with digital information and objects. The vision of augmented reality by TUI turns walls and tables into interface surfaces, coupling graspable objects like coffee cups with digital information as well as exploiting other senses than vision (e.g. touch by airflow) in communication. With TUI, computing will become "truly ubiquitous" (Ishii and Ullmer 1997, p. 13; Punie 2003), an integral, although invisible, part of our everyday environment.

Today we have a rich supply of minuscule, very cheap sensors, so-called sentient objects. Sentient objects interact with the physical environment, making applications "aware" of the physical space they occupy. By combining several sensors (e.g. for temperature, movement and position) everyday objects can be augmented and become aware of their own status and the context they are in (Gellersen et al. 2002). The Mediacup is an example of this sort of multi-sensor technology (Beigl et al. 2001). Sentient objects, which are especially important in nomadic environments, extend the possibilities of communication between machines and humans further. Consequently, the development of both context-aware technology and augmented reality environments gets a boost from sensor technologies. Leonard Kleinrock (2001) envisions a world beyond the more or less static virtual reality environments, speaking of smart spaces that encompass the real world: "Most things in our physical real-world environment will be Internet-enabled via embedded technology. The environment all around us will be alive with technology – in the common surfaces and in our desk, clothes, eyeglasses, refrigerators, vehicles, hotel rooms, even our fingernails and other places in our bodies" (p. 45). The technology of smart spaces is envisioned as human-centred but it is still largely an open question how the users could and should make sense of, utilize and control it (Kleinrock 2003; Punie 2003).

Speaking of controllability, the popularity of the spreadsheet owes to it being programmable (by formulas and macros) by the user (Myers et al. 2000). Resnick and Berg (2000) argue that the computing elements embedded in the environment have so far been black boxes, of whose working principles the users have little or no understanding. Resnick and his colleagues have developed so-called manipulables which are programmable, personalizable and thus also controllable by the user. For instance, Crickets are computational tools (very small general purpose computers) for children. By embedding ordinary objects with Crickets the children learn about the objects and related phenomena. Crickets reclaim the builder's knowledge that scientists of the past had when they built and customized their own instruments, thus making the way things function transparent (Resnick and Berg 2000). These sort of manipulable computational tools are real objects with embedded intelligence that can be programmed or reprogrammed by the user. The key to end-user programming seems to be interface design. End-user programming has perhaps seemed like an unrealizable dream at times but the digital manipulables and the strengthening of the open source movement indicate that the idea could be realized in larger scale in the near future.

7.5 More room for low knowledge

Generally speaking, context-awareness, multisensority and virtuality enrich the perceptual or sensory dimensions of digital objects and interaction, adding for instance three-dimensionality, touch and awareness of the surrounding space, thus extending the scope of low knowledge. However, the epistemic conditions of a truly nomadic interaction differ in some novel and interesting ways from a situated face-to-face interaction, the latter being usually applied as a model for “natural” human interaction.

Because computers have so central place in our economy and society in general, there is a tendency to think that only things that can be digitised are proper knowledge. All ephemeral things seem to be of less value as knowledge. New technologies extend the range of things that can be digitised. Dance is a prime example of something ephemeral, belonging to the domain of tacit knowledge. The motions are stored in the body or at most written down with some special notation (choreographic labanotation). The motions are usually communicated from choreographer or dancer to dancer through bodily contact. Nowadays, it is possible to store motion digitally.

To date, computers have mainly supported linear thinking. The software supporting, say, the business management, is as a rule based on deductive methods, statistics, linear optimisation and similar forms of linear thinking (Kilroy and McKinley 1997). Linear thinking is suitable for stable environments but few managers work in such stable environments. When it comes to other, even more unstable or ill-structured domains, other than linear thinking methods are required. It seems that the demand for non-linear thinking is increasing for several reasons. Information Society Technology (IST) is all around us, not just in professional contexts but in everyday life. More and more non-professional people use IST daily. IST itself applies more nonlinear information processing methods. Logic programming based on abductive logic, neural networks and fuzzy logic level the way for users to manage more complex workaday or everyday phenomena. As a result, the future interface technology will conform to the way we humans think, talk and move, not the other way round (Abowd and Mynatt 2000; Punie 2003).

Multisensority and TUI enrich digital interaction by engaging other senses than vision. Engaging the peripheral senses by TUI allows focusing on the task at hand. However, deciding what the real task at hand is (i.e. foregrounding), is difficult to do since background knowledge is largely tacit and increasingly embedded in the technological infrastructure. As is known from human interaction in general, keeping some knowledge at the background is not something neutral but may be a significant exercise in discursive power (Duguid 2005). Another problem may be caused by the fact that different senses have different kind of memories, with differing duration. Nomadic environments should be able to deal with this sort of perceptual temporalities in an unintrusive manner.

Compared to a natural environment, digital environments are artificial in the sense that the experiential (e.g. learning) materials can to a greater extent than before be trumped up, arranged and manipulated. When the users are given means to manipulate digital artefacts, they obtain so-called maker’s or builder’s knowledge. They know what something is made of and how it operates because they themselves have made it. Maker’s knowledge makes digital interaction more transparent to users. Nevertheless, what may become a source of concern is that one can make digital artefacts that are completely imaginary. When using the digital media one can for instance ignore the natural interrelations between size and form. In the real world all things are supposed to have their natural size and proportions: if a human being were five meters tall but with the same proportions as normal people, he or she would collapse as the bones could not support such a construction. One may wonder how much computers and other digital media have influenced such phenomena as post-modern architecture, the so-called Walt Disney architecture, whose central characteristic is the defying of conventional ideas of proper form, size and proportions.

Human cognition and learning are fundamentally situated things. The activity related to, and the context in which something is experienced or learned, is an integral and inseparable part of that particular experience and of learning itself. Mobile technologies thus enable the user to be on the spot in the physical world where for instance the physical objects are located. Compared to pre-nomadic technologies, the user's experience is more situated than before. However, compared to situated face-to-face interaction, either the interlocutor or the physical objects are not simultaneously present – otherwise there would be no sense in using a mobile device. Learning, in truly nomadic environments, may not take place because learning is also enculturation, which implies a closer interaction between the interlocutors. As a result, technology enhanced learning may not carry over to the real world; the user may not be able to perform in an authentic situation (Brown et al. 1989).

The fact that either some of the objects or the interlocutors do not share the same physical space causes problems with reference, that is, problems with indexicality (Brown et al. 1989; Sørensen and Pica 2005). The semantic web is a solution of sorts to this problem. The semantic web could be developed so that it connects the signs used by computers to real people, objects, processes and places. Controlled languages (e.g. ClearTalk) which both humans and machines can understand already exist. Fully automated natural language interpretation in turn seems to be extremely difficult, if not impossible, to accomplish (Sowa 2000).

The basic model for everyday H2H interaction is considered to be situated face-to-face conversation. The means of natural, non-verbal communication can be to some extent exploited in nomadic computing environments. But how close to a natural language conversation H2M interaction can be made? Mihai Nadin (1988) suggests that the idea of computer systems engaging in human-like conversation is fundamentally flawed because the many-valued logic of natural language conversation cannot be reduced to the two-valued logic of computers. *Pace* Nadin, in H2M interaction the machine does not have to have the same logic as humans for the interaction to work. Genes are based on binary logic and still manage to "interact" with individual organisms whose function is based on many-valued logic. Secondly, it should suffice that the interface responds in a *human-like* manner. Thirdly, sharing the same logic does not guarantee understanding, as we know from H2H interaction. This is to say that natural language conversation can be simulated but it does not solve all problems of H2M interaction.

Digital interaction or "conversation" can be documented at the same time as it takes place. In this respect computer-mediated social spaces differ from real world social spaces (Coppock 1995). Also, in cyberspace our communications do not disappear but may turn up years or decades later in a new context, and there is not much we can do about it. Some preventive measures have been developed, however. The physical, social, task-based and temporal boundaries can be determined and controlled by the user, the system, the designer or a third party, by embedding cheap and disposable chips and radio transmitters in objects as part of packaging (Abowd and Mynatt 2000; Jiang and Landay 2002). The transmitters notify control programmes of boundary crossings. Digital objects can in this way be ascribed survival habitats and use-by-dates. This sort of scrap or disposable computing will most likely become more common in the future (Downes 2003).

Digital artefacts are copies (the same): there is no original. Low knowledge, in contrast, is about differences, focusing on unique things. Nowadays, real objects can be augmented by embedding intelligence for instance in the form of digital tags that identify them individually. Objects may tell us what they are, what they are made of and by whom, where they come from and where they are going (Downes 2003; Patokorpi and Kimppa 2006). An interesting consequence is that smart objects give clues to users. We are certainly from before familiar with "artificial" or virtual clues in our everyday surroundings: writing and other conventional signs exist all around us. Nevertheless, people instinctively expect some clues to be unintentional (natural). The fact that a clue is natural or at least unintentional is taken to mean that it can be relied on precisely because it is not “loaded”. Like in a court of law a witness statement which is given unawares of the consequences is more credible than one which is given knowingly. We humans are used to having objects that are dumb in our surroundings, and it is difficult to foresee the full epistemic consequences of increased coupling of natural and artificial objects.

How personal is personal if mediated by ubiquitous technology? In order to remain at the background, which is the idea in calm computing, ubiquitous systems need to have the capacity to automatically build a model of the user based on the data of the user’s behaviour. The user data obtained may consist of records of past behaviour or, by using sensor technology, of the present behaviour. Assuming that the system keeps building models of the user’s personality, how can the user override the machine’s decisions when the model is wrong? Not only will the user be forced to do things he or she would not otherwise do but he or she is likely to stay ignorant of that he or she had a choice in the first place. And as similar choices strengthen the pattern, the user may become a prisoner of his or her own profile.

To summarize, a more detailed scrutiny reveals that the epistemic consequences of true nomadicity are rather complex and paradoxical. Compared to both face-to-face interaction and pre-nomadic interaction, technology enhanced nomadicity has subtle but significant differences in matters related for instance to foregrounding, support for non-linear thinking, support for sense perception, virtuality, perception of the relations between matter and form, situatedness and enculturation. Many ethical issues arise, too, but they are beyond the scope of this work.

Conclusion

The train of thought presented in this work proceeds as follows. In very advanced computing environments the interaction between machines as well as between machines and humans has become so open and “humanlike” that it cannot be described or explained with the help of the algorithmic model of computing any more. Information Society Technology (IST) has penetrated all walks of life, and is being applied, among other things, to enhance education. Information and Communication Technology (ICT) enhanced learning realizes the central ideals of constructivist pedagogy. Abduction goes a long way in describing and explaining the special epistemic circumstances of ICT enhanced learning and digital interaction in general. ICT cuts out aspects of knowledge and reality, making abduction at some point inoperable. Aura and tacit knowledge, too, help in marking out the limits of discursive means via abduction (i.e. semiotic means) in cyberspace. Abduction, tacit knowledge and aura share some closely related features which justify identifying a domain of knowledge that is called low knowledge. Low knowledge typically regards all things as unique and concrete. Context-awareness, multisensority and virtuality, in turn, broaden the potential of abduction and low knowledge because they bring us (as users) a step closer to a real-world, situated face-to-face interaction, that is, a step closer to kicking the tires, feeling the fabric, casual chatting and taking a walk in the woods.

Control, among other things, will become an issue in completely automated environments (Spiekermann and Pallas 2006; Sørensen 2002) as for instance part of our personality will be moulded automatically by technology. Some writers (Airaksinen 2005) believe that people will lose their individuality and autonomy. Truly nomadic technology raises also many other ethical issues that are at least equally complex than the epistemic issues discussed in this dissertation. Such ethical issues are, among others, presence, autonomy, individuality, fragmentation of the lifeworld, empathy, estrangement, inequality, communality, commitment and non-participation. These ethical issues are beyond the scope of this dissertation.

Far from advocating technological determinism, it is nevertheless assumed here that technological development has an impact on how we perceive and think of ourselves and of the world around us. In other words, technology brings about historical epistemological changes. Abduction has of course in all times been a central part of the process of human knowledge. The point here is that nowadays in an IST and mobile environment abduction is getting all the more central, and consequently the epistemology of the people using these technologies is changing. This is the bottom line of the argument put forward in this work. The epistemic change is studied mainly with the help of one mode of inference – abduction. It will be left to others or for later work to examine the overall mechanism of epistemological change, whether it would be in terms of epistemes (Michel Foucault), scenes of inquiry (Nicholas Jardine), networks (Bruno Latour), or something else.

The circle is closing and it has come time to see whether this study has succeeded in giving answers to the questions it set out to examine. As was mentioned in the Introduction, the principal research question in this work is:

- What is the role of abductive reasoning in digital interaction?

In order to address this principal research question, a number of minor research questions were introduced. Let us begin summing up the results by first going through the minor research questions, how they relate to the key knowledge constructs, and how the answers provided to them contribute to information systems and related research.

The first minor research question is:

- Does the emerging IST differ in terms of its epistemology from similar, previous technologies?

The development of advanced computing technologies is in this work studied against the theoretical backdrop of digital nomadicity. The knowledge construct of digital nomadicity has been borrowed from previous research. Digital nomadicity implies that an epistemological change of sorts has taken place as we are passing from prenomadic technology to truly nomadic technology. It is suggested in this work that the change is rather of the nature of an epistemic rupture than a full-fledged paradigm change. Building on the ideas of digital nomadicity, fluidity and interactivity, the concepts of metaspace, transient hierarchies and multiple-profiling are proposed to round up a vision of truly nomadic and ubiquitous computing environments (i.e. digital nomadicity). Due to complicated epistemic changes, not only geographical and technological barriers or boundaries but also the barriers created by local and parochial techno-social systems have to be taken into consideration in order to level the way to true nomadicity. A key question in the near future is how the user of advanced mobile technology could be empowered to have more control over the multiple spaces he or she inhabits and the numerous boundary crossings that he or she is forced to perform. Metaspaces, transient hierarchies and multiple-profiling are applied to demonstrate that the various barriers and boundaries existing in cyberspace can be conceptualised, examined empirically and thus taken into account in both research and design.

Constructivist learning theory is the main knowledge construct applied in Chapter 3. Its job is to make research into technology enhanced learning, learner psychology and thought processes more manageable as it has a coherent view on how the above mentioned things work or should work. The second minor research question set out to test the constructivist pedagogues' claim that constructivist learning theory and ICT enhanced learning are in perfect harmony with one another. In the Introduction this question is expressed as follows:

- How can ICT support constructivist learning?

The empirical literature indicates that some technological domains seem more suitable for constructivist learning than others. By applying hermeneutic psychology and philosophical argumentation some potential or actual weaknesses in the chain of connections between constructivist pedagogical principles, psychological processes, supporting technologies and the actual application of ICT in a learning environment can be identified. One example of a weak link is personalisation technologies whose immaturity hampers the constructivists' attempts at enabling learners to create personal knowledge. Pragmatism enters the picture as a ready source of criticism, bringing out a certain one-sidedness of the constructivist view of man and learning.

Chapter 4 deals with mobile learning, focusing on the following research question:

- What should mobile learning objects be like from the user's point of view?

The structure and dynamics of mobile learning objects must be in line with the central features of mobile learning; they must promote learning experiences which are repeatable, expedient, personal, immediate and situated. Following these guidelines should result in mobile learning objects that are small, intelligible, object-like and interoperable (general qualities) as well as expedient, situated, immediate, persistent, reusable, personalized and manipulable (specific qualities). Today's mobile technology does not cater equally well for all of these requirements or desirable qualities. In particular, the state of the art of mobile technology is not yet generally advanced enough to support in any significant degree the interoperability, personalizability and manipulability of mobile learning objects.

Abduction is discussed in the Introduction as well as in Chapters 1, 2 and 3 but makes its full appearance first in Chapter 5. Thus Chapter 5 sets out to find out:

- What is abduction like as a pattern of everyday reasoning?

Well over ten forms of abductive inference can be discerned. The versatility of abduction is striking. As its various forms or patterns cross the line between thought and perception, the conscious and the unconscious, it helps for instance clarifying some central disagreements between proponents of different learning theories. Peirce's abduction could be compared to Einstein's relativity formula, which succeeds combining two things

– time and space – that had not been combined before. A study of the forms of abductive reasoning helps us better understand ICT enhanced learning and IST user behaviour as well as give us some valuable hints to the design of human-computer interaction in general.

Another question, running through, so to speak, Chapter 5 is:

- What is the role of abduction as a particular thinking style in technology enhanced learning and digital interaction?

Abduction supports ICT enhanced learning, especially when the learning materials and the environment have been arranged in concord with constructivist educational principles. The relationship between an educational theory, technology and a thinking style is not simple, but it would seem possible to build a full-fledged technology enhanced learning programme on the basis of abduction as a particular thinking style. Empirical studies seem necessary for one to pursue this topic further.

Chapter 6 starts with the observation that abduction, tacit knowledge and aura have some similarities, and that these similarities seem to justify in treating them under the common denominator of low knowledge. The question is:

- What is low knowledge and what is its role in digital interaction?

Low knowledge is a personal yet democratic form of knowing that focuses on differences and details, treating individuals as whole universes. Low knowledge may be a key to a better understanding of the mobility and immobility of knowledge because it brings forth some essential limitations to human knowledge in prenomadic technology environments. Numerous little differences in the epistemic conditions of a real-world environment as compared to a digital world environment exist, thereby delimiting the ways in which the user thinks, acts and interacts.

As Chapter 6 focused on the limitations to human knowledge in prenomadic technology environments, Chapter 7 examines some key advances in digital, nomadic technology, which help in surpassing earlier limitations. Thus the pivotal question is:

- How do context-awareness, virtuality and multisensority affect the epistemic conditions of digital interaction?

Context-awareness, multisensority and virtuality enrich the perceptual dimensions of digital objects and interaction, adding for instance three-dimensionality, touch and awareness of the surrounding space. Consequently, there will be more room for the finding of clues and for creative sense-making; more room for low knowledge. In other words, compared to pre-nomadic technologies, users will be able to utilize their natural perceptual and cognitive capacities to a greater extent than before. Nevertheless, truly nomadic interaction does not equal situated face-to-face interaction but there are subtle yet significant differences in matters related for instance to foregrounding, support for non-linear thinking, support for sense perception, virtuality, perception of the relations between matter and form, situatedness and enculturation.

As a final effort to demonstrate that the knowledge constructs cohere, they are presented schematically in Table 4 below. The table should certainly be taken with a grain of salt but at best it points out some fundamental, persistent undercurrents as well as slight variations in theme, as will be explained below. The column headings derive from a simple application of a user perspective: How the user is expected to think (cognition); how the user is expected to do whatever it is that the user is doing (action); how to interact (interaction); by the help of what (technology) and where (environment).

Table 4: Knowledge constructs and their mutual relations

	cognition	**action**	**interaction**	**technology**	**environment**
digital nomadicity	abduction	situated	fluid	context-aware, multisensory, virtual = nomadic	hybrid
constructivism	abduction	collaborative	peer-to-peer	personali-sation, simulation and mobile	real-world-like
mobile learning	abduction	situated	communi-cation based	mobile	real world
mobile learning objects	abduction but ideally also induction and deduction	immediate, repeatable and situated	persistent, personalised and manipulable	mobile, personalisation and manipulation	ideally anywhere
abduction	N/A	sense making under uncertainty	text-based and graphical	hypertext or all prenomadic	digital world
		situated	multimodal	nomadic	hybrid
			face-to-face	none or low tech	real world
low knowledge	abduction but with contextualised and multisensory clues	situated and collaborative	democratic, contextualised and multimodal	nomadic	digital world
					hybrid
				none or low tech	real world

As the table sums up the previous tables, reading the rows should not at this point be too difficult. Thus the first row is to be read so that digital nomadicity compels the user to resort to an abductive style of thinking, take action in a situation, interact in a fluid manner by the help of truly nomadic technologies in a mixed real-world and digital (i.e. hybrid) environment. Column-wise the table shows slight variations in the persistent, main themes. Hence the cognition column adds induction and deduction to the reasoning forms for mobile learning objects. Mobile learning objects are ideal constructions and the use of other forms of reasoning, manipulation technologies (e.g. end-user programming) and the scope of their applicability (anywhere) are pious but for the time being fairly unrealistic expectations. With a reference to the abduction row, one has to accept that digital objects are different from real objects in terms of their epistemology. A central difference between them is that real objects are concrete and unique, which has an impact not only on how the user thinks or reasons but how he or she interacts and feels. To regard digital and analogue objects as similar is to fall a victim to a representational fallacy. Thus the view presented here goes against the idea that there are from the user's point of view no significant epistemic differences between digital and analogue technologies. Accordingly, in the table above the dividing line between the real world and the digital and hybrid worlds should in principle go all the way to the left, to the cognition column. However, the user can up to a point regard real and digital objects as equivalent, which means that not just the designer and the scientist but also the user may fall victim to the representational fallacy. Regarding real and digital objects as representations of reality allows one to think and act in both cases as in response to symbolic signs. In order not to get too deep into semiotic subtleties, suffice it to say that owing to its conceptual nature abduction allows one to draw finer epistemic distinctions than has been possible before, which is reflected in the number of boxes in the abduction row. Low knowledge, in turn, covers a richer, coherent unity of epistemic features which makes it more complex and its effects sometimes paradoxical or contradictory.

Out of the six knowledge constructs, mobile learning objects, abduction and low knowledge are more or less original contributions to IS research. It is perhaps fair to say that abduction as a form of everyday reasoning has so far been little applied to the study of ICT enhanced learning and low knowledge is perhaps here being applied to digital interaction for the first time. The practical usefulness of the design principles of mobile learning objects is fairly clear. The same goes for multiple-profiling, although first empirical work will tell whether these two knowledge constructs stand up to the challenge. In answer to the main research question one could say that abduction tells us (or models) what goes on in the user's head and low knowledge clarifies the broader epistemic conditions as users behave as human beings have been conditioned to behave in the course of the biological evolution and cultural development. Therefore abduction and low knowledge may significantly contribute to the design and assessment of human-faced ISTs.

Finally, it should be borne in mind that this is a *theoretically* oriented research on abductive reasoning and IST. If it turns out to be insightful and accurate enough, there may be pointers for building future applications especially in mobile learning, interface design, presence and personalization technologies. The application of abduction in a form as close to *logica utens* as possible in programming seems also a natural next step to take. Speaking of natural next steps, the role of inductive inferences in digital interaction would also require closer examination in the future. Also, many empirically oriented research questions about the role of informal reasoning in general in HCI suggest themselves.

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Appendix 1

Assignment

1. Summary

The purpose of this assignment is to use mobile devices (Ipaqs) in order to work out the substance for the course paper of the course 4082 Mobile commerce. The main objective of the course paper is to provide a business plan for a mobile value service. You will work exclusively with (i) video materials and news channels (accessible through the Ipaq) and (ii) notes, observations and discussions conducted through the Ipaq.

In the text below, I explain how to get started with the devices, and the various tools/applications/materials that are available for use. The working environment is left purposefully open so that you can use the devices innovatively to work out the substance. However, one requirement is that you should use the m-diary functionality of the m-learning environment to iterate discussions with your group members.

Evaluation of the assignment will be made on the basis of a short summary that you will submit to the instructor.

The assignment will be monitored by a master's thesis student. This student is writing her master's thesis on the use of m-learning tools. She will send you a couple of questionnaires (not more than 4 questionnaires) during the next couple of weeks. In the context of this evaluation, you will also be invited to a focus group session early in May.

2. M-learning environment

The central tools that you need to complete the assignments have been put together on one webpage. The page is accessible through the Ipaq. Its URL is: www.abo.fi/~ftetard/mlearn.htm

2.1 Ipaqs

The Ipaqs that have been distributed to you are equipped with WLAN network cards, which means that you can, within the university campus, access the Internet wirelessly through the Sparknet network (http://www.sparknet.fi/index.php). The use of the Sparknet network is free for students. Use your university user name and password to log in to Sparknet. Ipaqs can be used both in online and offline modes. They include lots of features: explore these features and use the ones which you think can help you in the assignment.

2.2 M-learning platform

The m-learning platform is an environment that has been specially designed to enable communication between mobile group members. You can understand it as a mobile discussion forum, or a mobile blog. The m-learning platform is organized in groups (see 3.1 below). You will belong to one group during the assignment. When you belong to a group, you can use several communication features:

- send e-mails and messages to other persons, groups…
- write an m-diary: this feature enables you to discuss several matters, send replies to discussion items. This is a central feature.
- retrieve materials send by the course leader: this function will probably not be used during the course.

The m-learning platform is available at: http://www.abo.fi/~ftetard/mlearn.htm .

2.2 Video materials

The main assignment page includes links to several video clips. These clips have been tested and should be working with the Ipaqs. These clips cover various issues regarding mobile commerce: the technology, the market, business and cultural issues. You can view these clips and evaluate their content (note that some clips might deal with hype regarding the potential of mobile commerce, but, for the most of it, the content can be very useful for the substance about mobile value services). These can also be an important source of information for the discussions you will be conducting. The list of video clips will be updated on a regular basis in April.

2.3 AvantGo news channels

We would like you to use AvantGo news services to get regular updates on technology and business news. AvantGo is a new service that pushes to you information channels you have subscribed into (for example: if you are a sports fan, you can get updates on sports news).

AvantGo works with Ipaqs. You should register on the Web at www.avantgo.com and subscribe to the channels you are interested in. Once you have registered, you get your news updates wirelessly with the Ipaq. There are many channels to subscribe to, but you might be interested especially in channels dealing with business, technology news, mobile technology news and so on. Some channels are updated frequently, while some others are not: you should try out for yourself and look for the best pieces of news that might contribute to your assignment.

3. Groups, evaluation and follow-up

3.1 Groups

4 groups of 3 persons participate in the assignment. Assignment of groups will be made on a first come, first serve basis. A list of participants is sent to you; if no preference is expressed, groups will be assigned randomly.

3.2 Evaluation:

The basis for the evaluation of this assignment is the discussion(s) that take place within the m-diary. Submit a 5-page (minimum) report including:

- how you experienced the assignment
- the main discussions that were conducted during the assignment
- what the main insights of this assignment are
- how the assignment will contribute to your course paper.

4. FAQs

There are, for the moment, no FAQ. Any questions related to this assignment should be directed to the instructor. Answers to FAQ will be posted on the assignment's main page (www.abo.fi/~ftetard/mlearn.htm).

PART 2

RESEARCH PAPERS