Designing Learning Tools

Methodological Insights

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TEEMU LEINONEN
Kallio, Helsinki, October 2010

A

1
Introduction

Learning tools are everywhere. We may learn from everything around us. Many objects found in nature and a great multitude of man-made cultural artifacts can be considered as *tools* that *can* be used for *learning*. We learn — in other words changes in our cognitive structures and behavior come about — when we use different objects as tools. It is important, however, to emphasize that not all objects are *learning tools*, though not *only* learning tools can be used as tools for learning.

The key concepts of this study are *learning tools* and *design methodology*.

What is a *learning tool*? Säljö (1999) pointed out how throughout history people have developed tools to solve intellectual and practical problems and how learning can be studied precisely as a process of using these tools. In relation to discussion about distributed intelligence, Pea (1993) claims that tools literally carry intelligence in them, that they are major carriers of patterns of previous reasoning and can be used by new generation with little of no awareness of the struggle that went into designing them. Besides a multiplicity of different artifacts for different intellectual and practical purposes, all human cultures have arguably also produced artifacts specifically designed for the purpose of learning.

Erik Ahlman, a Finnish cultural philosopher, discerns four grounding features of a tool used by a culture (Ahlman, 1976, p. 105). Ahlman observes a cultural tool from the four basic viewpoints of its being:

1 *used* by people;
2 produced or put into use by people *consciously*;
3 *disseminated* for general use among people, and
4 used *continuously* by people.

Following Ahlman, the concept of a learning tool as a cultural tool has a necessary logical connection to the ideas of *conscious purpose* and *iterative usage*. Cultural tools are constantly created by cultures to carry out specific tasks, to serve some particular acknowledged purposes (Ahlman, 1976, pp. 106-107).

When viewing formal schooling and its history, we can easily recognize certain artifacts designed specifically for teaching and learning, such as blackboards, pointers, mechanical and digital simulations, and learning games. It is worth emphasizing that the focus of this study is on those cultural tools or artifacts that are *specifically* designed for learning. The main interest of this study is in exploring the design of advanced computer-related learning tools.

What is *methodology*? The concept of *methodology* refers mostly to the philosophical principles and rationales behind sets of methods and procedures for inquiries. In this study the focus is on the methodology of designing learning tools — *design methodology*. Design methodology can be considered to concern those philosophical assumptions and procedures that are expected to lead to a good and well-working design and, in this sense, also to a significant and meaningful design — as criteria for good design. When focusing on methodology, this study investigates questions and suggestions about *designing design tools*.

The *Introduction* (Chapter 1) starts with a brief presentation of the history of computer-related learning tools and introduces some earlier research trends related to them. The Introduction ends with a presentation of the research questions and the methodological approach of this study. The chapters on *The Tools Designed* and *Research Articles* (Chapters 2 and 3) include explanatory summarizing descriptions of the learning tools in question and the accompanying research articles. The original articles are placed at the end of this introductory essay. The *Research Framework* (Chapter 4) will present several theoretical and philosophical standpoints that are implicit in the research, but were not extensively discussed in the original research articles. The *Summary of the Key Findings* (Chapter 5) aims to construct a concluding and coherent picture of the methodological discoveries and insights of the research. The *Discussion* (Chapter 6) open up and contribute to the discussion about the role and form of research of this kind in a wider context of design research as an academic discipline.

1.1. LEARNING TOOLS IN CONTEXT

The rise of personal computers (PCs) in the late 1970s and early 1980s brought computing into the arena of learning and teaching. PCs made computing affordable and accessible for a multitude of fairly wealthy people, as well as for many wealthy schools, mainly in the United States and Europe. (Molnar, 1997)

In the early 1980s PCs were still tools of relative simplicity, designed for technology-savvy customers interested in building computers and programming and largely to play computer games (Saarikoski & Suominen, 2009). In the 1980s multimedia PCs with computer games, as well as audio and video capabilities, made PCs more appealing for more people (Saarikoski & Suominen, 2009) and in the mid-1990s, for instance in Finland, the rise of the Internet and World Wide Web made PCs everyman's tool (Suominen, 2009). It can be claimed that today, in many parts of the world, life can be difficult without access to a PC and the Internet. Regardless of their complexity, PCs have become everyday objects (Norman, 1999).

From the history of media we know that new forms of media do not necessarily replace old ones. TV did not replace radio and the Internet has not replaced TV. New forms of media complement the old ones rather than countervailing them (Gardiner, 2002). The process of complementing has become more visible with the digitalization of information. In the new digital media, different forms get mixed and are mixed with each other and in this way generate new forms that may emulate or include features of the earlier forms (Ito, 2006; Jenkins, 2006, pp. 110-113; Kay & Goldberg, 1977).

The same phenomena of complementing and, at the same time, mixing seem to take place within computer-based learning tools. For instance, the approach of viewing a computer as something that is able to model an accomplished human teacher with artificial intelligence used to be a crucial research topic in educational technology in the 1970s and 1980s (O'Shea & Self, 1984; Molnar, 1997), although today it is hardly a mainstream topic.

However, the paradigm — for example in cases of expert systems and automated tutoring — is still with us in slightly different forms (Albano, Gaeta, & Ritrovato, 2007; Neira, Alguero, Brugos, & Garcia, 2000). From this it may be concluded that older paradigms about computer-based learning tools live on and continue to have an effect on us; the newer paradigms and forms live simultaneously with the old ones (Figure 1).

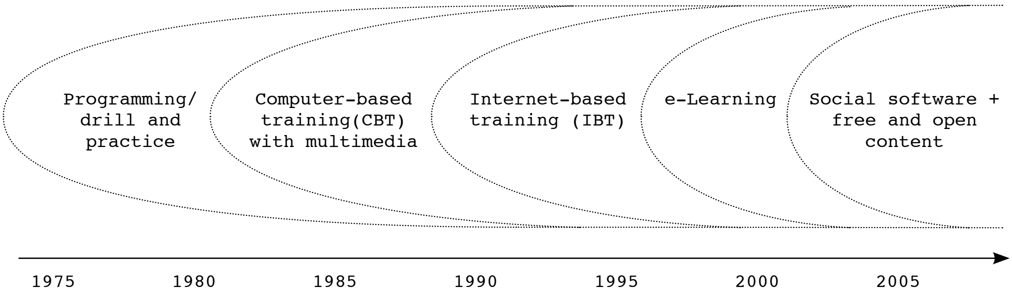


Figure 1: Timeline of the Main Paradigms of Using Computers in Learning

Below I will present a chronological, thematic, and summarizing history of the mainstream development of computer-based learning tools in five phases. It is worth mentioning that the categorization is a generalization of the stages.

I – LATE 1970S – EARLY 1980S: *programming, drill, and practice.*

According to my own experience, in the late 1970s and early 1980s the computers used in schools were often running MS Basic, an operating system that had only a shell user interface. At the time there was generally very little software available and many school classes with computers focused on teaching programming with such tools as the Logo environment (Papert, 1997). In the United States Logo was so popular in schools that, according to Harvey, the early success of Logo in elementary schools earned the programming language a *"reputation as a trivial language for babies"* (Harvey, 1997).

Later on, educational software in schools was often written or created by teachers themselves and shared among colleagues (O'Shea & Self, 1984, pp. 219-220). Most commonly, this software consisted of simulation and drill-and-practice types of exercises (Barker, 1989, p. 80).

Something characteristic of the first wave of computer tools for learning was the idea of providing self-paced programs providing a flexible schedule and in this way giving students a chance to take an active role in the learning process. It was assumed that mastery would be obtained through drill-and-practice. (Molnar, 1997)

In the mid-1970s Alan Kay and Adele Goldberg of the Learning Research Group at Xerox Palo Alto Research Center were primarily interested in computer technology that could be used by children to communicate and manipulate knowledge. In the laboratory they designed a *Dynabook* — a notebook-sized computer device that could be used by anyone, including children, to handle their *"information-related needs"* (Kay & Goldberg, 1977).

Kay and Goldberger describe the Dynabook as follows.

> *"... the computer, viewed as a medium itself, can be all other media if the embedding and viewing methods are sufficiently well provided. Moreover, this new "metamedium" is active — it can respond to queries and experiments — so that the messages may involve the learner in a two-way conversation. This property has never been available before except through the medium of an individual teacher."* (Kay & Goldberg, 1977)

Even if there are echoes of the programming and drill–and-practice paradigm in the Dynabook vision, it also represents a highly valuable new way of thinking. According to Kay and Goldberger, the core idea behind the Dynabook was to work as its owner's *"dynamic medium for creative thought"* with an emphasis on its having properties enabling children to create things with the computer: from drawing and painting to music and computer simulations (Kay & Goldberg, 1977).

II – LATE 1980S – EARLY 1990S: *computer-based training* (CBT) *with multimedia.*

The arrival of multimedia computers, with advanced graphics, sound, and audio, as well as a graphical user interface, raised new expectations among educators of the usefulness of computer tools in teaching and learning (Barron & Kysilka, 1993; Sims, 1988). In the creation of markets for more powerful multimedia PCs and CD-ROMS, the educational and student markets played an important role. Educational CD-ROMS were introduced and marketed as motivating and efficient ways to study (Rassuli & Tippins, 1997).

III – EARLY 1990S: *Internet-based training* (IBT).

The World Wide Web made a dramatic change to the situation in PC markets and the use of PCs in teaching and learning. Consumers' new and independent chance to find and publish information on almost whatever topic in just seconds was considered a great change factor in teaching and learning (Collis & Meeuwsen, 1999). The expectations about the impact of the Internet on learning were not only positive. The worries related to the accuracy of the information on the Web, which opened up needs and opportunities to build closed, password-protected, Internet-based learning environments. In these participants could then take courses that were designed and updated by experts (French, 1999; Harris, 1999a). At this point computer-based training was brought to the Internet, but as yet without multimedia. Especially in the business world, internet-based training was widely marketed as a new cost-efficient method for human resource development (Harris, 1999b).

IV – LATE 1990S – EARLY 2000S: *e-Learning.*

Internet-based training matured in the late 1990s and early 2000s and was now renamed e-learning. According to several scholars (Rosenberg, 2001; Seufert, 2002), the chief executive officer of CISCO Systems, John Chambers, claimed in a keynote speech to the 1999 Comdex Trade Show in Las Vegas that *"the biggest growth in the Internet, and the area that will prove to be one of the biggest agents of change, will be e-Learning. Education over the Internet is going to be so big it is going to make e-mail usage look like a rounding error in terms of the Internet capacity it will consume."* John Chambers' enthusiasm about promoting e-learning is an example of the attempts of the time to create new markets for technology providers and educational publishers. In practice, e-learning courses were actually not so different from the older internet-based training courses, except that now there were specific products designed to deliver courses and stronger attempts to build infrastructure for e-learning business, the exchange of courses, and transactions (Moore, 2002; Seufert, 2002). The specific products were called Learning Management Systems (e.g. Blackboard and Moodle), and the e-learning infrastructure builders got involved in defining standards in specific industry working groups (for instance, the IMS Global Learning Consortium).

V – LATE 2000S: *Social software, free and open content.*

The late 2000s meant a breakthrough for the phenomena of social software and free and open content in educational technology. The vast popularity of blogs and wikis has brought the Web back to its initial ideas and ideals, to a system that is a combination of a collaborative working environment and an efficient publishing platform for the free sharing of information (Berners-Lee, 1992, 2006; Berners-Lee, Cailliau, Luotonen, Nielsen, & Secret, 1994; Berners-Lee & Hendler, 2001; Alexander, 2006). The considerable success of such peer and open content production projects as Wikipedia, founded in 2001 and Open Courseware, founded in 2002, demonstrated that free and open content does not necessarily have to exclude high quality in information production. Especially in the case of Wikipedia and other Wikimedia projects, the model of production, adapted from the Open Source[1] software, has proven that small contributions by independent people can become very important when they are part of a bigger system (Tuomi, 2002).

From the viewpoint of pedagogical theorizing, it is tempting and quite possible to find interconnections — or even exemplifying forms of applications — between the activities that take place with social software and free and open content and such forms of social constructivism which emphasize the significance of dialog and knowledge construction in a learning situation (Paavola, Lipponen, & Hakkarainen, 2004; Senge, 2006; Säljö, 2004). For instance, Pekka Himanen (2001) compared Open Source hackers' learning style to the academic open model of peer reviewing, where hackers are not only learning but at the same time teaching each other online with social software.

1 The term Open Source is used in this study when referring to software that comply the criteria defined by the Open Source Initiative (http://www.opensource.org/docs/osd).

When viewing the timeline above (Figure 1) it is obvious that this study belongs to the time after the Internet revolution as a consequence of the Web in the early 1990s. It is worth mentioning that one important effect of the Web was that it made computers and digital technology not just everyman's information technology, but also the primary communication technology. The Web, a world-wide computer system that is able to connect multiple nodes of information, applications, and people with links, serves as a starting point and a necessary condition for the design of the learning tools presented in this study. The Web, an open system described by David Weinberger (2002) as *"a world that we create as we explore it"*, which anyone may join and start to enrich with more information, applications, and people, was both the underlying platform and a source of inspiration in the design processes of the tools in question in this study. In this way the study is evidently committed to the late 2000s phase of the history of computer tools for learning. Its aim was to search for advances and solutions primarily from and to the framework of social software and free and open content.

There is apparently some parallel development of computer-related learning tools and the research conducted in the area. The approaches, the methods, and the theoretical frameworks used in the research are various.

For instance, in educational technology research there are studies that rely on different classical educational theories, and on theories of knowledge management and computer science (Mayer, 2003; Rosenberg, 2001, pp. 76-85). As a consequence, researchers who come from different disciplines may hold very different views of some key terms, such as learning. While educational researchers may consider learning to be a complex socio-cultural process of situated activity gaining understanding and new meanings (Säljö, 1996; Engeström, 1987; Hakkarainen, Järvelä, Lipponen, & Lehtinen, 1998; Paavola et al., 2004), for a certain branch of computer scientists learning may be primarily conceived as a machine's ability to adapt to some external inputs of pieces of information (O'Shea & Self, 1984, pp. 3-6; Emde, 1996).

In relation to different approaches to research into computer-related learning tools, I have recognized four major paradigms of research from earlier studies. I call them:

1. *the teaching machine* paradigm;
2. *the learning machine* paradigm;
3. *the content* paradigm, and
4. *the collaborative learning* paradigm.

Each of these approaches have been used in designing computer-related learning tools. The paradigms are also related to certain theories of learning. Behind the teaching machine one can recognize principles of behaviorism. The learning machine reflects some ideas from cognitive constructivism. The content paradigm relies both of them, whereas the collaborative learning paradigm stems from social constructivism. Often, however, the paradigms and the theories have been used simultaneously and in parallel in design.

1 – The origins of the *teaching machine* paradigm are in artificial intelligence research and studies of expert systems. The thread of thought here is that at some point computers' artificial intelligence (AI) is expected to be able to replace or support a human teacher by providing advanced learning tasks to students, by carefully analyzing their progress, and by offering progressively more challenging tasks on the basis of these analyses (See, for instance Neira et al., 2000). This approach has its historical roots in the use of film and television in distance learning in situations where there is an acknowledged need to train large numbers of people to carry out relatively routine tasks, such as battlefield behavior in military organizations (Noble, 1991; Rosenberg, 2001, p. 21). Later research based on the *teaching machine* paradigm has progressed to attempts to define a specific *instructional design theory* and to produce and use *learning content repositories* and *learning objects* (Wiley, 2002; Wiley & e all, 2002; Wiley, 2000).

2 – The *learning machine* paradigm relies on viewing computer-based learning tools as environments for playing in; here children can construct new objects and situations that it is not actually possible to build in real life and the real world. Accordingly, when children are constructing advanced things with software, *things that think*, and playing with the simulations, it is believed that this leads to higher-level thinking skills (Papert, 1994, 1997).

3 – The *content* paradigm can be seen as one result of the revolution of the Internet and the Web. When the Web made it possible to offer almost unlimited access to sources of information, research into learning contents, different delivery methods, and their overall impacts gained more attention. The applications of the content paradigm often rely on courses that one may take online. Research on the sequencing of course delivery, instructional design, automated tests, and automated tutoring has worked as a bridge between the content paradigm and the teaching machine paradigm (Wiley, 2000; Rosenberg, 2001, pp. 170-172; Smith & Broom, 2003).

4 – The roots of the *collaborative learning* paradigm in research into computer-related learning tools are located both in computer-supported collaborative work (CSCW) research and in computer-supported collaborative learning (CSCL) research. In educational research, however, the idea of collaborative learning has been discussed in different forms since the Greek philosopher Socrates' Socratic Method and Plato's Academy, where the main study practice was dialogs that took place between the participants. The ongoing reflection and evaluation of beliefs was thought to lead participants to a critical and deeper understanding of the issues being considered. Later in the history of educational research, ideas of collaborative learning and the role of the community in it were put forward, for instance, by Lev Vygotsky (1896 – 1934), John Dewey (1859 – 1952) and Paulo Freire (1921 – 1997) (Vygotsky, 1978; Dewey, 2007; Freire, 1975). As a starting point for CSCW research it is reasonable to mention Douglas Engelbart's 1968 demo of the oN-Line System (NLS) designed for collaborative knowledge work (Engelbart & English, 1968). The foundations of CSCL research can be actually traced to several universities in the late 1980s and early 1990s in the United States and Canada (Koschmann, 1996).

Besides relying heavily on the ideas of *social software* and *free and open content*, this study is closely related to the *collaborative learning* paradigm. The earlier work done in CSCW research has been a great inspiration and has had an influence on the design of the learning tools presented in this study. The first article was written and the tool described in it was designed in the CSCL research framework.

A third important source of inspiration in the design and research work has been the apparent rise of a new online culture relying on social software and open content. On the Web people have created and innovated new forms of collaborative work and learning (Tuomi, 2002). In recent years the Web — in the meaning of culture and practices — has changed so rapidly that today we may see that the whole CSCW/CSCL research field has come under pressure for some dramatic changes.

In this study I have decided to use the generic term *learning tool* when referring to the computer-related learning tools described in it. Using the term *learning tool* — instead of, for example, Virtual Learning Environment (VLE), Learning Management System (LMS), Learning Support System (LSS) or Learning Platform (LP), although these concepts have lately become popular in the literature related to the use of ICT in education — is deliberate and conscious decision. By using the generic term *learning tool* I intend to pay attention to these system properties as *tools*. With the use of the term *tool* I also intend to promote the demystification of these *systems* and emphasize that they are related to and belong to our common everyday life.

1.2. RESEARCH QUESTIONS AND METHODOLOGY

Designing *software learning tools* in a context of complex cultural, social, and psychological systems requires specific methodological approaches. Although *software*, which is arguably the most decisive part of a computer, can be approached as a physical object — and deeper ontological considerations left aside — designing software can be said to be quite different from the design of concrete material objects like hammers, urinals, chairs, or their equivalents. When considering software as just another *design material*, it can be described at first as extremely flexible and modifiable. Although I do not completely agree with what one accomplished computer programmer once proclaimed: if you can describe it, I can program it, I do, however, agree that the possibilities in terms of forms and functions are extremely numerous, if not almost unlimited, in software design. It is also worth noticing that the contexts where software is contemporarily used — people's everyday lives — are often extremely complex, especially in cultural, social, and psychological terms.

This is the case of software-based *learning tools* designed to improve the quality of learning. The complexity of the issue increases further if and when the quality of learning is defined in terms of enhancing critical thinking and improving problem-solving skills (Leinonen, Toikkanen, & Silfvast, 2008).

The main objective of this study is to provide new methodological insights and defendable criteria for the *good design* of computer-related learning tools. The primary and overall unifying research question can be formulated as follows:

> *How can software learning tools be designed in such a way that they would be beneficial and good in complex social learning situations and learning systems?*

Complex social learning situations and learning systems in this study are, for example, situations where school teachers and pupils aim to implement collaborative progressive learning and self-organizing online communities interested in organizing voluntary learning activities, whereas *benefits* and *good* are value-laden and even ideological questions.

Besides aiming to find answers to this question, the research also seeks to frame answers to the following questions: *What could be the objectives and forms of the academic, practice-based design research of software learning tools? and What should be the objectives and role of practice-based design research as part of other academic research?*

This study relies on my personal involvement and experience gained by participating in the design processes of four distinct, and for the most part unique, software tools that aimed to enhance learning in different contexts. The research is practice-based. Personal experience in practical design work is used in this research as the primary methodological approach, especially when searching for answers to the question of *how* to characterize the design methodology of learning tools. The more specific methods in the research work were theoretical considerations of decisions about the design methodology that were made in the practical design work. This study aims to present — as Donald Schön (1991, pp. 50-56) calls it — the action of a reflective practitioner in and on action. The reflection in action took place in the actual design practice, whereas this study reports more the reflection on action.

Each of the four design processes presented in this study can be said to have been different regarding, for example, the resources and efforts involved. All of them, however, find a common unifying feature in that they are based on certain theoretical and also partly value-laden, even ideological, principles and ideas. The ways in which these learning tools were designed have not been selected in order to complete a study comparing different practices or methods of design. Rather, they can be viewed as *practical experimentations* and *strategies* to reach a *developmental* and *expansive process* (Engeström, 1987). In this way, the *methodology* and the methods of the design processes, as well as my concept of it — my thinking and reflections on it — were also in a state of constant development while I was moving from one design process to another. In this study, I will try to present these methodological insights in a way that could be useful for other designers of learning tools.

It is worth mentioning here that many of the methodological insights reported in this study actually developed in many respects from surprises and what can be considered as being side products of unexpected phenomena and the consequences of actions during design processes. My own reflections about the designing of learning tools have led me to reconsider the methodological principles behind the design cases. The design explorations were future-driven without having pre-defined end-results.

The future-orientation makes design and research based on design-practice difficult. According to Jones (1992, p. 9) *"designers are obliged to use current information to predict future state that will not come about unless their predictions are correct."*

Moving on to a more concrete level, this study deals with and describes some actual designs of computer-related learning tools. Here this study can be seen as clearly belonging to the categories of Design Research interested in the methods and design process in the way discussed earlier, for instance, by Simon (1996, pp. 2-8), Jones (1992), Schön (1988), Lawson (1997) and Seitamaa-Hakkarainen (Lahti, Seitamaa-Hakkarainen, & Hakkarainen, 2004; Seitamaa-Hakkarainen, 2000) and Qualitative Research as defined, for instance, by Creswell (2003, pp. 179-185). The inquiry as a whole has a strong intention to understand, explore, and propose design solutions for concrete human and social challenges.

Designers and researchers must face some significant questions related to the status and primacy of their work. The focus is concerned with the realization and presentation of the research, as well as the question of how to deal with the research subjects. By this challenge I mean especially the emphasis on aiming to *theoretically* explain or *critically* subject to questioning or aiming *practically* to participate and its effect on social practices. Juha Varto (2009) has constructed a useful and elucidative, if also somewhat stereotypical typology of two distinct types of researchers. Varto calls them the *technical* and the *questioning researcher*. My approach in this work, in both the design and research of learning tools, follows the characteristics of a questioning researcher. I shall describe these briefly below.

The research work of a questioning researcher has its roots in the practices of everyday life and is driven by them. A questioning researcher reflects about the significance of her own research for human life, for her own life, and for different human practices. She may often point out that things that are usually considered to be obvious, normal, or natural are problematic. She views herself and the people that are involved in her research as all belonging to the same reality, and she realizes that her research can have effects on human practices on multiple levels. She does not consider the facts of her research as being in any way neutral, but considers that values have effects on our understanding of them. The motivation of a questioning researcher may be found in enriching human existence and deepening our understanding of the world and of ourselves. In this way the inquiry of a questioning researcher holds an ethical meaning as a valuator of human existence and behavior (Varto, 2009).

With hands-on experience from four design cases and with a questioning, reflective, and understanding mindset, I have aimed to crystallize how to design when the primary aim is to design good learning tools.

2
Tools Designed

The research articles of this study were written and published during 2003–2010. The design work described and discussed in them was carried out in the years 2002–2008[2]. Because of the close relationship between the research articles and the tools, it is reasonable to describe the latter briefly here before presenting the research articles. The tools are, in chronological order:

TOOL I: FUTURE LEARNING ENVIRONMENT 3 (Fle3): Web-based toolset for collaborative knowledge building (Article 1)
TOOL II: MOBILED: Mobile audio wiki (Article 2)
TOOL III: LEMILL: Web community for collaborative authoring of open educational resources (Article 3)
TOOL IV: EXPERIMENTAL ONLINE CLASS ON WIKIVERSITY: Mashup and remix of several social tools to create an open online learning community (Article 4)

2 The design and development of the Future Learning Environment (Fle3) tool is an exception. The design and development of its earliest prototypes and versions was started in the late 1990s. The actual design work of the particular version described and discussed in the article was, however, done between 2002 and 2004.

1 – FUTURE LEARNING ENVIRONMENT 3 (*Fle3*) is a web-based toolset for collaborative knowledge building. Viewed more generally, it is a specific *virtual learning environment* designed to support a method of *Progressive Inquiry learning* (Hakkarainen et al., 1998; Hakkarainen et al., 1999; Hakkarainen & Sintonen, 2002; Leinonen, Kligyte, Toikkanen, Pietarila, & Dean, 2003; Rubens, Emans, Leinonen, Skarmeta, & Simons, 2005). *Fle3* can be divided into three distinct tools: 1) personal *Webtops* to collect and organize information; 2) the *Knowledge Building* tool (Figure 2) for scaffolded discourse aiming to increase the participants' knowledge about selected topics, and 3) the *Jamming tool* for the collaborative design of digital artifacts (Leinonen et al., 2003).

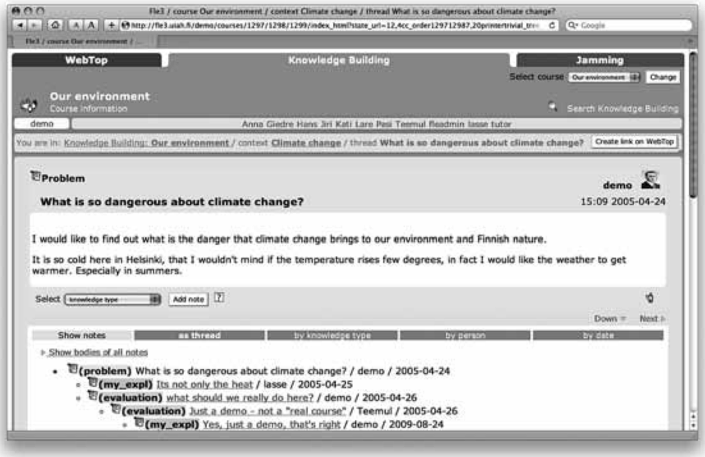


Figure 2: Future Learning Environment's Knowledge Building tool.

The development of *Fle3* took place during 2001–2002, as a continuation of the work that was done on *Fle2* (2000-2001) and FLE (1998–1999). Since *Fle 3*'s was released as *Open Source software* in 2002, it has been translated into more than 20 languages and has been used on all continents.

The theoretical foundations and frameworks of *FLe3* are in *social constructivist learning theory* and in Vygotsky's theory of the *zone of proximal development* (Vygotsky, 1978). *Fle3*'s enhancing of students' and teachers' quality and quantity of discourse and argumentation on the topics under study was expected to help them to reach the limits of their abilities, recognize them, and work in their zone of proximal development (Dillenbourg, Baker, Blaye, & O'Malley, 1996). *Fle3*'s design was realized in a participatory way with the close collaboration of a number of stakeholders, including pedagogical experts, teachers, and pupils. The three prototypes (FLE, *Fle2*, and *Fle3*) were developed, tested, evaluated, and studied in actual use at different levels of education; the results were used in subsequent design iterations. Parallel with the design and development of Fle3, there was the designing of a progressive inquiry learning method — a concrete model of learning based on social constructivist models of teaching and learning. In this way one of the Fle3 project's main objectives was to facilitate, support, and validate the development of the *Progressive Inquiry* learning method. (Leinonen et al., 2003; Rubens et al., 2005)

II – MOBILED: *Mobile Audio Wiki* is a unique *mobile learning tool* and *service* originally designed for use in formal learning in schools of the Majority World [3]. The *MobilED* service provides access to a *Wiki*-based audio information system. By sending text messages (SMS) or by calling the service number, the user may access audio notes in various categories of the tool and then add new notes to them that are available to be listened to and utilized by other users. The tool's *Web-based interface* provides access to the same content with more management features, such as managing categories and reorganizing the audio notes. (Ford & Leinonen, 2009)

Figure 3: MobilED server prototype hardware installation.

MobilED was designed between 2004 and 2007, in a series of workshops that took place in India, South Africa, and Finland. The first prototype was tested in two schools in South Africa in 2006. The Open Source prototype attracted relatively high levels of international interest and several parties have continued developing it.(Ford & Leinonen, 2009)

3 The term Majority World is used here to refer to such, largely inaccurate terms, as Developing Countries and Third World. In this case the term refers to all disadvantaged and underserved people regardless of their nationality or geographical location.

MobilED was designed to utilize the potential of growing mobile phone penetration rates in a new innovative mode in the Majority World. The design team's goal was to design a service beyond phone call and text message (SMS) communication by introducing an easy-to-use information system realizing the paradigm of stored and recorded information used, for instance, to create and maintain a repository of learning and reference materials and classifieds and forums for jobs, housing, for sale ads, personals, services, local communities, and events. *MobilED* was carried out with the collaboration of various design, software, pedagogical, and development experts. We were able to release a prototype package by combining the Open Source software of *MediaWiki*, *Asterisk*, and *Kannel* with some extra code and extra hardware (Figure 3). The software package was released under an Open Source license. During the process of software development, testing, contextual inquiry, and development studies we redefined the original design challenge and we ended up by shifting the design challenge from formal school learning to more independent community-run information systems. (Ford & Leinonen, 2009)

III – LEMILL — a specific *Web* community for the collaborative authoring of open educational resources — is a multifunctional online service for finding, authoring, and sharing open educational resources. *LeMill* includes Web-based learning content and descriptions of teaching and learning methods and tools. *LeMill* is similar to a *Wiki*, with some additional tools that are common in social networking services. All the learning resources in *LeMill* can be edited and improved by other people; with the social networking tools people may match their interests, create groups, and start projects. (Leinonen, Purma, Põldoja, & Toikkanen, 2010)

The design and development of *LeMill* started in 2005 with the founding of an international team including designers, software and pedagogical experts, and teachers located in Finland, Estonia, Hungary, and Norway. The first Open Source prototype was released in early 2006. At the time of writing *LeMill* had already been translated into 13 languages. The *LeMill* community consists of over 11000 teachers who have created more than 10000 learning content resources, over 5000 descriptions of teaching and learning methods, and over 1000 descriptions of teaching and learning tools in 35 languages (Figure 4).

The objective of *LeMill* was to increase the sharing of learning resources created by teachers in Europe. Providing an online service for teachers with easy-to-use tools to create and collaboratively improve their own and each others' learning resources was expected to enhance the sharing of the learning materials and collaboration on them. The design process consisted of contextual inquiry studies, formal participatory design workshops, product design work, and the release of tens of prototypes. The working and the features of the prototypes were studied by interviewing people using them and by analyzing the quantitative data from the service. The *LeMill engine* was developed on *Plone* (an Open Source content management system) and was written in the *Python* programming language. The *LeMill engine* was released under an Open Source licence, which assures anyone the opportunity to start their own *LeMill* website. (Leinonen et al., 2010)

Figure 4: LeMill network service's community section.

IV – THE EXPERIMENTAL ONLINE CLASS ON WIKIVERSITY is a design experiment exploring the possibilities of open education with self-organizing and university students. An objective was to intervene in the *Wikiversity community* and in this way enable the community members to see new possibilities in it. The experiment consists of the design and implementation of a distinct course and an online class in the *English Wikiversity* on the topic of *Composing Free and Open Online Education Resources* (Figure 5). Our aim was to model online teaching and learning that combines self-studying, collaborative learning, and knowledge building in a structured, supervised, and goal-oriented manner. The course was set up online openly and anyone could take part. It consisted of a ten-week program with objectives, selected course materials, class meetings, and weekly assignments. 72 students registered for the study course and 49 started it by doing the first course assignment. 15 students completed the course by doing all the assignments.(Leinonen, Vadén, & Suoranta, 2009)

The experimental course was designed in late 2007 and early 2008 and the class took place in spring 2008. In 2008 and 2009 the same course was localized in Finnish and Estonian and was run in the *Wikiversities* in these languages.

The design of the course relied on the paradigms of free adult education and free schools, emphasizing free access and self-organized learning with an open-ended curriculum, the contextualization of learning in the participants' everyday lives, and problem-based and dialogical study methods. The design was carried out by adding to *Wikiversity* a draft plan of the course with the theme, the initial schedule, the initial topics, and some principles related to study practices. The initial plan sparked a relatively high amount of attention among the *Wikiversity community* and online at large. The course page was edited by over 20 people, of whom 5 (including myself and my colleague) made major changes to it. (Leinonen et al., 2009)

Figure 5: Composing Free and Open Online Education Resources course homepage on Wikiversity.

3 Research Articles

The research articles of the dissertation are all peer-reviewed articles, of which three were published in journals (Articles 1, 3, and 4), one as a book chapter (Article 2), and one in the proceedings of an international conference (Article 5). The articles are listed below in chronological order according to the design works described in them, but not in the chronological order of their publishing:

ARTICLE 1: *Design of web-based collaborative learning environments. Translating the pedagogical learning principles to human computer interface* (Rubens, Emans, Leinonen, Gomez Skarmeta, Simons 2005). Article in *Computers & Education*. Volume 45, Issue 3 (November 2005), Elsevier. Collaborative learning environments. Pages: 276-294.[4]

ARTICLE 2: *MobilED - Mobile Tools and Services Platform for Formal and Informal Learning* (Ford & Leinonen, 2009). Chapter in *Mobile learning: transforming the delivery of education and training*. Edited by Mohamed

4 © 2005 ELSEVIER. Reprinted, with permission, from ELSEVIER, Design of web-based collaborative learning environments. Translating the pedagogical learning principles to human computer interface, Rubens, Emans, Leinonen, Gomez Skarmeta, Simons, 2005.

Ally. Issues in distance education. Published by AU Press, Athabasca University. Pages: 195-215.[5]

ARTICLE 3: *Information Architecture and Design Solutions Scaffolding Authoring of Open Educational Resources* (Leinonen et al., 2010). IEEE Transactions on Learning Technologies, 27 Jan. 2010. IEEE Computer Society Digital Library. IEEE Computer Society.[6]

ARTICLE 4: *Learning in and with an Open Wiki Project: Wikiversity's Potential in Global Capacity Building* (Leinonen et al., 2009). First Monday, Volume 14, Number 2 - 2 February 2009.[7]

ARTICLE 5: *Software as Hypothesis: Research-Based Design Methodology* (Leinonen, Toikkanen, & Silfvast, 2008). ACM International Conference series: The proceedings of Participatory Design Conference 2008. ACM.[8]

The first three articles describe three different and self-reliant educational tools: *Fle3, Mobiled,* and *LeMill.* The fourth article describes a mash-up and a remix of several existing social software tools for learning, and the intervention made to an existing community, Wikiversity.

The articles are not only descriptions of certain computer-based learning tools. They also raise various research questions and topics connected to the contexts of the design of the tools, of the design processes, and the experimentation done with them. The fifth article describes a research-

5 © 2009 AU Press Athabasca University, Reprinted, with permission, from AU Press Athabasca University, MobilED - Mobile Tools and Services Platform for Formal and Informal Learning, Ford & Leinonen, 2009.

6 © 2010 IEEE. Reprinted, with permission, from IEEE Transactions on Learning Technologies, Information Architecture and Design Solutions Scaffolding Authoring of Open Educational Resources, Leinonen et al., 2010.

7 © 2009, First Monday & Leinonen, Vadén, and Suoranta. Reprinted, with permission, from Leinonen, Learning in and with an Open Wiki Project: Wikiversity's Potential in Global Capacity Building, Leinonen et al., 2009.

8 © 2008 Trustees of Indiana University. Reprinted, with permission, from Trustees of Indiana University, Software as Hypothesis: Research-Based Design Methodology, Leinonen et al., 2008.

based design methodology that was developed within design and research work done among and around these learning tools.

The articles and tools presented in the dissertation are all co-authored, with several accomplished co-designers and co-researchers. An obvious explanation for this comes from the nature of the research and the design work: design and research in this subject area is generally collaborative and collective, for several reasons, of which some are also practical.[9]

Article 1 and Tool 1 are results from a large-scale, multi-party European research and development project called *Innovative Technology for Collaborative Learning* (ITCOLE 2001–2003). The aim of Article 1 was to describe how pedagogical theories and principles were implemented in three different software tools. In the project my role was particularly to be the design director. In addition to the design work of the Fle3 software tool, I was responsible for providing design expertise and design consultation for the process of developing two other software tools (BSCL and MapTool) developed by two other project partners. Article 1 describes the pedagogical principles involved, the software tools, and the evaluation study conducted to assess how the users (teachers) felt about the tools' technical usability and pedagogical effectiveness. In the writing of Article 1 my responsibility was mainly to provide the descriptions of the design process and the software tools. The evaluation study was for a large part implemented by other project partners, though I took part especially in the interpretation of its results and conclusions. The other authors contributed specifically to the parts reporting the evaluation study.

The Article 1 relies and builds extensively on *computer-supported collaborative learning* (CSCL) as its theoretical approach and research background. The applications of cognitive research into learning, especially *interrogative models* and the *framework of progressive inquiry learning*, comprise the settings of the theoretical frameworks of the first tool and the article (Brown & Campione, 1996; Hakkarainen et al., 1999; Hak-

9 The design teams and the research groups have consisted of various experts covering areas such as art and design, interaction design, software and hardware engineering, educational psychology, learning science and educational politics. In all the design teams I have act as the design director with overall responsibility of the design work.

karainen, 2003; Hakkarainen et al., 1998; Hakkarainen & Sintonen, 2002; Scardamalia & Bereiter, 1993).

Article 2 and Tool 2 are results from research cooperation with the *Meraka Institute* of the CSIR, South Africa. Equally co-authored with Ford, the article describes the development and piloting of a mobile tool designed for formal and informal learning in the context of so-called developing countries or Majority World. In the project my role was the concept and interaction design of the tool. In addition to the design of the original *MobilED* concept I also, for a large part, designed and implemented the first pilot of it in South Africa. The article describes the context where the project was carried out, the tool itself, and the results from the first pilots. In the writing of the article my main responsibility was to provide the description of the design process and description of the tool. In addition to these I took part in writing the description of the first pilot and the sections analyzing the pilots. The other author wrote the parts describing the context and description of the second and the third pilot.

The Article 2 and the Article 4, and the learning tools introduced and described in them (MobilED and Wikiversity), deal with institutional, organizational, and social topics: *computers in classrooms* (Statham & Torrell, 1996), *organizational learning* (Senge, 2006), and communities of practice (Wenger, 1999). They also relate to the philosophical-practical approaches of the *pedagogy of the oppressed* (Freire, 1975) and *the deschooling of society* (Illich, 1971).

Article 3 and Tool 3 are results from another large-scale European research and development project called *Calibrating eLearning in Schools* (CALIBRATE 2005–2008). The article focuses on defining the design challenges and the solutions related to the use of open educational resources in European schools. In the project I was the design director leading the design, with the role of the conceptual designing of the tool. Article 3 presents the *LeMill* software tool as one solution to the design challenges; it also reflects on the design decisions made in relation to other similar tools. Furthermore, the article describes the design process and deals with some relevant methodological questions. In the writing of the article my responsibility was structuring the article in such a way that it presented our main design challenges and our solutions to these in a coherent way.

The other authors wrote the parts discussing the more technical issues, including the discussion comparing our design to other similar systems.

The Article 3 is, on the whole, the most technical. It also refers most extensively to contemporary discourses about *learning objects* (Friesen, 2004), *open educational resources* (Schaffert & Geser, 2008), and *learning content metadata standards* (Nilsson, Johnston, Naeve, & Powell, 2007; Wiley, 2000, 2002b; Duval & Hodgins, 2004). These topics can be seen as being especially important when considering trends in educational technology research that focus on *course and learning content management* (and publishing) and on *instructional theory* (Wiley, 2000).

Article 4 reports results from an experimental online study course implemented in 2008 on *Wikiversity*, an online *wiki platform* and community for online learning. The tools used in the study course were a selection of existing social software tools remixed to be used in this particular case. In this respect Article 4 is somewhat different from the other articles. Still, the development of the online study course with the different tools included a lot of design work. My role in it was to perform the conceptual design of the tools and study course, and to work as the main teacher and tutor in it. Article 4 also introduces some earlier studies and considerations of using *wikis* in education and learning; it also presents the design and peer production process of the online study course and its implementation. As the first author of the article I contributed the main background study of wikis, the theoretical pedagogical framework, and the design and implementation of the case and analyses of it. The two other authors provided the wider philosophical and social insights contained in it.

Article 5 focuses on a methodology developed during the actual design of the learning tools. Through analyses of the patterns identified in the three cases presented in Articles 1, 2, and 3, in this article our aim was to conceptualize the intentions of the methodology and create a model of an iterative research-based design process. As such, Article 5 relies on the three design processes, with special attention being paid to the *design methodology*. The article had already been drafted before the design experiment described in Article 4 was performed. Therefore Article 5 does not make references to the specific case of Article 4. Because of the slightly different research and design settings in Article 4 — the use of tools that already existed — the possibility opens up of reflecting how the methodology in question is present in it. As the first author, I contributed the main concepts, the description of the methodology, and conclusions to the fifth article. The other authors contributed to the article with several additions.

The Article 5 concentrates on the design process and design methodology. It is grounded in the philosophical, theoretical, and methodological approaches of *participatory design* (Ehn, 1988; Ehn & Kyng, 1991) and *design for human ecology and social change* (Papanek, 1985).

4
Research Framework

The multiplicity of theoretical approaches involved in the design processes described in the articles find their main explanation in the actual design and research context and framework where they took place. The impact of the partnerships with representatives of different disciplines and stakeholders is obvious. Still, many threads of thought that interconnect them can be pointed out.

Below I will refer to excerpts from selected theoretical and philosophical background sources relating to the design of the learning tools discussed in this study. These theoretical approaches and insights are not discussed extensively in the articles themselves, but can be seen as a common foundation for them. My purpose with this presentation is to explicate some theoretical and potentially general background issues related to designing learning tools and to extract from some already-existing theoretical approaches certain *doctrines* that are considered highly relevant for the study. These theoretical approaches serve as bases for further elucidations of the subject matter of designing learning tools. They are also used as grounds for the construction of new meanings relevant to the subject matter.

In Sections 4.1, 4.2, and 4.3 I will introduce some philosophical views and research paradigms that have inspired my own design thinking. These are introduced to help the reader to ground my later arguments related to design methodology.

4.1. Technology and Tools: Disturbing, Pragmatic and Free

In the following section I will introduce some thoughts of Martin Heidegger, Erik Ahlman, and Richard Stallman on technology and tools and present the main ideas of activity theory. Heidegger is a classic of the philosophy of technology and criticism of modern technology. Extracting and reflecting on some of Heidegger's stands on technology bring into discussion some important stances about the principles of the design of learning technology. Erik Ahlman's quite unique *general doctrine of tools* (In Finnish yleinen välineoppi) can be used as an elucidative philosophical approach for viewing the fundamentals of designed objects as tools. *Activity theory* has been widely put into use as a framework for analyzing software design and design research and thus has a justified and relevant place concerning issues related to the good design of learning tools. Moreover, in my view, Richard Stallman's *software programmers* practicality, with its uncompromising commitment to certain social and political ideas, can be used to express and bind together some relevant theoretical ideas about design practice.

4.1.1. Modern Technology versus Traditional Handicraft Technology

Martin Heidegger begins (1994) his presentation titled *Die Frage nach der Technik* (originally published in 1962) with an *instrumental* definition of technology by viewing technology as a means to reach objectives. This definition is not, however, satisfactory for Heidegger. For him technology rather finds its true place when viewed as a part of *human activity*, which includes the production of tools, equipment, and machines and the usage of them and also the fulfillment of human needs and purposes that technology can provide (Heidegger, 1994; Jaaksi, 2006).

For Heidegger technology has a significant feature of being disturbing. What is disturbing in technology connects mainly of how technology effects in our viewing of fellow people and our understanding of human existence. For Heidegger modern technology is not just about the instruments that people use, but more of an inclusive system of a kind which contains a tendency to view human beings from inside technological instrumentality and thus tie human existence to modern technology itself.

If we do not think critically about the effect modern technology has on our view of ourselves and our fellow-men and without asking about people's roles in technological systems, we are bound to them and not free (Heidegger, 1994; Jaaksi, 2006).

Concerning the dangers of modern technology, Heidegger is thus not mainly concerned with its possible breakdowns, but rather with its perfect functioning in a way that can make people think of themselves as its resources (Heidegger, 1994; Suoranta & Vadén, 2010, p. 19). For Heidegger the loss of freedom that is related to the rise of modern technology comes about especially when the users of technology are not in straightforward manual contact with technology. This is an important feature of Heidegger's separation of *modern* technology from *traditional handicraft* technology (Heidegger, 1994; Jaaksi, 2006).

Heidegger produces an interesting insight into how our everyday objects are what he calls *"present-at-hand"* (in German Vorhanden) or *"ready-to-hand"* (in German Zuhanden). The relations and functions between the existing and visible *"present-at-hand"* objects and touchable *"ready-to-hand"* objects are interesting from designers' points of view. Heidegger points out a commonly recognizable general feature of tools and designs: a badly-working design catches the attention easily — it becomes existent, *"present-at-hand"*, while well-designed *"ready-to-hand"* objects are artifacts that function as intended, are transparent to the user, and are often taken for granted (Heidegger, 1994; Jaaksi, 2006).

With reference to Heidegger's idea of objects becoming existent when there is a breakdown in that coupling, Terry Winograd and Fernando Flores (1986) argue that the designer of a computer tool must be aware of this. The emphasis on creating user-friendly computers and software is an expression of it. (Winograd & Flores, 1986, pp. 35-37).

Pelle Ehn (1988) also uses Heideggerian thoughts in his design theoretical and philosophical book *Work-Oriented Design of Computer Artifacts*. In addition to drawing a distinction between the *"present-at-hand"* and *"ready-to-hand"*, Ehn brought Heidegger's concepts *"existence"* (Dasein) and *"being-in-the-world"* (In-der-Welt-Sein) to the design domain. *"Existence"* is pre-rational experience of the world — an ideal of living. When designing a tool, the designer is *"in-the-world"* that embodies activity with users' experiences and the materials in use. (Ehn, 1988, pp. 63-69).

In relation to software design, Stahl (2006) points out that even though Heidegger and several other scholars have noticed that physical artifacts are bridges across the mind-body distinction, our understanding of software artifacts is still very limited in these terms. In the case of software, designers are embedding a lot of meaning in it, in terms of its behavior, but still the software may behave independently and unpredictably, as well as in a manner that depends on the user's actions (Stahl, 2006, pp. 260-261).

Keeping in mind Heidegger's concerns about instrumentality, we may ask whether the learning tools that we are designing function in a way that can make people think of themselves as resources of them. For instance, it can be argued that with some social networking services, such as Facebook and Wikipedia, there are signs of some level of loss of freedom. People have externalized their social relations to a website that enslaves them by compelling them to use or monitor the site every hour. A second question in my study, based on my reading of Heidegger, is how to design learning tools for everyday use. In short, is it possible to design learning tools that are not *modern* technology in the Heideggerian negative sense but more like *handicraft* technology?

4.1.2. Cultural Tools

While I have presented Heidegger as standing for a deep critical concern about the relationship between modern technology and humans, the Finnish cultural philosopher Erik Ahlman provides us with an approach to design that is more analytical and pragmatic than critical. Ahlman's fourfold characterization of a cultural tool has already been introduced; now I will reflect some more on Ahlman's philosophy of tools.

Ahlman links the concept of culture strongly to people's conscious activities, where the world or reality (in Finnish *"todellisuus"*) is actively modified to something else than what it is naturally. The production and usage of different tools to reach acknowledged end purposes, which are assimilated to values, is commonly present in all communities of people (Ahlman, 1976, pp. 111-112).

Consciousness and the *continuousness of usage* of certain objects are central and critical for Ahlman's (1976, p. 106) definition of and criteria for a genuine *tool*. People often act and do things that are meaningful and useful without being conscious of their actions. For instance, a reflex may be a reason for raising a hand or a bag can be used to protect us from, say, the attack of a bear. But even if a bag is accidentally used as a tool for successful protection, following Ahlman's line of thought, it has not yet become a tool for protection or a weapon in a cultural meaning since the use of a proper cultural tool must be conscious and continuous. Thus, for example, a caveman who used a stick to kill an animal did not make the stick a tool, if it was used only temporarily and thrown away after use. But if a caveman, for example, kept certain types of sticks continuously at hand and used them for the same purpose and internalized and communicated the specific method of using sticks in this way, we have a hint of what a cultural tool is about — in this case a weapon and a method of using it. Additionally, if only *one* individual is using some object or method for a certain purpose, this is not enough for it to count as a tool in a cultural sense. A genuine cultural tool must be distributed among people.

Ahlman's pragmatically oriented approach comes from his attempt to define the general features of a *good* tool. Principally, for Ahlman a tool can be good from two basic viewpoints. First, a tool can be good because the *objective* it facilitates is good. Second, a tool can be good because with the help of it one can modify the world or some part of the world, for which the tools is designed. The later definition focuses on the tool's function. (Ahlman, 1976, pp. 107-110)

In relation to the tool's function Ahlman defines four criteria for a good tool. A good tool must:

1 do what it is supposed to do, precisely and fully;
2 use as little energy as possible;
3 be as time-efficient as possible;
4 cause as little discontent as possible (Ahlman, 1976, pp. 107-110).

In his writings about the *general doctrine of tools ("yleinen välineoppi")*, originally discussed in a publication published in 1920 (Ahlman, 1967) and revised in a book published in 1939 (Ahlman, 1976), Ahlman makes very few references to other scholars. From the text, however, we may interpret implicit connections to, for instance, the Educational Slöyd movement started by Uno Cugneus in Ahlman's home town of Jyväskylä in the 1860s. Educational Slöyd — handicraft-based education — was thought to be a means to attain some general educational objectives, such as building the character of the child, industriousness, greater intelligence, and moral behavior (Reincke, 1995, pp. 39-50). In Educational Slöyd, the assumption that a proper tool use can bestow benefits also has its downside: there may be tool use or tools that are harmful or less beneficial.

Ahlman's pragmatic philosophical explication of cultural tools is useful and applicable in adopting viewpoints on the design of learning tools. A learning tool can — in my view — be both an object and a method: a concrete thing intermingled with a way of doing. In the process of design it is reasonable to aim to design and produce some specialized tools for some specific kind of learning or to formulate methods using existing tools. In this way a specific tool may aim to be a response to the fulfillment of some specific method or, on the other hand, some existing object may become a learning tool because someone invents a method (tool) of using it for learning and communicates it to others. For instance, Virtual Learning Environments and Learning Management Systems are attempts to create a specific tool for learning, while weblogs or wikis are not learning tools, although we may design methods — learning tools — for using them in learning.

4.1.3. Principles of Activity Theory

Parallel lines of thought and even concepts in the passages from Heidegger and Ahlman presented here can be found when a comparison is made with *activity theory*. Activity theory is one of the most widely discussed theoretical frameworks in contemporary educational psychology (Engeström, 1987, 1999), but also in the fields of human-computer interaction (HCI) and interaction design (Kaptelinin, Kuutti, & Bannon, 1995; Kaptelinin & Nardi, 2006; Kuutti, 1991; Norman, 2005). The origins of activity theory lie in the cultural-historical psychology developed in Soviet Russia in the 1920s and 1930s by Lev Vygotsky and his colleagues. Vygotsky's disciple Aleksey Leont'ev is considered to be the founder of activity theory (Kaptelinin & Nardi, 2006, p. 29). Its main concepts are presented in Leont'ev's article *Activity, Consciousness, and Personality* (Leont'ev, 1978). Basically, activity theory aims to understand human beings and the social entities, such as objects, groups, and communities, humans create in their activity thorough analyses of the genesis, structure, and processes of their activities (Kaptelinin & Nardi, 2006, p. 31).

Activity, subject, object, and *development* can be said to be the most fundamental concepts of activity theory. The basic representation of activity is a simple *subject* <–> *object* relationship. Activity in the subject-object relationship is here the key source of the development of both; as such the theory emphasizes focusing on the subject and the object together, not separately. To understand the relationship and development, the basic unit of analysis must be *activity* as a whole (Kaptelinin et al., 1995; Kaptelinin & Nardi, 2006, pp. 32-33; Leont'ev, 1978).

Yrjö Engeström, a key figure in contemporary cultural-historical psychology and activity theory research, has proposed an activity system model where mediating artifacts play a central role. In Engeström's well-known model the minimum elements of a human activity system are: (I) the object, (II) the subject, (III) the tools, (IV) the rules, (V) the community, and (VI) the division of labor (Figure 6). For Engström these are all interconnected; they have mutual relations and an effect on each other. (Engeström, 1987, 1999, 1995).

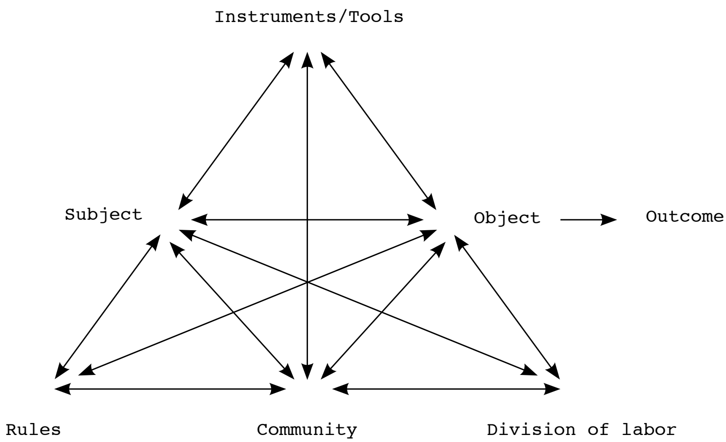


Figure 6: Human Activity System (Engeström, 1987, 1999).

Engeström's (Engeström, 1987, 1999) triangular activity system model has been used to develop a number of research tools for analyzing and evaluating technologies and their use (see, for instance (Kaptelinin & Nardi, 2006, pp. 73-115). Additionally, several design research and experiments have been implemented that discuss or are at least implicitly based on the activity theory. In the field of art and design activity theory have been used to compare the various factors that have a role in the creation of art, design and archeological artifacts (Diaz-Kommonen, 2002; Díaz-Kommonen, 2004). In the field of educational technology an Open Source learning platform Sugar has adapt in its design many ideas that could be tracked back to activity theory. The operating system does not run applications but present activities for young children users. It is designed to emphasize learning through doing, facilitating sharing and collaboration, and collaborative learning. (Buchele, 2009; "Sugar Labs — learning software for children," 2010)

4.1.4. Free Software

Richard Stallman is a founder of the Free Software Movement and the GNU project developing a free operating system. Stallman is not a researcher or scholar in a traditional sense. Stallman is a programmer. He has, however, written several widely read and oft-referred-to philosophical essays about software and copyright and people's rights in the era of digital information technology. Many scholars interested in the impact of new technology on modern life admit that the work of Stallman has been the main source of inspiration for their work (for instance, Lessig, 2004).

Stallman's (1984; 1998) basic claim is that software should be free, as defined by his four criteria of software freedom. These are: (1) the freedom to use the software; (2) the freedom to modify the software; (3) the freedom to distribute the software, and (4) the freedom to improve the software and distribute the improvements to others. In practice software should not have owners in a traditional sense. Stallman's arguments for software freedom are practical and ideological. As a programmer, he feels that as computers are making it easier than ever before to copy and modify information, this characteristic of the tool should be put into use to its maximum extent. On the other hand Stallman is committed to the idea of freedom and considers people's freedom to *"share with their neighbor"* to be social and ethical. In this way free software builds on a culture of helping your neighbors. Stallman sums up the ethical side of his thought, for instance, in a free software song, as follows:

"Join us now and share the software
You'll be free hackers, you'll be free.
Join us now and share the software
You'll be free hackers, you'll be free.
Hoarders may get piles of money,
That is true, hackers, that is true.
But they cannot help their neighbors
That's not good, hackers, that's not good."

– *Richard Stallman: Free Software Song* (Stallman, 1991)

From Stallman's arguments on free software we may draw some generic design principles and ideas related to software learning tools. The value of his thinking for learning is also obvious: if the objective of a learning tool is to help people to learn, it is hard to argue why the designer would set limitations on how the tool should be used, shared, or improved. The idea of using computers to their full potential to share information is also reasonable from the learning point of view. It can be argued that access to information and its flow are critical in learning.

4.1.5. Summary

I have already pointed out Heidegger's insight that a good tool often slips out of attention; it easily becomes invisible to its users. I also recognized Ahlman's characterization of a good tool as being useful for a specific purpose, efficient from the viewpoints of energy and time consumption, and from lacking unwanted side effects. Now, from the grounds of activity theory and especially from Engeström's activity system model, another insight can be formulated, where a good tool need not be invisible or necessarily efficient in the Heideggerian and Ahlmanian sense. Activity theory enables us to open up an insight, whereby the focus of a tool being good can be seen more in its qualities of *providing* the subject with *abilities* to act with objects. In the design of a learning tool, activity theory also provides a framework to name who and what actually are the objects, the subjects, the rules, the community and the division of labor and what are they like and interconnected. At the same time activity theoretical view opens up a criterion, whereby a good tool can be expected to have the quality of keeping connections open for the subject to act openly with the other elements of the activity system. Or, even further: a good tool has the quality of having an effect on and being affected — even modified — by the other elements of the system. Stallman's idea of free software fits in well with the insight gained into activity theory. To have the quality of being affected and modified, the software tool must be free in the way that Stallman defines freedom.

In the design of the tools presented in this study the matter of what makes a tool a good tool was considered and discussed during all the stages of the design processes. The aim of designing a good tool is visible in a number of design and development decisions, as well as in the underlying design methodology discussed in Chapter 5.

The aim of the tools in question in this study was to serve abstract and large-scale activities that are actually related to major socio-cultural, technical, and economical issues. In the design of the tools the design team aimed at enhancing activities facilitating knowledge building, scaffolding progressive inquiry[10], improving the availability of quality learning materials, promoting the creative use of ICT in education, and solving the lack of collaboration in the creation of learning material. Our design team designed the tools to function in these tasks as well as possible, while still understanding their limitations in terms of their ability to change the entire activity systems or the culture they are functioning in.

The learning tools in question in this study can be compared to some other tools with similar objectives. In a way education policies, curriculum design, teacher training, and the development programs of schools as work and study places are used as tools for the same purpose as the one the software learning tools were designed for. This leads us to consider Heidegger's criticism of technology. Are software learning tools alienating people and making us all resources of the technological system without having any immediate way of influencing it as they are not *"ready-to-hand"* objects? Is there any way a learning tool designer can avoid this? Is there any way to keep the learning tool open for a handicraft approach?

10 Progressive inquiry is a pedagogical model and approach to teaching and learning where the aim is to facilitate similar kinds of practices of working with knowledge to those that characterize scientific research communities. It was developed by Kai Hakkarainen's research group at the University of Helsinki. See, for instance, (Hakkarainen, 2003) and (Hakkarainen et al., 1998)

A solution used in the design of the learning tools discussed in this study is to rely solely on free and open standards and free and Open Source code in the implementation of the software. This guarantees that anyone may, at any point, check the code and modify it in a handicraft way. The use of free and open standards and free and Open Source code does not impose constraints on modifications of the software to make it fit different activity systems. In practice this means, for instance, such things as translating the user interface and localizing the software into different languages and cultural setting or adding new roles to the users, thus defining new kinds of distribution of labor.

4.2. KNOWLEDGE INTERESTS: HERMENEUTIC EMANCIPATION

In this section I will summarize some ideas of Jurgen Habermas and Karl Popper that have influenced my design thinking. Habermas' theory of knowledge-interests is taken mainly to mirror and elucidate the principles which generally motivate design — design interests. Its function in this study is to stand as a theoretical framework which enables me to analyze questions of how different constructions of different learning tools serve different knowledge interests.

Further in this section Karl Popper's ontology of the *Three Worlds* and an excerpt from his epistemological contributions — although brought up here only in a popularized version — serve this study's subject matter in several ways. I find it likely that Popper's threefold ontology is, when taking a view of the interaction between the Popperian Worlds, helpful for designers in clarifying their contributions in this specific philosophical context. The idea is to constitute general functions of design and show how these operate in a Popperian framework. Popper's epistemological thought can be claimed to be visible both in the tools presented in this dissertation and in the methodological insights gained during the design of the tools. Evolutionary epistemology, the idea of a growth of knowledge in which all theories are true only provisionally, is central in all four learning tools designed during the research. The idea is also present in the methodological insights presented as a result of this research and in the actual process of doing this research.

4.2.1. *Interrelation of Knowledge and Human Interests*

Contemporary designers commonly work in complex cultural and socio-technological systems with various human interests and impacts. Designers should be well aware of the interests the designed tool is to fulfill, whereas the designer's interest should be to design as good tool as possible to complete the interests of the people.

Jürgen Habermas' (1987) theory of the interrelation of knowledge and human interests is useful for reflecting and analyzing interests related to the design of learning tools. Further, Karl Popper's (1978) Popper's tripartite ontology has helped me to understand the different *worlds* in which designers operate when mediating different human interests.

Habermas separates three interests of knowledge (see Table 1), named empirical-analytical or technological, hermeneutic and self-reflection or emancipatory interests (Habermas, 1987, pp. 191-213; Niiniluoto, 1980, pp. 70-73).

	SCIENCE, ENGINEERING, SYSTEMATIC SOCIAL SCIENCE	HUMANITIES	CRITICAL SOCIAL SCIENCE, PSYCHOANALYZES
INTEREST OF KNOWLEDGE	**Technological**	**Hermeneutic**	**Emancipatory**
FUNCTION OF KNOWLEDGE	Prediction	Understanding	Ideology critical, emancipation
OBJECTIVE	Control of nature and society	Interpretation and transmission of knowledge	Freedom from wrong knowledge

Table 1: Habermas' Human Interests of Knowledge, according to Niiniluoto (1980, p. 72) (Translation from Finnish by me)

The technological interest is viewed, according to this theoretical framework, as being dominant in the natural sciences, engineering, and systematic social sciences. Its motivation and aim — that is its interest — is to predict and control. The hermeneutic interest is common in the humanities. Its aim is to understand. It interprets the world and transmits traditions. The emancipatory interest is apparent in critical social sciences and, for example, psychoanalysis. It aims to provide emancipation from wrong knowledge or false consciousness: it is ideology-critical. (Habermas, 1987, pp. 191-213; Niiniluoto, 1980, pp. 70-73).

In addition to Habermas' interests of knowledge, Niiniluoto (1980, p. 73) proposes a fourth interest of knowledge in research: a purely theoretical, that aims to explain phenomena theoretically without any instrumental interests. Specifically in the context of educational research, Åberg (1997) introduces the *pragmatic integrative interest of knowledge* in educational research, with its primary aim being to improve the continuous qualitative development of educational activities and in this way to have an impact on the quality of life of people (Åhlberg, 1997).

It can be assumed that within the design of learning tools designers relate to some distinct interests of knowledge. For example, the *Learning Management* system briefly described above, which concentrates on delivering the contents and assessments of students' routine memory, combined with an attempt at controlling and measuring quantitatively the new knowledge students have gained, can be recognized as mainly serving the Habermasian technological interest. On the other hand, the *open wiki project* (Leinonen et al., 2009), for example, with no limitations on access or participation for those with access to the Internet, can reasonably be viewed as serving the Habermasian emancipatory interest.

One of the main purposes and ideas in the design process of the learning tools discussed in this study has been the possibility to enhancing people's ability to independently interpret and analyze the world and to augment critical thinking. At the same time there was an attempt to enhance their ability to build new meanings and thus to emancipate themselves, in a way, from false consciousness. Viewed in this way, the tools can be seen as also relating quite strongly to the approach of Varto's *questioning researchers* (see Section 1.2) and can further be viewed as value-laden — or even having an ideology of a kind.

4.2.2. Different Mental and Physical States

Karl Popper's epistemological thinking and his theory of the tripartite division of physical and mental states can illustrate the designer's possible approaches to knowledge interests. Popper (1999) has curiously stated that all life is problem *solving*. Though Popper's statement, when presented plainly like this, certainly leaves space for suspicion and counter-arguments, a charitable reading of Popper shows us a life of constant inventing to solve problems and adjusting from mistakes. The idea of life and human activity as self-correcting systems can be viewed as summarizing Popper's epistemological thinking. It goes along with Popper's leading principle in the philosophy of science, too, where facts and theories are considered as hypotheses waiting for someone to show them to be wrong or to improve them. (Popper, 1999)

Popper is famous for his theory of the tripartite division of physical and mental states (Figure 7). Popper's *World 1* is the universe of all physical entities. *World 2* is the world of mental states, states of consciousness, and psychological dispositions. *World 3* is the world of the contents of thought and the products of the human mind and cultures, such as stories, myths, scientific theories, social institutions, works of art, and also cultural tools. (Popper & Eccles, 1984, pp. 36-50)

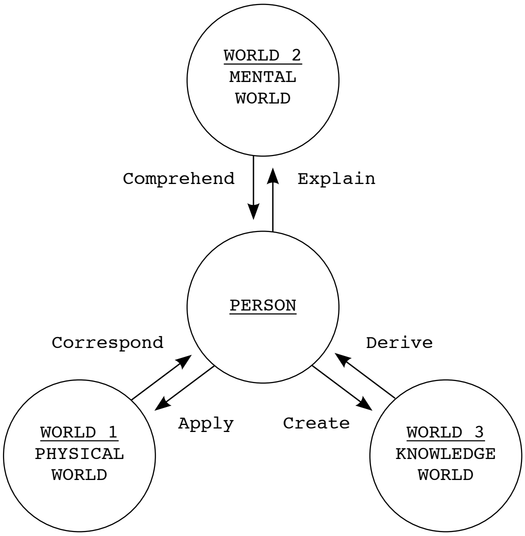


Figure 7: The person and his relationship to Popperian mental and physical states (Worlds 1, 2 and 3). (Modification of (Gaines, 1989).

Several scholars have used Popper's theory of three worlds to criticize the dominant theories of learning and the pedagogies based on them. For instance, Bereiter (2002, pp. 237, 288-290) and Paavola et al. (2004) claim that many theories of learning do not take into account World 3, but rather focus on World 2, people's mental state. In these theories the mind is seen as a container of knowledge, and learning is viewed as an accumulation of information (Paavola et al., 2004). When learning operates primarily in World 3 it can be meaningful to call it *knowledge building* — the focus is on the world of theories and ideas.

4.2.3. *Summary*

In the design of the learning tools considered in this study, the design team had mainly hermeneutic and emancipatory interests but also technological interests with the focus on designing tools. Through the use of the tools it is hoped that they could also work to fulfill these interests. Our design teams' way of following, interpreting, and understanding the people with whom we were designing was hermeneutic. On the basis of an attempt to understand both the people's situation and the wider context, the team aimed to design tools that are emancipatory: something that will empower people and free them from wrong paradigms or wrong knowledge. For instance, with the design of Fle3 we did not only want to make a tool for knowledge building but also to challenge the trend of designing and purchasing Learning Management Systems (LMS). We thought that the development of the e-learning field with the main focus on LMS and learning object standards was dubious, because the approach was focusing on providing learning as the accumulation of information. With Fle3 we wanted to free people from wrong LMS paradigm and pay more attention to the design of more meaningful learning processes and tools.

In the design processes the design team moved between Popper's three worlds: from designing cultural tools and developing learning theories in and to World 3, attempting to understand our own and our participants' mental states in World 2, as well as the limitation of World 1, in which we are not only designing but also living. Examples of this are presented in the Chapter 5.

4.3. DESIGN THINKING: SOLVING WICKED PROBLEMS IN A PARTICIPATORY WAY

In this section I will bring to the discussion several design theorists I have found useful in the process of developing the design methodology presented in this study. Nelson and Stolterman, as well as Schön, are among the few pure design theorists, in addition to Ehn, who has a special interest in participatory design. Nelson, Stolterman, Schön, and Ehn all see design as a process of solving wicked problems and reflection in action within a social arena. Their ideas can be considered as the design-philosophical foundation of the methodological insights presented in the study.

4.3.1. Design as Service

Designing tools can be considered to be as old as humankind and at the core of a culture. Nelson and Stolterman (2003, pp. 33-35) claim that when compared to the natural sciences, which attempt to investigate the world and gain a universal concept of it, design relates to an intention to change the world deliberately. Its attempts to change the world — to provide new ways of doing things, to give different perspectives and interpretations about the world — can be seen further as relating design to *artistic* activity, although the focus in design is not on self-expression and self-service but on other-service (Nelson & Stolterman, 2003, pp. 47-48).

As a cultural activity design may be located somewhere between or at the intersection of art, science, engineering, and handicrafts. Like science, design relates to methods, but following methods in design is not — as is often seen to be the case with science — considered to be as important as the results. In contrary, in design the originality and ingenuity of the result, the design, are often stressed in quite a similar way as in contemporary communities of art (Hannula, Suoranta, & Vadén, 2005). In a design process, the methods, the way of achieving the end product, can even be viewed as being practically irrelevant as long as the product is good.

When taking viewpoint of problem solving — the way of setting and approaching problems in design — problems can be in many of its parts considered to be and approached as wicked, incomplete and contradictory (Buchanan, 1992; Nelson & Stolterman, 2003, pp. 16-17; Rittel, 1972; Rittel & Webber, 1973). Furthermore, in design it is seen to be important to understand problems as having multiple solutions, that each and every formulation of a problem is at the same time an attempt to solve it and that solving one problem may create even more complex problems (Rittel, 1972). For example, according to Nelson and Stolterman (2003, pp. 139-141), ordinary problem solving is reactive to some unwanted state, while designing is an attempt to create a *positive* addition to the present state. The designer can never assume that a perfect design is somewhere out there, waiting for someone to discover it. A designer can just *contribute* to the current state with her intentional actions (Nelson & Stolterman, 2003, p. 31).

According to Donald Schön, design requires the skills to *"recognize and appreciate desirable and undesirable design qualities"* (D. Schön, 1987, p. 159). In this way the activity of designing is viewed with an emphasis on reflecting and thus coming into dialog with the qualities and available materials in the specific situation at hand (D. Schön, 1987, pp. 159-160). Schön calls the process of combining the designer's understanding of the materials with the situation, where intuitional skills often add meaningful new artifacts and methods to it, *artistry*.(D. Schön, 1987, pp. 22-30)

Defining different intentions in the design process can, in my view, relate and lead to the demystification of a design. Nelson and Stolterman present a model of contract intentions in design which presents four distinct intentions; these are: (I) *Helping* (fixing, assisting, patronizing), (II) *Art* (persuading, influencing, manipulating, proselytizing), (III) *Science* (describing, explaining, predicting, controlling), and (IV) *Service* (serving, conspiring, empathizing) (Figure 8). In this framework the helping-service dimension is viewed as the most crucial. A designer may approach the design challenge with the intention of helping — by fixing something for someone. In this case the power and resources remain with the designer, and the targeted beneficiaries of the design are put in a position of being indebted. (Nelson & Stolterman, 2003, pp. 66-69)

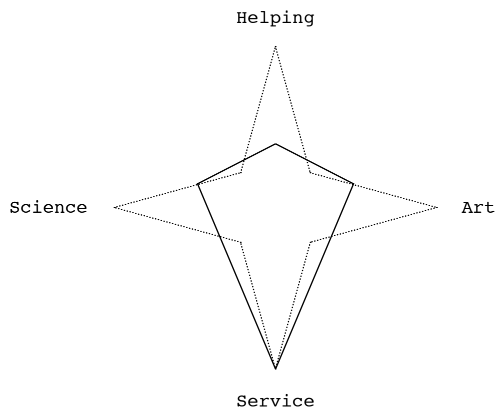


Figure 8: Contract Intentions of Design (Modification of (Nelson & Stolterman, 2003, p. 67).

In the *service relation* the designer and the beneficiaries (customer) of the design are seen as equal partners. Here the designer aims to serve, to solve the actual and meaningful design challenges with the beneficiaries.

Progress in this dimension can be seen as essential to design: service type of contracts is the primary contract in design. (Nelson & Stolterman, 2003, pp. 66-67).

The science <=> art dimension is reminiscent of the search for a balance between scientific research and artistic practice. Scientific research and the understanding of it give relevant information about the subject matter and the situation where the design takes place: for example, about the underlying laws of nature of the materials available and the political-cultural-historical contexts in which the designer is operating. On the other hand art, viewed as an act of making things that are practically quite useless on the basis of our imagination and creativity, may lead us to see things differently.

4.3.2. Participatory Design

Pelle Ehn is considered to be one of the earliest practitioners and theorists of *participatory design*. According to Ehn and Kyng (1987), the design of computer tools for workplaces means not only the design of a tool, but in fact the design of a *labor process*. In participatory design those who will be the actual users of the tools that are designed are recognized as the primary source of innovation in the process. In participatory design ideas arise as a result of collaboration between participants who may have very different types of expertise and backgrounds. For the designer, this requires them to actually spend time with the people in question in their everyday life situations, rather than, for example focusing on testing prototypes in a laboratory environment. In participatory design, especially in the originally Scandinavian tradition, challenges in design are expected to arise from the human context and neither the problems nor the solutions and prototypes should be imposed outside this. (Muller & Kuhn, 1993; Spinuzzi, 2002)

The rationale behind participatory design may also come from the importance of tapping into the participants' tacit knowledge (Polany, 1966). With participatory design workshops — with rich documentation with audio recordings, videos, pictures, and texts — it is possible to make some of the tacit knowledge as explicit as possible. Practices that may look more as if they serve social needs than being designed to be productive may also help in the transfer of tacit knowledge. For instance, Ehn used to organize football matches with the office workers and computer scientists designing computer systems for office work. (Ehn & Kyng, 1991)

In computer science human-centered design — sometimes also called user- or customer-centered design — has, as a design approach, some relevant issues in common with the participatory design approach. In human-centered design the focus is on users' needs in actual use situations. From the original focus on needs and tasks, some scholars, for instance Norman (2005) and Jaimes (2006), have requested human-centered design to pay more attention to the human activity systems and cultural context where the future product will be used. Thus the human-centered design movement partly approaches the leading ideas presented in the participatory design literature (Muller & Kuhn, 1993; Schuler & Clement, 2004).

4.3.3. Summary

In the design team working with the learning tools we were very conscious of the fact that we were dealing with wicked problems. At no point did we try to take on a role of helping, but rather we tried to serve the people we were designing for. This led us to work according to the principles of participatory design. In the process of becoming participatory designers we also noticed that if designing computer tools for work is also the design of a work process, consequently, the design of learning tools is therefore the design of learning processes and that when a tool is put into use in a learning context it shapes the situation and the process, as well as becoming an object of further modification and meaning-making by its users. The prototypes of tools created in the process can thus be considered to be hypotheses that could work in some actual contexts of learning, that can be current and actual, prospective or desired ones.

5
Summary of the Key Findings

In this chapter I will summarize the key findings of the study: the *methodological insights*. These insights draw on, and were gained, during four different design processes. Because of this, at first, it is reasonable to summarize the overall contexts, design challenges, and design solutions of the four design cases (See Table 2).

During the design cases, in the design team we noticed that it was impossible for us and the people we were designing for and with to define the challenges for the design in a straightforward manner or to specify the affordances of a tool that could contribute to solving the unclear challenges. Dealing with uncertainty required a continuous open dialog between the designers and the participants. While working with the participants we were gradually able to gain an understanding and put more effort into proposing and working out design solutions.

As tool designers we noticed that providing tools as solutions to challenges with existing social structures is extremely sensitive and has remarkable prospects, both positive and negative. This was recognized as being the case because not only do the tools have the potential to change some specific social actions, but they may also have an impact on the whole social structure and its practices. For instance, on a high political level, we may assume that at least partly because of Fle3 and the related research the Finnish National Core Curriculum for Basic Education 2004

DESIGN CASE	OVERALL CONTEXT	CHALLENGE	HYPOTHESIS OF A SOLUTION
Future Learning environment 3 (Fle3)	School children/ pupils teachers and parents in Finland/Eu.	Lack of student-centered knowledge building activities.	Computer supported collaborative learning tool could change the existing pedagogical practices to the dirction of including more knowledge building activities in them
MobilEd	School children, teachers and general public and self-organized local media services in Majority World.	Lack of quality learning materials (local media) and creative ways of using information and communication technologies in learning (and in media distribution)	Audio wiki that is usable with widely available mobile phones could help people to set-up and maintain their own information systems.
LeMill	Teachers and educators in EU	Teachers and educators do not share their learning materials and do not improve them in a collaborative way.	An online service with learning resources that can be edited and improved by others with tools for social networking and matching of interests among the participating teachers could enhance sharing and collaboration around learning material.
Experimental online class on wikiversity	Self-organizing study groups and university students online.	Open online learning is not structured, supervised and goal oriented.	An open online course with weekly program, weekly learning tasks, collaboration and supervision could change the ways of organizing and practising open online learning

Table 2: The Four Design Cases: The Context, the Challenge and the Hypotheses of a Solution

(Opetushallitus, 2004) emphasizes creative problem-solving skills, knowledge building, and progressive inquiry learning methods, as well as the use of collaborative information and communication technology in schools. Furthermore, it looks that in Georgia, where LeMill became very popular, the local Ministry of Education has promote the service as the national repository for digital educational materials and an important tool in their attempt to provide digital learning materials in the Georgian language.

The relationships between social structures, practices, and tools in daily life can be illustrated with an example taken from school architecture. A school auditorium with a built-in teachers' podium can in fact be seen to form a certain type of social structure and practices that frame learning situations. The arrangement of such an auditorium can be viewed quite openly as communicating the suggestion, or even importance, of a certain type of teaching and learning, where the teacher is expected to be the one with the voice and students are in the role of listeners. The architecture and the tools can actually be very restrictive by providing space and tools only for one certain kind of teaching and learning.

Below I present the main methodological insights gained while working with the design cases. These three insights are my answers to the research question: *How can software learning tools be designed* in such a way that they would be beneficial and good in complex social learning situations and learning systems? The model of a *research-based design process* has already been tested in all the cases. The ability to see *design as informed guessing* was a relieving insight and also played a wider role in the later design cases. The third insight, named *interaction of knowledge intentions in design*, analyzes how designers must move between different knowledge intentions and Popperian Worlds to achieve good design.

The crystallization of these three insights is the result of an expansive process of development and reflective thinking while working through four design cases.

5.1. RESEARCH-BASED DESIGN PROCESS

Research-based design is not to be confused with design-based research. In design-based research, the aim is to do research with designed interventions into real-world situations. In *design-based research* design interventions are a research method. In *research-based design*, the designs (artifacts and tools) are the main outcomes and research helps to draw routes to that outcome.[11] (Barab & Squire, 2004; The Design-Based Research Collective, 2003; Leinonen et al., 2008)

On the other hand, for instance, coming from the field or educational inquiry Lakkala (2010) sees that the object of design-based research can

11 Other sources of confusion are that sometimes a design that is based on results of any research, such as usability research, is called research-based design and in an educational context any design that implements a researched instructional theory or pedagogy can be called research-based design.

be not only curricula, pedagogical activities, activity structures, scaffolds and educational microcultures, but also educational artifacts. Lakkala continues that because of this the research methodologies and theoretical perspectives in design-based research may vary a lot. Consequently research-based design — focusing precisely on educational artifacts and tools — can be seen as one methodological approach inside the design-based research. However, as the design-based research builds on art and design tradition, not on educational inquiry or learning science tradition, I see it as an independent paradigm. In the field of human–computer interaction (HCI) Fallman (2005, 2007) sees the difference between design-oriented research and research-oriented design in a similar way. According to him research-oriented design builds on the design tradition and the artifacts designed are the primary outcomes, the main results, of the activity.

A research-based design process can be described as being, first of all, iterative, with attempts being made to have an effect on systems. It is iterative, because the focus of the design is not on the tool alone, but on the whole system of people and their activities and the tools around them. The role and impact of the tools is understood to be limited. Nevertheless, the role of the tools is not underestimated — they carry affordances and may have an empowering or limiting impact on the people in the systems.

In the design case of Fle3 the multiple challenges and the importance of seeing beyond the tool were recognized as creating a need to design not only tools but also new epistemological infrastructures in school education (Rubens et al., 2005).

In the MobilED design a specific research framework was designed in an attempt to contribute to large-scale development goals. At the center of the work there was not only the tool as an outcome, but also the societal and developmental outcomes the tool could facilitate and enhance (Ford & Leinonen, 2009).

When designing LeMill we noticed that regardless of the high level of interest in Open Educational Resources among researchers in ICT in education, there was no room for OERs in the everyday activities of an average teacher. By understanding that we cannot fix the daily activities of teachers, we decided to aim to have an indirect impact on them by designing a tool that would support a new kind of everyday practice of teachers and learners (Leinonen et al., 2010).

In the case of Wikiversity there was the idea of developing the practices of the existing community by implementing action research in it. Again, the focus was on the whole Wikiversity community and movement and the tool designed, the course as an example, was considered to have an impact on it (Leinonen et al., 2009)

The first main finding of this study is the formulation of a new design process, called a research-based design process (Figure 9). In a research-based design process it is essential to guarantee an iterative and expansive process of defining, redefining, designing, and redesigning in an open dialog with multiple stakeholders (Leinonen et al., 2008). The phases do not exclude each other but, rather, take place in parallel. The amount of effort put into them and their importance in the process also vary with time.[12] In the design cases of this study, completing a single full circle took approximately from 9 months (Wikiversity) to 2 years (Fle3).

The full process can be described as a hermeneutic circle where all the design and research phases and operations carried out increase designers' and researchers' understanding of them. The phases are:

1 contextual inquiry;
2 participatory design;
3 product design, and
4 the production of software as a hypothesis.

In the research-based design process presented in this study there are similarities to some earlier models pointing out activities constituting meaningful design process. For instance, Kensing, Simonsen and Bsdker (1998) have propose such principles as participation; close links to project management; design as communication process; combining ethnography and interventions; co-development of IT, work organization and user's qualification; and sustainability as a foundation for a design method, named as MUST. The MUST is a method for IT design in an organizational context with the participatory design tradition. In the MUST

12 I have estimated that in an ideal process in practice, each phase when starting would get 2/3 of all the attention, when the other three phases would equally share the reminding 1/3. In the end of the full circle each phase would get equal attention, 1/4 each.

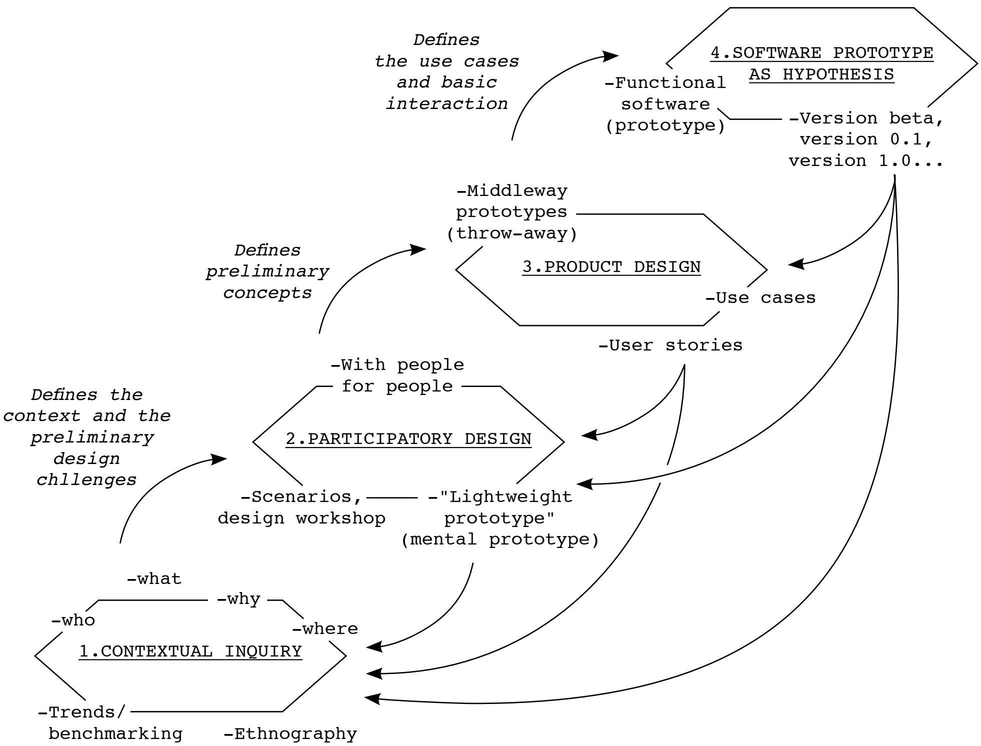


Figure 9: Research-based Design Process: Contextual Inquiry, Participatory Design, Product Design, and Production of Software as Hypothesis (Leinonen et al., 2008).

method the design process included five main activities: (a) project establishment, (b) strategic analysis, (c) in-depth analysis of selected work domains, (d) developing visions of the overall change, and (e) anchoring the visions. (Kensing et al., 1998). If we compare research-based design process presented in this study to the MUST method, we see that there are many similarities in the approach. However, when the MUST aims to define specific method, the research-based design process is more a methodological framework and description of different phases in the process.

Below I present each phase of the research-based design process in more detail, with examples explaining how the phases took place in the four design cases of this study.

1 – CONTEXTUAL INQUIRY. The research-based design process starts with an exploration of the socio-cultural context of design. The aim is to

understand the context and to define the preliminary design challenges. Beyer and Holtzblatt (1998, pp. 46-47) compare contextual inquiry in design to apprenticeship, where designers inquire and learn by following and participating in the practices of their customers. Contextual inquiry include many practices which Jones (1992) calls methods of exploring design situations. These are, for instance, stating objectives, literature searching, investigating user behavior (interviews, questioners) and other kind of data logging and data reduction (Jones, 1992, pp. 193-271). In practice, in the model described in this study, contextual inquiry means performing a grounding clarification of:

- who the designing is meant for;
- what the possible social, cultural, economic, and political design constraints and opportunities are;
- what the trends related to the context are, and
- what the people are aiming to achieve.

In contextual inquiry designers may use various rapid ethnographic methods, called by some scholars *rapid ethnographic assessment methods* (Squires, 2002), such as daily participant observation and conversations with different levels of formality, from small talk to structured interviews that are recorded and later analyzed. In parallel with the fieldwork, designers should benchmark earlier design and research related to the context and analyze the trends in the field. The exploration of the context generates the preliminary design challenges, which are later specified in more detail.

In the contextual inquiry phase of the design of the *Future Learning Environment* 3 (Fle3) our design team defined the context as including such key elements as schoolteachers, children and pupils, the Progressive Inquiry learning method, quality learning, networked computers, and the Web. The preliminary design challenge in this case was found to be a lack of student-centered knowledge-building activities.

In the MobilED case the contextual inquiry originally focused on school learning in the Majority World, but later in the process the context was changed to make it more generic by looking at communities without local media services. In practice, a large part of the contextual inquiry was carried out in two schools and in one research institution in

South Africa, where the preliminary design challenge was defined to be the lack of quality learning materials, creative ways of using ICT, and, later, a lack of local media.

In the case of LeMill the overall context and the preliminary design challenge were largely defined in a European research project looking for more efficient exchanges of learning materials, the use of teachers' expertise to create new and novel learning material, and to promote an exchange of teaching methods and tools across Europe. The contextual inquiry was performed concurrently in several locations, mainly in Finland and Estonia, by visiting, meeting, and observing teachers in schools, as well as in their homes. During the process the design team noticed several essential elements, such as open and free user-generated content, wiki-like creation, editing and community, social media, social networking, and multilingualism and multiculturalism. These were then included into the context.

In the case of the experimental online class in Wikiversity the design team included into the context the emergence of self-organized study groups online (Downes, 2008; Fini, 2009; Leinonen et al., 2009), the Wikiversity community itself, and university students interested in experimenting with new kinds of learning. The contextual inquiry was carried out fully online by participating in and observing Wikiversity community activities, as well as other open education initiatives. The design challenge built from the contextual inquiry was defined as being the fact that open online learning is rarely structured, supervised, and goal-oriented.

2 – PARTICIPATORY DESIGN. Researchers and practitioners of participatory design widely agree that their perspectives, backgrounds and areas of concern are so diverse that there can be no single definition on participatory design ("CPSR - What Is Participatory Design?," 2008; Schuler & Clement, 2004). When participatory design for some scholars is a political issue others see it more as a pragmatic way to design (Schuler & Clement, 2004). In the research-based design process the participatory design is a phase, where the designers are particularly focusing on people's right to participate in a design process. From a wider philosophical point of view, however, it could be claimed that the research-based design process as a whole is a participatory design process.

In this study, participatory design is considered to be a stage with most input from various stakeholders with direct focus on actual and practical design. During the participatory design, the design-research team involves stakeholders in design workshops that aim to define preliminary concepts: early but concrete ideas of what the tool and its affordances could be. With playful and even artistic practice, designers may engage people in preparing scenarios and sketches, as well as mental and light physical prototypes. The process of defining the preliminary design concepts is one that, at the same time, deepens everyone's understanding of the context and the design challenges.

In the Fle3 design process the design team organized a number of sessions with teachers and pupils from several European countries. The sessions included looking at paper prototypes and writing user stories. Furthermore, tens of teachers and hundreds of students were using Fle3; from these pilots the designers and researchers collected both quantitative and qualitative data from server logs and interviews with the participants. In the design of MobilED the design team member's were in close contact with many experts in Finland and South Africa, including teachers and their pupils. Most of the design workshops — including discussions, scenario building, and testing in a real school context — were observed and documented with pictures and videos. In the design of LeMill the design team worked with groups of teachers from Finland, Estonia, and Hungary, carrying out participatory design sessions with scenarios and paper prototypes, as well as thematic interviews and discussions. The sessions were audio recorded and later analyzed by the designers. In Wikiversity the participatory design was started by launching a draft course plan and schedule for community editing. The community knew the planned course starting day, which ended up as being the actual deadline for the participatory design. In addition to the editing of the wiki pages, the participants were encouraged and helped to discuss the course design on the wiki's discussion page, in online chat (IRC), and in their blogs.

3 – PRODUCT DESIGN. Based on the participatory design sessions, the third phase attempts to define use cases and basic interactions using user stories and throwaway prototypes. In the model described in this study with focus on design of software learning tools, the product design refers to the operations carried out by the designers and the software engineers to translate the results from the contextual inquiry and particularly from the participatory design to information architecture and human-comput-

er interaction models. In the research-based design process the product design phase includes activities aiming to composition: *"brining parts, pieces, functions, structures, processes and forms together in a such a way that they have a presence and make an appearance, particularly of unity, in the world"* (Nelson & Stolterman, 2003, p. 207). In the product design phase of designing software learning tools, the design team should use agile software development methods, such as scrum and extreme programming, enabling rapid development of high-quality software (K. Schwaber & others, 1995; Ken Schwaber & Beedle, 2002; Wells & others, 2003).

The aim of the product design phase is to give a more concrete form to the ideas presented in the earlier stages of the process. In practice in this phase the professional designers will create some distance between themselves and the stakeholders in order to have a chance to use specific design languages, such as interaction prototypes and UML (universal modeling language) diagrams.

In the Fle3 design process our design team used a number of paper prototypes, as well as screen prototypes, to share the early ideas with teachers and other experts. On the basis of their feedback, the design team continued writing user stories, according to the extreme programming manner, which were then used in the functional software prototype development stage as the baseline for interaction design models. In the design of MobilED the design team produced video prototypes with use scenarios to share the design ideas and concepts with a wider community of stakeholders. Following the presentation of the preliminary concept, the design team wrote user stories for agile software development and built prototypes to conceptualize the ideas from the participatory design sessions. In both Fle3 and LeMill, the design and the software engineering team often released an early beta version for people to take a look at and gave feedback on the direction the design team should take in further development. In this loop the design team then made internal analyses of the feedback and made new prototypes. With the Wikiversity, the core design team — including myself and my co-designer/researcher — carried the responsibility of making sure that the online course would be ready and would take place as planned. In the internal discussions the design team members made a number of scenarios and plans to manage possible challenges with the course. For instance, the design team members agreed on how to take care of vandalism and how to keep a book about students' performance. In this way the product design phase was more about designing guidelines for the product management rather than focusing on the specific tools used in the course.

4 – PRODUCTION OF SOFTWARE AS HYPOTHESIS. In the last phase, a number of artifacts are delivered, from early functional prototypes to more feature-rich applications. In agile software development methods the software team aims to release often small functional pieces of software. In relation to the whole design process described in this study, the aim is to build software prototypes for and to see what effect they have on the environment and the community using them. The prototypes are hypotheses, potential solutions to the design challenges defined earlier in the process.

Each of the design cases described earlier (Fle3, MobilED, LeMill, and the Wikiversity course) produced functional software that has since been tested with a number of users in different contexts. In the case of Fle3 our design team was following the principles of extreme programming, where as with MobilED and especially with LeMill the design and software engineering teams were implementing scrum method. The Wikiversity case did not include large amount of programming work and because or this the production phase was more add-hock.

The testing and feedback gathered from the pilots in which the prototypes were tested increased our understanding of the context and also resulted in changes to it. Simultaneously, this had an effect on the design process and the final product under development.

5.2. DESIGN AS INFORMED GUESSING

In a research-based design process the amount of information gathered, in one form or another, is often breathtaking. All possible information should be documented, not to be fully analyzed, but to guide the design process: to be used as a reference and to help in the case of a need to recall some event during the process.

In an early stage of the Fle3 design process, a background study with an extended analysis of the practices of using computers in European educational contexts and a study analyzing nineteen carefully selected different pieces of software labeled under the Computer Supported Collaborative

Learning and Computer Supported Collaborative Work (CSCL/CSCW) were conducted. In the actual programming stage of Fle3 the designers and programmers collaborated closely with pedagogical researchers, face to face and online, about the software requirements. Furthermore, the pedagogical researchers carried out evaluation studies with teachers with a focus on the technological and pedagogical usability of the systems under development. (Rubens et al., 2005)

In the case of the design of MobilED the beginning of the work included a number of workshops concerned with the generation of ideas that were documented on PostIT notes and photographed for distribution among the design team. Later on in the process the design team produced a video scenario explaining the initial idea in an easy-to-understand format and used it in discussions with a wider group of stakeholders. After getting the first prototype up and running its use in a school pilots was observed by means of intensive note-taking, as well as being video-recorded for later analysis (Ford & Leinonen, 2009)

In the LeMill design process our design team conducted a background study analyzing majority of the existing Open Educational Resource platforms and organized face-to-face and online discussions about them among the members of the design team. The design team organized participatory design sessions with 2-3 teachers in Estonia, Finland, Hungary, and Norway. The teachers read prepared scenarios and then discussed each of them in a structured group interview led by the researcher-designer. The results from the participatory design sessions were then shared with everybody via the development wiki site of the project. Later on, the same development wiki site worked as the platform for user stories and task tickets for programmers (Leinonen et al., 2010)

In Wikiversity the data used in the design process were the content representing people's activities in all the Wikiversity sites, but with a special focus on the English Wikiversity, as the most lively community. The design team aimed to get an overview of the community by observing it, by participating in it, and by questioning the members of the community (Leinonen et al., 2009)

The practice of keeping one's eyes open for many different kinds of sources of information, data, and impulses — but at the same time remaining focused on the main task — is needed in design, where there is a strong service approach. In our cases the tools were designed in the spirit of forming a shared understanding of what meaningful learning is, as well as what learning tools and features of tools are worth achieving. Doing meaningful synthesis, a composition that makes sense, is impossible to do without a large pool of information and thinking related to the topic.

Another look at Nelson and Stolterman's (2003, p. 67) model of contract intentions in design may help to analyze and illustrate the attempt in a design process to see the whole. When thinking about the model in the context of learning tools, we may add half-cardinal dimensions to it: a dimension of media versus technology and one of social science/pedagogy versus decoration (Figure 10). In the design of learning tools the innate context is media — understood largely as something mediating something — whereas the scientific context is, rather naturally in this study and design cases in question, social sciences and pedagogy.

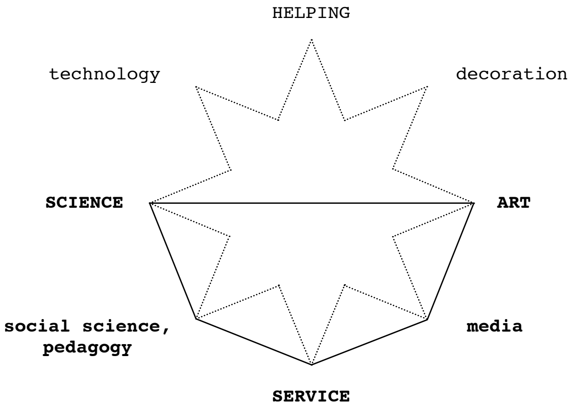


Figure 10: Intentions of Research-Based Design Process in Learning Tool Design (Leinonen et al., 2008).

The service emphasis in the design of learning tools is easy to understand. The tools are there to serve learners. However, it can be claimed that without simultaneously understanding and contributing to both ends of the dimension of science and art one cannot design meaningful learning tools. The designer must understand the pedagogical ideas and the media to achieve this. The designers must use theories and methods of social science and pedagogy, but should also aim to enrich the field with their contribution. Nevertheless, the approach to the fields should be utilitarian; they are expected to serve the design process.

Regardless of the fact that the designer is often defined as being the one who makes things beautiful, this should not be central in the design process of learning tools. When decoration becomes central in the design of a learning tool it is a sign of there being less focus on service: social science/pedagogy and media. Still, one may expect a professional designer to be capable of designing tools with a simple and elegant appearance.

Media can be seen as applied art serving people, in a similar way to which technology is applied science primary helping people. In that sense technology is very reminiscent of design, though design is often called rather applied art than applied science. In a design process the balance between science and art is essential. In design, media should be seen as an important end of the technology-media dimension. Media are close to a service: they are there to serve the people who will benefit from the design. The role of the people in the creation of media is a subject position. The learning tool can influence the subject, but at the same time the subject can legitimately challenge, redefine, or reject it.

In the design of learning tools one may pay relatively little attention to technology. The design should start from the basis of the subject's needs rather than from what the technology can provide. In technology, as well as in decoration, the needs of the users are perceived one-dimensionally. If the users reject a technology or decoration, no redefinition of the goal occurs. Instead, the fault is found in the singular user's technical skills or taste of design.

The second finding of the study is that in the research-based design of learning tools one must rely on informed guessing. Designers must perform research and experiments that rely on all the two dimensions of design (science-art and helping-service) and in the specific case of learning tools the designers must be aware of half-cardinal dimensions (technology - media and social science/pedagogy - decoration), too. This is necessary for the designer to be able to increase the overall understanding of the situation in which she is operating. The use of science and art, with an emphasis on the social sciences, pedagogy, and media, is there to serve the attempt to serve the beneficiaries and stakeholders of the design. The goal is to attempt to understand and to design better, not to explain.

From a purely scientific point of view research carried out in this way can be criticized for being overly simplifying and sketchy. As the aim is primarily to serve the design it is still justified. The guesses and hypotheses made in this way are better informed than those done without the research work. The informed guessing means that the designers should aim and accept that all the design decisions can not be inferred from the research, but can be based on hints and clues gathered within the research operations.

5.3. Interaction of knowledge intentions in design

Especially during the last design case, I started to see design not only as a questioning activity aiming to solve problems or a process of looking for solutions to challenges, but also as a composed process of knowledge creation. The attempt to understand and work with the people in a design process is, at its best, able to channel the participants' knowledge to the tool being designed. With a little poetic license one may say that the tool may start to incorporate the designers' souls.

This, however, requires the designers to be conscious of the different knowledge intentions and possible changes to them during the design process. A good designer is able to move between different knowledge intentions and involve different experts in the process, depending on the knowledge intention at hand in different phases.

This can be illustrated with a table including Habermas' three knowledge interests in one dimension and Popper's Worlds in another (Figure 11).

By locating the phases of the research-based design process in the table we can see the relationships and impact of knowledge intentions and the different phases of research-based design process on each other.

With the *contextual inquiry* a research-design team aims to get a picture of the mental states of the people who they are designing for. In this, however, the designers must mainly rely on hermeneutic understanding and interpretations. Studying mental states is done by looking at the stories, myths, theories, and social institutions, as well as the works of art and tools the people use in their everyday lives. The observation and data gathering take place mainly in the field by participating in and observing the people's everyday life practices.

Participatory design, the collaborative activities with the people, is the glue joining the other phases of the design process. Stories, scenarios, plays, and tools are used to involve people in the design process —

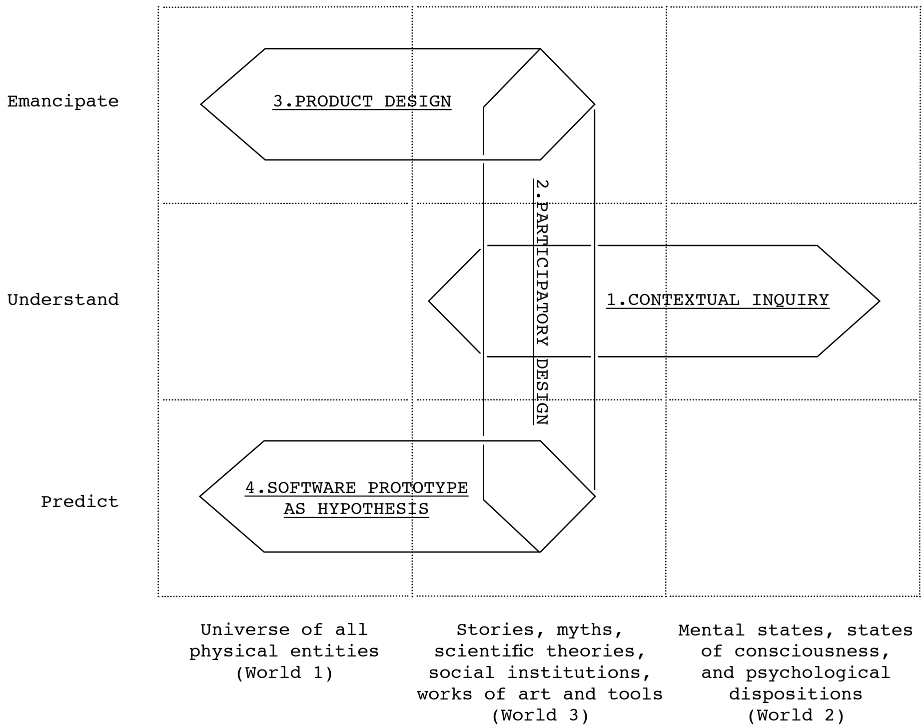


Figure 11: Interaction of Interests of Knowledge and Movement Between Different Popperian Worlds in Research-based Design Process.

to get them to communicate and share their internal thoughts and ideas. Participatory design, however, does not only serve the data gathering and interpretation of people's everyday lives. At the same time it contributes to the product design and development of the software as a hypothesis.

In the *product design* phase, a designer focusing on service is mainly interested in emancipating people: to free them from something unpleasant or to help them to reach some of their objectives. In product design the emancipatory interest of knowledge is so in-built that it is easy to forget it. An architect designing a house is naturally expected to emancipate the people who will live in the house. He is, for instance, expected to free the people from such annoying things as rain and cold. Unfortunately, the attempt to emancipate often goes wrong when the designer does not know enough about the people's needs and challenges. The designer may all in all neglect contextual inquiry and participatory design or overlook the results from these phases.

In the *software as hypothesis* phase designers must come back to the world of science, engineering, predicting, and control over the physical world. In this stage the aim is to make the necessary changes to the physical world to reach the objectives defined in the earlier stages.

The third finding of the study is that the designer of learning tools must be aware of the knowledge interests and move between them. Without the ability to understand and mediate different knowledge interests — of the designers, the participants, different stakeholders, and the people who will try to use the tool for learning — the designer is not able to make design decisions. The analyses and interpretations of different knowledge interests must also vary according to the phase of the design process and the world, in the Popperian sense, where it takes place. The designer of learning tools must operate in a jungle of different interests but still keep herself focused and able to make decisions.

6
Discussion: Towards Academic Practice-based Design Research of Learning Tools

In this study I have aimed to answer one primary research question and two subsequent, but wider questions. My thesis — my answers to the research question: *How can software learning tools be designed?* — is presented in Chapter 5. I suggest that design researchers relying on practice should follow a *research-based design process,* to aim and accept that design is often based on *informed guessing,* and to be aware of the need to move between different *knowledge intentions.*

The results should not be taken as a recipe for good design, but as a collection of methodological insights that can be found useful in the process of choosing and defining more specific design methods when designing experimental learning tools.

When looking for answers to the research question I simultaneously tried to frame *what the objective and forms of academic practice-based design research could be* and *what the objective and role of academic practice-based design research as part of academic research should be.* To proceed with the subsequent questions, I must take a wider perspective on the topic of doing design research on learning tools in the era of New Media.

While doing the study, I realized that it is difficult to locate the research in the traditional classification of academic disciplines. The study is close to such applied areas of research as design, media studies, education, computer science and human-computer interaction, but is not explicitly part of any of them. A crucial character of my research is the design of information and communication technologies — New Media — facilitating and enhancing the development of new kinds of tools and social practices in the field of teaching and learning. All the design cases described in the study have aimed to design products and practices that can be designed further. The New Media as a whole, and the tools in question in this study are all related to meta-design. According to Fischer and Scharff (2000) *"meta-design characterizes activities, processes, and objectives to create new media and environments that allow users to act as designers and be creative"*. While involving participants to the design process we have aimed to build environment that allows *"owners of problems"* to act as designers (Fischer, Giaccardi, Ye, Sutcliffe, & Mehandjiev, 2004).

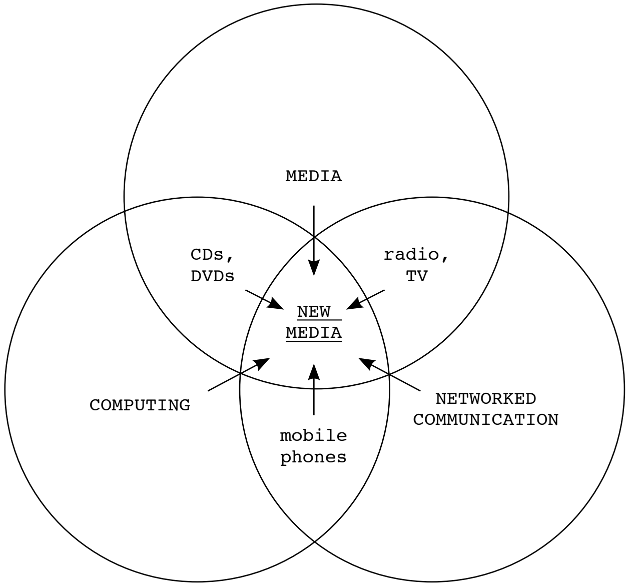
An important feature of the work is the design of New Media when these are defined as a *"mix between existing cultural conventions and conventions of software"* (Manovich, 2002). The founding of the concept of New Media can be located to the emergence of digital and computerized media products, such as CD-ROMs and websites, in the late 1980s and early 1990s. The reason for calling these products New Media was to distinct them from such old media products as television and radio programs, feature films, recorded music, newspapers, magazines and printed books (Manovich, 2002). The new digital technology made it possible to explore new forms of media that are interactive and also able to emulate and remix all existing media formats and technologies (Kay & Goldberg, 1977). The fast growth of Internet usage after the launch of the World Wide Web made the question of social networks central in New Media.

In his popular book Being Digital, Nicholas Negroponte (1995) describes how digitalization is driving media convergence, resulting in New Media. In his vision the network plays an important role. He describes how the traditional printing, telecommunication, and computer industries will converge. According to Negroponte, publishers and media companies must put new computing technologies into use to distribute their products for readers through communication networks, while the operators of telecommunication networks must think about content and computing, and the computer industry should look in the direction of the content and telecommunication industries. (Negroponte, 1995)

In 1995 Negropontes was primary focusing on industries and business organizations. When looking at the short history of networked New

Media today, we can see that the effects of the New Media have not been crucial for industries only but have also had an effect on people's everyday lives and culture in every place with access to networked New Media.

Figure 12: New Media as a Convergence of Three Areas of Industry and Human Activity.



With a picture merging the three converging fields together, we may find the core of New Media (Figure 12). This may help us to understand what is happening in there. New Media can be located in the center, where people are taking advantage of all three fields simultaneously. The ability to operate in the center has led to a number of successful enterprises, such as Google, Amazon, PayPal, Yahoo, Facebook, Craigslist, and Wikipedia. In addition to these, thousands of smaller companies and projects have shown that there are new opportunities in the New Media: a possibility of doing things differently. In these companies and projects the key is not convergence but emergence. The attempt is to change the way we live our lives, socialize, communicate, work, love, hate, and learn.

A new field emerging from the socio-technical changes in society can be studied by questioning, analyzing, and theorizing the change, or by active participation and interventions in the change. This study, as a whole, is an intervention. With it I have attempted to have an effect on the design of learning tools in the era of New Media. The study is not only about actions and a description of those actions, but also aims to contribute to the process by which we try to understand the changes. In this way the roles of questioning, analyzing, and theorizing are important and present in the study. A justification for the methodological choice in the study is related to my consciously taken role as a questioning researcher (Varto, 2009). I believe that my participation and intervention in the change will increase the significance of my research for human life and for different human practices.

Questioning research is important because we can already assume that the role of technology and technology-mediated communication in education will increase. As an academic I may simply stand by, see what happens, and do research on it later or try to point out things that are problematic in the development and have an impact on the direction the technology develops in — to have a voice in the design of the tools.

Design research based on design practice is naturally close to technology research, engineering, industrial design, new media design and art, but can also be seen as a practice that is important for all. According to Simon, design is a *science of the artificial* and, as such, should not be only a component in technical education but a core discipline for every liberally educated person (Simon, 1996, p. 138). In my study I have partly brought design research and design thinking to the field of learning science and educational research with a special focus on learning tool design.

Being experimental has been the constitutional premise of the practical design work presented in the study. Being experimental in a design process means that the things that are designed can be considered to be failures as products. This makes this kind of design research different in principle from design for customers. In experimental design, when it is considered to be design research, it is still important to be as systematic and analytical as possible, but at the same time the process should be kept open for creativity and serendipity. This leads to space for unexpected changes in the process. Sometimes the outcome may be entirely different from what was originally expected. For instance, a solution that is designed may solve a design challenge that was not seen when starting the process. The possibility of having surprising results, in a process that nevertheless aims to define clear challenges that are solved, can be compared to pharmacological research (Leinonen et al., 2008). In pharmacological research, in the design of drugs, it is known that sometimes a drug that is initially studied as a cure for some symptom may have a positive or negative effect on it or an effect on a totally different symptom. Because of this the first studies in pharmacology are always done with organs and tissue or animals and only later with humans.

At this point, there are no clear answers to the two subsequent and broad questions explored in addition to the actual research question. My thesis is, however, that the study is able to contribute to the process of exploring the topics and shed light on some new areas in them. On the basis of the research carried out in this study, it can be argued that there is a need for academic practice-based design research. Design research — that is practicing design to study design — can deliberate and bring alternative approaches to the discussion; it can be critical and comprehensive. In academia there is also the possibility of doing multi-disciplinary research with high-level experts, with their ideas and knowledge from different fields. This may help us build a holistic picture about the phenomena and topics related to it. In multi-disciplinary research the flow of ideas may go in multiple directions. When traditional academic fields collaborate with designers they may both see their own work in a new light. Therefore the objective of academic design research should be to contribute, in addition to the design field itself, to all the related disciplines in question in practical design cases. In this study these disciplines were educational research, pedagogical questions, learning science, the philosophy of education, and educational politics, but also, for instance, computer-supported collaborative work and learning, and New Media. The role of practice-based design research in the whole picture is often invisible, because design practice often operates as the glue connecting the different disciplines (Kelley & VanPatter, 2005). It is also invisible, in a similar way to glue. When it works well, we do not pay attention to it. When it is missing we see only bits and pieces and do not necessarily know what would come out of them if we could join them.

It is obvious that this study relies on intuition. More research aiming to perform deductive and inductive reasoning is needed to validate the results presented in the study. In this study, in the research articles, and partly embedded in the design artifacts in question, however, I have condensed evidence that supports my argument.

This study is reflective and dialogical. As such it aims to take part in the academic discussion around the topics of design research and the design methodology of educational technology and learning tools. More widely, as mentioned earlier, it aims to contribute to the discussions that are taking place at the crossing point of New Media design and educational research.

The assumption is that this study will partly help us to understand better the phenomena of learning becoming more technology-mediated and will help us to design better tools for this. In practice, it may help us to *do the right thing*.

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B

ARTICLES

DESIGN OF WEB-BASED COLLABORATIVE LEARNING ENVIRONMENTS. TRANSLATING THE PEDAGOGICAL LEARNING PRINCIPLES TO HUMAN COMPUTER INTERFACE

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Abstract

KEYWORDS:
Architectures for educational technology system;
Cooperative/collaborative learning;
Distributed learning

Seven pedagogical principles guided the development of a collaborative virtual environment, within an international project called ITCOLE. The progressive inquiry model as a theoretical framework had a large impact on describing these principles. Furthermore, this article describes the two web-based software systems – Synergeia and FLE3 – that were developed in the project. Teachers evaluated this software in the light of two perspectives: user friendliness (ease of use) and user satisfaction (especially the pedagogical usability). It is concluded that the participants find the software easy to use. The user satisfaction ranges between good and average. Details about the different types of evaluation are reported in the paper.

1
Introduction

The development of information and communication technology (ICT) is changing the way in which people work, communicate and learn. Co-operative and collaborative environments will allow group work, group conferences or joint effort in knowledge building. Nevertheless, technological possibilities, instead of pedagogical principles often lead the development of virtual learning environments (Rubens, 2003). This has led to disappointing results in the past. Recently pedagogical principles are leading in the development of virtual learning environments. According to Simons (2003), the time is finally ripe for "digital pedagogy".

In the ITCOLE-project pedagogical principles were the fundaments of the development of web-based Collaborative Learning Environments (CLEs). One of the main challenges in the ITCOLE-project was the design and development of collaborative software systems that maintain the (synchronous/asynchronous) collaboration and that can be integrated in a web-educational environment.

This article describes these pedagogical principles. Furthermore, it introduces the software developed and it presents the evaluation results of the software.

1 ITCOLE stands for Innovative Technologies for Collaborative Learning and Knowledge Building. The project was funded by the European Union in the IST program, IST-2000-26249.

2
Pedagogical principles for software development

The development of the ITCOLE software was based on an extended analysis of current practices of using computers in European educational contexts (Lakkala, Rahikainen, & Hakkarainen, 2001b) and on analyses of functionality and interfaces of existing computer software for collaborative learning and collaborative work (Kligyte & Leinonen, 2001). The analysis of these practices was based on information about the use of Internet and networked learning environments for instructional purposes in the participating countries. As a result of this analysis thirteen principles for designing web-based Collaborative Learning Environments (CLEs) were formulated (Lakkala et al., 2001b). These principles were not related to the development of the software exclusively. According to the ITCOLE researchers the design of a CLE is only partially a software design challenge. It is also a matter of designing appropriate pedagogical and epistemological infrastructures. Within the scope of this article we will only address the most relevant pedagogical principles, related to software development.

The functionality and interfaces of existing software dedicated to collaborative learning systems (Kligyte & Leinonen, 2001) were studied and used by the interface designers involved in this project. This constituted the starting point for the development of new web-based software devoted to international and multi-domain activities. The study analyzed

19 different software designs, used for both collaborative work and learning. Under the labels of both Computer Supported Collaborative Learning and Computer Supported Collaborative Work (CSCL/CSCW), there are a considerable number of software and computer platforms, but the nineteen systems selected for closer analysis were considered to be a representative sample of all different systems (Kligyte & Leinonen, 2001).

2.1. DESIGNING FOR FLEXIBILITY AND MODULARITY

Since there is a variety of pedagogical cultures and practices in the participating countries, it was estimated that the design of the ITCOLE software should be characterized by flexibility and modularity. The functionality and interface of the system would be derived from pedagogical considerations and could be adapted to the different school environments and contexts as well as used in conjunction with other pieces of software. Moreover, adaptation to various national pedagogical cultures and different educational contexts was needed. Therefore the creation of a modular learning environment was suggested, so that the users were able to select the modules they could use in the context of each project. According to Lakkala et al. (2001b) this could be called pedagogical usability, i.e., correspondence between the system's design and the educational environment, situation, and context in which it will be used.

2.2. FACILITATING KNOWLEDGE BUILDING RATHER THAN PROVIDING A DISCUSSION FORUM

By synthesizing different ideas of cognitive research (e.g. Brown & Campione, 1996; Scardamalia & Bereiter, 1994) a framework for progressive inquiry was expanded and elaborated (Hakkarainen, Järvelä, Lipponen, & Lehtinen, 1998). In brief, this model could be described as a sustained process for advancing and building the type of knowledge needed for scientific inquiry. It entails that new knowledge is not simply assimilated but constructed through solving problems of understanding (knowledge building). Characteristic of this kind of inquiry, instead of direct assimilation, is that the student treats new information as something problematic that needs to be explained (Bereiter & Scardamalia, 1993; Chan, Burtis, & Bereiter, 1997). By imitating practices of scientific research communities, students can be guided to engage in extended processes of question- and explanation-driven inquiry. An essential aspect of this kind of inquiry is to engage collaboratively in the improvement of shared knowledge objects, i.e., hypotheses, theories, explanations, or interpretations (Scardamalia & Bereiter, 1996). Through intensive collaboration and peer interaction, resources of the whole learning community may be used to facilitate advancement of inquiry (Hakkarainen, Rahikainen, Lakkala, & Lipponen, 2001). In the ITCOLE-project the model of progressive inquiry was the leading pedagogical framework (Emans & Sligte, 2003; Lakkala et al., 2001b; Rubens et al., 2003; Stahl, 2002). Besides, another pedagogical principle for the development of the ITCOLE software was the requirement of models and tools that help the participants to develop and share knowledge, to store knowledge and experiences of individual teachers and students, and their projects in order to create a collective memory (see De Laat & Simons, 2002). Instead of regular discussion forums, support for knowledge building had to be provided. Participants should be allowed to identify key ideas, to take them for further elaboration, and build on to them. In terms of software design, fostering knowledge building entails the system to allow and encourage the users to develop shared digital artifacts in addition to engage in knowledge-building discussions. The ITCOLE software had to provide tools that support the process of collaborative design and elaboration of digital artifacts.

2.3. SCAFFOLDING PROGRESSIVE INQUIRY

As a consequence of applying the progressive inquiry model, the importance of using a category of inquiry labels, to support the inquiry processes within the ITCOLE software, was addressed (based on the practices of Scardamalia & Bereiter, 1993). Knowledge building should be facilitated with knowledge scaffolds that will help students to get into the inquiry processes, in this way supporting knowledge advancement. Users' participation was structured by asking them to label their messages according to a category of inquiry. When these categories were properly used, the participants' inquiry process was scaffolded and support was offered to engage in higher-level cognitive processes (Lakkala et al., 2001b). This design feature was based on the theory that the educational use of these kinds of labels supports the management of a relatively large number of messages in the databases, handles the threaded structure of discourse, and also facilitates community-building (Baek, Liebowitz, Prasad, & Granger, 1999; Häkkinen, Järvelä, & Dillenbourg, 1999; Ogata & Yano, 1998).

The researchers emphasized the importance of having coherent sets of inquiry categories rather than only individual – random – categories. Therefore so called "thinking types" were used to support progressive inquiry, although the researchers also addressed the importance of having fully editable inquiry categories that could be tailored to different pedagogical contexts. Thus, besides the progressive inquiry thinking types also other sets of thinking types were and could be used.

2.4. THE ROLE OF TUTORING IN PROGRESSIVE INQUIRY

Since active engagement of the tutor is an important condition for facilitating progressive inquiry (Lakkala et al., 2001a), the ITCOLE software should be equipped with Tutor Tools that would enable printing the students' productions and summarizing advancements of inquiry. According to the researchers, it is important to create tools that will help to provide summaries of discussions and each student's contribution during a task, and, therefore, help a tutor to get an overview of what is going on in the CLE.

Furthermore, the researchers expected that synchronous tools could provide important new possibilities for situated and dynamic guidance that would not be possible in asynchronous systems alone.[2]

2.5. PROVIDING TOOLS FOR STRUCTURING AND COORDINATING ACTIVITY

According to Lakkala et al. (2001b) an important pedagogical principle was the simultaneous provision of structures that would help students to coordinate their collaborative activities and guide them to reach a series of milestones rather than be left on their own. A great deal of coordination and structuring was needed in order to support adequate participation

2 These tools were developed during the ITCOLE-project, although they were ready to use when the research was done. So, the use of these tools was not evaluated.

and to guide students to engage in in-depth inquiry. Therefore the ITCOLE software should contain coordination tools that help a teacher, tutors, students and their teams to set up main goals and sub-goals concerning their investigations. For example, a space for setting up a time table, milestones and shared goals of projects as a whole as well as corresponding aspects of a team's or individual students' inquiry.

2.5. DESIGNING TOOLS FOR PROCESS ANALYSIS

Sophisticated tools that allow students and teachers to follow their progress in the inquiry process were needed. For the researchers and designers of the ITCOLE software these tools also should provide statistical information of the usage of different tools and functionalities of the software.

2.6. PROVIDING SUPPORT FOR COMMUNITY BUILDING

Based on a literature study (Jermann, Soller, & Muehlenbrock, 2001; Schlichter, Koch, & Chengmao, 1998; Munro, Höök, & Benyon, 1999; Häkkinen, Järvelä, & Dillenbourg, 2000) the ITCOLE researchers emphasized the importance of developing tools that help a partially or completely virtual community to manage their collaborative activities, build their community, and achieve mutual understanding (Lakkala et al., 2001a, 2001b). The software should support users in developing a sense of community and belonging, even in cases when they are distributed across space and time (developing a sense of belonging, re-creating one's identity in relation to the virtual community, and by building shared histories).

In section 3.4 we will relate the pedagogical principles to the developed ITCOLE software.

3
ITCOLE software

In the ITCOLE project two applications were developed: Synergeia and FLE3. For Synergeia and FLE3, synchronous functionalities were developed separately, under the name of MapTool. In this section we will describe these applications. First, we will pay some attention to the software development process. The concluding paragraph presents the relationship between the pedagogical principles – described above – and the developed ITCOLE software.

3.1. SOFTWARE DEVELOPMENT

Before the design and integration of the new system, the technical partners of the ITCOLE project studied several collaborative environments, analyzing what features should be offered and what communication system fits with the necessities in the ITCOLE research (Kligyte & Leinonen, 2001).

Dealing with synchronous features it is necessary to introduce items such as session management, synchronous and asynchronous collaborative components support, an extensive coordination model and awareness and monitoring systems.

According to the communication models that were analyzed, the hybrid model was ideal for our design. More concretely, this model combines synchronous communication with asynchronous communication.

In the ITCOLE project a software development method was applied, called Extreme Programming (Beck & Fowler, 2001). Furthermore, basic principles of Participatory Design were used (Avison & Fitzgerald, 1995).

An important quality of this approach is intensive interaction with the target group. In this project programmers collaborated with pedagogical researchers (face to face and online) about the software requirements (based on the pedagogical principles). The programmers developed a first version that was tested in schools. Teachers and students wrote user stories that were used to generate requirements for the second version. In a user story a user wrote about the purpose of an activity within the environment, the activity itself and what he or she experienced. Of course, because of constraints such as limited resources (e.g. time, money), it was not possible to implement every end user requirement. Within the scope of this article this model will not be elaborated in detail (see, for example, http://www.extremeprogramming.org).

3.2. SYNERGEIA

The first software, that was developed, was Synergeia. Synergeia is an extension of BSCW (Basic Support for Cooperative Work). BSCW (Basic Support for Cooperative Work) enables collaboration over the Web. BSCW is a "shared workspace" system which supports document upload, event notification, group management and much more. Built on BSCW, Synergeia adapts this system of shared workspaces to create virtual places for learners to work and collaborate in groups.

In Synergeia learning places are typically arranged as a series of perspectives:

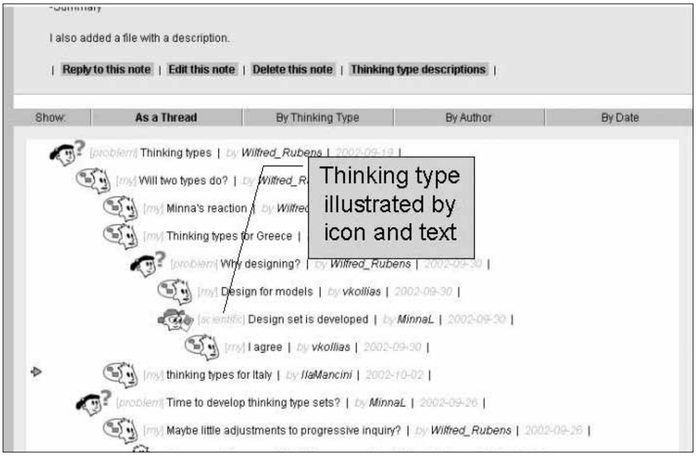
- a personal perspective in which a student can develop his or her own initial thoughts and assemble ideas from others or materials from the Web;
- a group perspective that is shared in a workgroup;
- a course perspective, where ideas and materials can be discussed with all course participants.

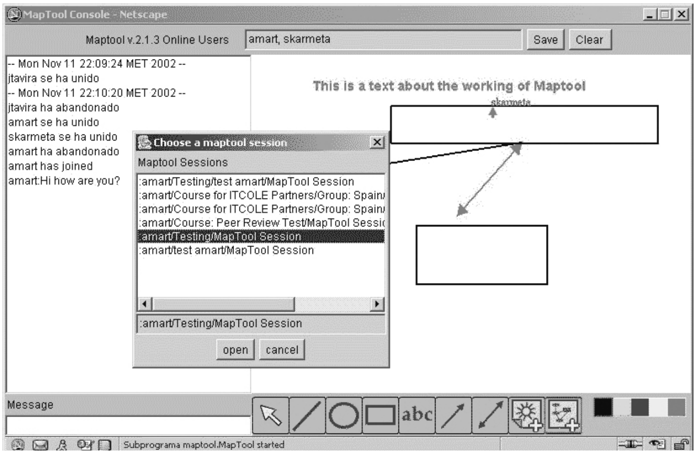
These perspectives have special features and access rights to help them work naturally in school settings without putting a major burden on teachers to design and set up such structures.

Synergeia combines features of two types of electronic learning environments: it consists of communication tools, and empty spaces to allow the teacher to create and shape his courses. But it also offers shared workspaces and document sharing from the collaborative workspaces.

Figure 1 and figure 2

An important functionality of Synergeia is the knowledge-building option (Fig. 1). Knowledge-building proceeds largely through interaction. Therefore, each perspective (personal, group and course) automatically contains a threaded discussion component, which is scaffolded with a set of thinking type categories for the notes. Before someone can enter a note, the decision has to be made what category of note a user wants to add to the existing discussion (Stahl, 2002).





MapTool is one of the synchronous tools that have been incorporated in Synergeia (Fig. 2).[3] It consists of a whiteboard and a chat tool. In this tool synchronous and asynchronous features have

3 MapTool was developed to be integrated in Synergeia and FLE3. At the time the research was carried out integration of MapTool in FLE3 was not implemented.

been incorporated. For that reason, any user can obtain and modify the result of a previous collaboration although he was not collaborating in the building process of this information.

As an integrated tool, the MapTool requires information from Synergeia to be able to carry out some operations inside each system and to establish the connection to the corresponding session.

When dealing with asynchronous features, this tool is activated in a course with a MapTool. It restores the previous session by invoking a method in the educational environment, which returns the MapTool file to the latest status. In order to maintain the latest changes made in the MapTool, the final status will be saved automatically. As any synchronous tool, this application has to follow some features in order to be able to maintain a coherent communication:

First, with the aim of keeping the flexibility condition when a user connects to the system, the actual status in the active session has to be sent to the new user. All the users in the same session have to be able to see the same data independently of the time they log-on. In this way this tool allows late comers in the system.

Second, in order to know who is responsible for the actual drawing in the whiteboard there is a tele-pointer, which consists of a red arrow and the user name (workspace awareness). Users can also see who is joining a MapTool session (presence awareness).

With the aim to encourage the internationalization, the MapTool receives from the educational environment the user language and it loads the corresponding labels for this language.

In order to solve the synchronization problem of the shared area, it has been decided from a the pedagogical point of view that all the users can have access to it at any moment but only one of them can manage a specific object.

Following the same architecture principles as in the MapTool, it has developed into another tool which allows users to send messages between them, avoiding that all the users in the session can see them. This tool, called Instant Messages, has only been integrated in Synergeia. This tool is an applet as well, and it loads its configuration based on the information received from Synergeia.

With the purpose to facilitate the view of how a MapTool session has been built, it has been implemented a tool called TutorMapTool which shows the changes made in a session using a time scale, similar to any video player. This tool also allows saving the result of the monitoring activity in files that can help in a posterior analysis, saving all the events of the actual monitoring, as well as saving only a part of these events.

In addition, it incorporated the option to retrieve data by using dates. In order to show how the users have been collaborating in Synergeia, it has implemented a web tool called MapToolLog which shows this data in a graphic mode as well as in a table mode.

Using Synergeia, teachers have many options for structuring projects or courses. They can also choose among several sets of thinking types in different knowledge building areas. Students can also use many features to structure their own group work. To provide a more personal appearance of the computer screen, photos of the students are prominently used to indicate whose workspaces or remarks are displayed. Synergeia shows extensive history reports and it displays lists of all members of a folder, with indications of each member's level of activity, for example, whether they are using synchronous tools at that time.

In the typical working scenario of Synergeia teachers register their students or other colleagues to the system. They create courses and enroll the students to these courses. In a course the teachers are able to form working groups among the enrolled students. In a group a teacher may setup an initial discussion for knowledge building. If students are logged in to the system, they will see their home area with their personal perspective and the courses in which they are enrolled. In a course they will find the working groups, in which they have to perform their knowledge building tasks. By entering a group they can join or start a discussion for knowledge building. They may also start or join a MapTool session to explore their ideas synchronously in a conceptual map. If they are finished with their tasks, the students can copy their results in the course perspective to present these to, or discuss these, with their course members.

3.3. FLE3

The second application, which was developed in the ITCOLE-project, was FLE3. FLE3 is designed for group-centered work that concentrates on creating and developing expressions of knowledge (i.e. knowledge artefacts). The knowledge creation takes place in a shared working space where students carry out progressive discourse interaction and add their knowledge artefacts to the database (Leinonen, Kligyte, Toikkanen, Pietarila, & Dean, 2003).

FLE3 consists of modules that are designed to facilitate collaborative knowledge building and collaborative design work. The modules are: a user's WebTop (virtual desktops), a Knowledge Building module and a Jam Session module. The staff users, who take care of the courses and course participants, have tools for managing users, courses and participants of the courses (Leinonen et al., 2003).

Each user of FLE3 gets a personal WebTop. WebTops can be used to store different items (documents, files, links to resources in the web, link to knowledge building notes and jam session artefacts) related to the studies or project and to organize them into folders. The WebTop is the teachers and the students "digital desktop" and "bookshelf" for their studies. The WebTop is not trying to fulfill all different data storage needs of the users, but it focuses on the data related to the users study work. The items in the WebTops are shared with other users in the same course or project, as users may visit each others' WebTops. The users can also find items in other people WebTops by using the FLE3 search engine. The openness of the WebTops implements the idea of open office space where people working in a same office can go and visit each others' work space, have a look at the books, documents and folders in there and take copies of them if agreed so. The open WebTops rely on trust and agreements between the users sharing a project with each other. With the WebTop users may create their own knowledge databases. Teachers and students may create their own categorization of information by naming folders. Inside the folders they may then include notes from Knowledge Building (alias), artefacts from Jamming or materials found from the web. The categorization and organization of information is made by themselves and different categories may include materials from different courses and classes. The categorization of information by naming things is seen as one important activity of learning. Only the owner of a WebTop may create, edit and remove items in his or her WebTop, but visitors may read the items and take copies. The WebTop also includes a shared "course folder" for each course or collaborative project. The shared folder is available in the Knowledge Building and Jamming modules as well (Leinonen et al., 2003).

With the Knowledge Building tool, groups may carry out knowledge building dialogues, theory building and debates by storing their thoughts into a shared database. The knowledge building discussion is scaffold and structured by knowledge types, which label the thinking mode of each discussion note. The Knowledge Building tool contains two default "knowledge type sets": (1) Progressive Inquiry and (2) Design Thinking.

The procedure is similar to the one in Synergeia (see above). To help writing contributions to the knowledge building, FLE3 offers a checklist explaining the participants how to structure the note in order to advance the learning process. For example, when writing a New Information – note in the design knowledge building the "Flea agent" asks the author: "Does the note present some new information related to the design task? Remember to mention the source where you got the new information: – by interviewing users – by analyzing the design context? – by studying earlier design solutions of others." As an aid for users to follow the knowledge building discussion and process, users may take different views to the knowledge building database by sorting the notes as a discussion thread, by writer, by knowledge type or by date. An advanced search engine for the knowledge building allows searching the database of notes by title, author, course context or words used in the note (Leinonen et al., 2003). These options are similar to the ones in Synergeia.

The Jamming tool is a shared space for collaborative construction of digital artefacts (e.g. pictures, text, audio, and video). A study group may work together with some digital artefacts by simply uploading and downloading files. Versions are tracked automatically and different versions are displayed graphically. Users may also add annotations to artefacts. When setting up a jam session the tutor may choose from three types of jam sessions: (1) "mutate on previous" or (2) "explore possibilities" and (3) "diverge and converge". This gives the users slightly different possibilities to make new versions and to make references to earlier versions. Originally the Jamming tool was designed for visualizing ideas in a group. However we have noticed that Jamming could be used for many different kinds of collaborative design work that requires versioning. The artefacts used in this process can be text, picture, poster, music, video, animation, multimedia or a piece of software (Leinonen et al., 2003).

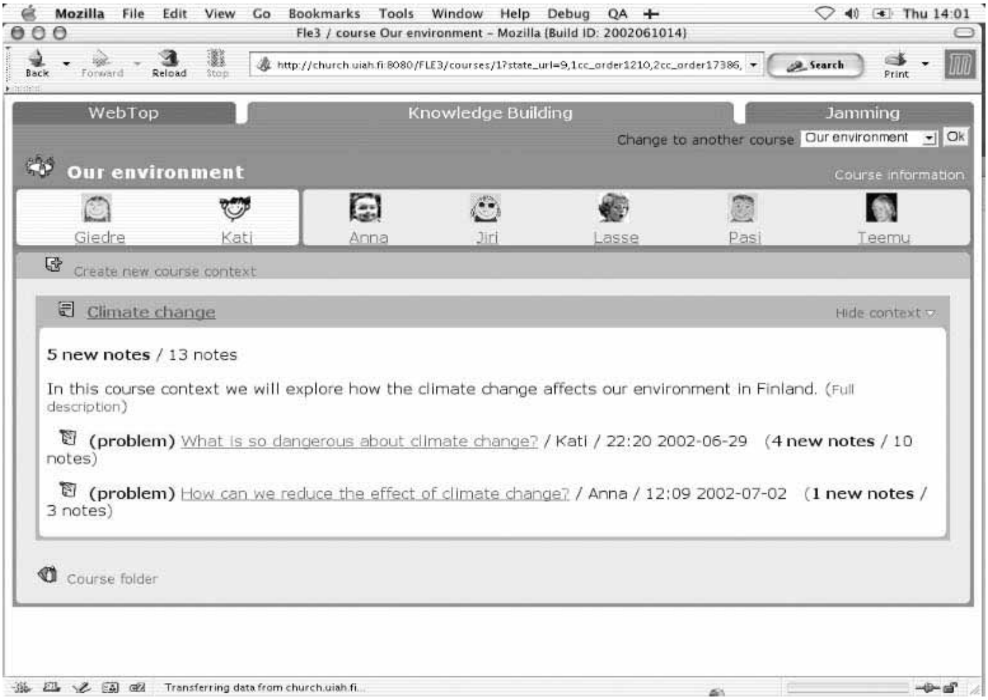


Figure 3.

The staff users, which take care of the courses and course participants, have tools for managing users, courses and participants of the courses. With the user management tools, staff users may add new users manually or invite them via email. With the course management tools, staff users may add users to courses with a role of student, tutor or teacher in the particular course.

Furthermore staff users may manage the knowledge type sets, create new ones, copy and edit existing ones and export and import them between FLE3 systems (Fig. 3) (Leinonen et al., 2003).

3.4. PEDAGOGICAL PRINCIPLES APPLIED IN ITCOLE SOFTWARE

Table 1 provides a summarized overview of the relationship between the described pedagogical principles (see Section 2) and the functionalities of the developed ITCOLE software. It is important to consider that MapTool was integrated in Synergeia.

	SYNERGEIA	FLE3	MAPTOOL
Designing for flexibility and modularity	*Personal/group/ course(project) levels (spaces) *Opportunity for teachers and students to structure content in different ways *The ability to define own sets of thinking types *Available in different languages	*Personal/group/ course(project) levels (webtop) *Opportunity for teachers and students to structure content in different ways *The ability to define own sets of thinking types *Available in different languages	*Opportunity to start a session on group and course(project) level *Obtain and modify previous collaboration *Option to come late
Facilitating knowledge building	*Separate KB-functionality *Different sets of thinking types	*Separate KB-functionality *Jamming functionality *Different sets of thinking types	* Whiteboarding and chat
Scaffolding Progressive Inquiry	*Use of thinking types, based on progressive inquiry	*Use of thinking types, based on progressive inquiry *Flea	
Role of Tutoring in Progressive Inquiry	*Option “summary” and “evaluation” in KB *Option of sorting contributions *Ability to copy and paste artifacts	*Option “summary” and “evaluation” in KB *Option of sorting contributions *Ability to copy and paste artifacts *Flea	* Instant messaging * Tele-pointer
Providing tools for structuring and coordinating activity	*Calendar *History reports *E-mail functionality (individuals or group)		
Designing Tools for Process Analysis	*History reports		*TutorMapTool *MapToolLog
Providing Support for Community Building	*Personal appearance computer screen *Pictures of members * Visibility active users *Display list of members *History reports	*Open webtop *Pictures of members *Visibility active users *Display list of members	*Visibility active users *Instant messaging

4
Evaluating pedagogy and technology interaction in the ITCOLE Software

Within the ITCOLE project, both technical aspects and technological features of the software are evaluated. The pedagogical aspects of the projects are described in the other papers included in this special issue. In this article, the evaluation of technological functionalities will be discussed, together with the interaction between pedagogy and technology. The following research questions will be answered:

I: Is the system easy to use from the viewpoint of the teachers (user-friendliness)?

II: Are the involved teachers satisfied by the functionality provided by the system?

The first research question deals with the user friendliness of the software systems. The second research question is concerned with the more basic principles of user satisfaction with respect to the various functionalities provided by the software systems. The pedagogical usability is an important aspect of the user satisfaction of teachers.

4.1. METHOD

Since two software systems were tested (Synergeia and FLE3 – MapTool was included as a tool in Synergeia), answering the research questions within the boundaries of the ITCOLE project was a complicated affair. To evaluate each system, two general questionnaires have been used to gather quantitative data (one questionnaire for teachers and one for students). This article focuses mainly on the quantitative analysis of the teacher questionnaires (Emans & Sligte, 2003). The questionnaire was tested at an early phase of the ITCOLE-project, evaluated and finalized.

Synergeia was used in three countries (Italy, Netherlands, and Greece) and the questionnaires administrated, were related to the technological and pedagogical usability of it. FLE3 was only used by the Finnish teachers (Table 2).

	Primary education	Secondary education	
Finland	7	Lower s.e.: 4 Higher s.e: 4	15
Greece	2	7	9
Italy	11	6	17
Netherlands	11	6	17
	31	27	58

Table 2
Overview of participating teachers per country

4.2. RESULTS FOR SYNERGEIA

4.2.1. Technical usability

Teachers were asked to give an overall rating of Synergeia on seven aspects. The answers could vary between (1) "very bad" and (6) "very good".

On average, the teachers are positive about Synergeia. It is easy to use (MD4.53; SDD1.09), and in general it is easy to go to the places you want to go to within Synergeia (MD4.29; SDD1.03). Screen design and information presentation are good (MD4.4; SDD0.84 and MD4.37; SDD0.89), indicating that items are at the right place on the screen, and that the information is presented clearly, although one teacher states that the user screen should have less buttons. The functionalities could be placed in the existing menus. Overall, teachers think that Synergeia has a good aesthetic value (indicating beauty or elegance) (MD4.05; SDD0.95). The least positive are teachers about the attractiveness for students (MD3.85; SDD1.19). The overall functionality of Synergeia is good (MD4.39; SDD1.02). There are no significant differences in the overall view on Synergeia between teachers in primary and secondary education. In general, The Italian teachers seem to be the least positive and Greece' teachers seem to be the most positive. The teachers were also asked to rate the technical usability of the functionalities within Synergeia. The rating is on a six-point scale.

The participating teachers are positive about the technological usability of the functionalities within Synergeia. Setting up a course (M D 4.95; SD D 0.89), creating groups (M D 4.74; SD D 0.95), uploading documents (MD4.82; SDD0.97), knowledge building area (MD4.87; SDD0.92), thinking types (M D 4.39; SD D 1.20), inviting people for a course or group (M D 4.50; SD D 1.08), and calendar (M D 4.15; SD D 1.20) have good scores. The MapTool (M D 3.57; SD D 1.55), instant messaging (M D 3.64; SD D 1.71), and the address book (M D 3.77; SD D 1.03) score only just above the average value of 3.5. The answers on the open questions in the questionnaire illustrate that not all teachers have used all functionalities. Some teachers were hampered by technical difficulties. For example a slow connection with the Internet makes it quite diffcult to make use of all functionalities. Other teachers only used a few functions, as they first wanted to get used to these functions (mostly the uploading of documents and website, the knowledge building area, and sometimes the use of groups). Tools like the MapTool, instant messaging and the calendar they planned to use later on. Some teachers claim that due to security reasons, not all functionalities could be used at the school computers.

Additional analyses have shown that there is a difference in the evaluation of thinking types between primary and secondary schools ($p < .01$). Primary school teachers think that the thinking types function better in a technological way. Beforehand, we expected that this functionality might be too difficult for primary schools, but this turns out not to be the case.

4.2.2. PEDAGOGICAL EFFECTIVENESS

Teachers were asked to rate the pedagogical effectiveness of functionalities of Synergeia on a six-point scale, ranging from (1) "very bad" to (6) "very good". In Table 3, the mean values per country are listed.

FUNCTIONALITY	GREECE			ITALY			THE NETHERLANDS			TOTAL		
	M	N	SD	M	N	SD	M	N	SD	M	N	SD
Groups	5,75	8	0,46	4,82	17	1,43	5,00	15	1,07	5,07	40	1,19
Uploading of documents, URL's etc.	4,86	7	0,69	4,76	17	1,09	4,41	17	0,87	4,63	41	0,94
MapTool	3,60	5	1,67	2,58	12	1,68	4,14	14	0,95	3,45	31	1,52
Instant Messaging	-	-	-	2,75	12	1,77	4,73	11	1,10	3,70	23	1,77
Knowledge Building Area	5,63	8	0,52	4,81	16	0,98	4,82	17	1,02	4,98	41	0,96
Thinking types	4,60	5	0,89	4,07	15	1,28	4,69	16	1,20	4,42	36	1,20
Address Book	5,50	8	2,51	4,94	17	3,58	3,91	11	2,12	4,75	36	2,96
Calendar	5,13	8	2,80	4,82	17	3,64	4,45	11	1,81	4,78	36	2,94

Table 3
Pedagogical effectiveness of functionalities within Synergeia, reported per country

Again, the functionalities MapTool and Instant Messaging are rated low, mainly due to a negative evaluation of the Italian teachers, and a (relative) absence of the Greece teachers. It might be that these more negative evaluations are due to a limited technical usability. However, both tools are still around the average-point of 3.5, indicating that they are somewhat useful for pedagogical means. The address book had a slightly worse evaluation for the technical usability, but teachers rate the pedagogical usability of this tool as good. Additional analysis have shown that the calendar has a higher pedagogical value in secondary education, compared to primary education ($p < .05$). Finally, teachers were asked to give their opinions about four statements on collaborative learning in combination with Synergeia. They had to rate these statements on a six-point scale, ranging from (1) I fully disagree to (6) I fully agree.

In general the teachers are very positive about collaborative learning and the role of Synergeia in the process of collaborative learning. The statement "Synergeia supports collaborative learning" and "Seeing each other's notes in Synergeia helps students reasoning on their ideas" have high scores (M D 5.27; SD D 1.14, respectively M D 5.12; SD D 1.10). Teachers are also very positive about using Synergeia and principles of collaborative learning in their future classroom activities, indicating that both the software as the ideas behind it are sustainable beyond the scope of the ITCOLE project. The statements "In the future, I will use collaborative learning in my classes" and "In the future I will use Synergeia in my classes" have positive scores (M D 5.46; SD D 0.90, respectively M D 4.90; SD D 1.18).

4.3. RESULTS FOR FLE3

4.3.1. Technological usability

The teachers were asked to give an overall mark for FLE3 on seven aspects. They had to rate these aspects on a six-point scale, ranging from (1) very bad to (6) very good.

On average, the teachers are positive about FLE3. It is easy to use (M D 4.93; SD D 0.70), and in general it is easy to go to the places you want to go to within FLE3 (M D 4.40; SD D 1.24). Screen design (MD4.60; SDD1.06) and information presentation (MD4.67; SDD0.72) are good, indicating that items are at the right place on the screen, and that the information is presented clearly. Overall, teachers think that FLE3 has a good aesthetic value (indicating beauty or elegance) (MD4.47; SDD1.36), and teachers think that from a student's point of view, FLE3 is attractive (M D 4.73; SD D 1.03). The overall functionality of FLE3 is good (M D 4.67; SD D 0.63). Only a few "negative" scores are given, three for the aesthetics, two for navigation, two for screen design, one for information presentation and one for the students' perspective.

In upper secondary education, teachers evaluate FLE3 less positively (on the average). Due to the small number of teachers, it cannot be said whether this difference between primary and secondary teachers is significant.

Teachers were also asked to rate the ease of use of various functionalities within FLE3. The rating of the answers is: (1) Difficult, (2) Not easy, not difficult, and (3) Easy.

According to these results, it can be concluded that the involved teachers think all functionalities of FLE3 are easy to use. Setting up a course (MD2.93; SDD0.26), inviting people for a course or group (MD2.73; SDD0.46) WebTop (MD2.73, SDD0.46), creating folders, files, links and notes on the WebTop (MD2.60; SDD0.51), management and organization of folders, files, links and notes (MD2.60; SDD0.51), knowledge building area (MD2.60; SDD0.51), thinking types (MD2.60; SD D 0.63), and attaching figures and links to knowledge building messages (M D 2.71; SD D 0.47) have good scores. Only the Jamming functionality is difficult to use (on average: M D 1.40; SD D 0.52). However, this can be explained by the fact that the teachers were not specifically introduced to Jamming, or how it could be applied, thus, only few of the teachers tried it. It can be stated that their opinions related to Jamming were based on first impression, not knowing even how the tool could be used.

4.3.2. Pedagogical effectiveness

The Finnish teachers were asked to rate the functionalities of FLE3 on its effectiveness for collaboration between students. They had to rate the usefulness on a three-point scale, ranging from (1) "little" to (3) "much". Table 4 shows the results.

It can be concluded that according to the participating teachers all functionalities are above average in their usefulness for collaboration. The score of the functionality Jamming is below average. This may be caused by the fact that teachers rate the technical usability of Jamming as not so good. However, as mentioned above, this can be explained by the fact that the teachers were not specifically introduced to Jamming, or how it could be applied. The management and organization of folders, files, links and notes also had scores just below the average. The best contributor to collaborative work of students is the knowledge building area, and the thinking types therein. Almost unanimously, the teachers claim that these are most useful for collaboration.

Furthermore the (Finnish) teachers were asked to give their opinion on statements, related to the pedagogical effectiveness of FLE3. The scale used here is a five point Likert scale ranging from (1) "I fully disagree" to (5) "I fully agree".

FUNCTIONALITY	PRIMARY EDUCATION			LOWER SECONDARY EDUCATION			UPPER SECONDARY EDUCATION			TOTAL		
	M	N	SD	M	N	SD	M	N	SD	M	N	SD
Webtop	2,33	6	0,52	2,50	2	0,71	2,25	4	0,50	2,33	12	0,49
Creating folders, files, links and notes on the Webtop	2,33	6	0,52	2,00	3	1,00	2,25	4	0,50	2,23	13	0,60
Management and organisation of folders, files, links and notes	1,83	6	0,41	1,67	3	0,58	2,00	3	0,00	1,83	12	0,39
Knowledge Building Area	3,00	7	0,00	3,00	3	0,00	3,00	4	0,00	3,00	14	0,00
Thinking types	2,71	7	0,49	2,67	3	0,58	2,75	4	0,50	2,71	14	0,47
Attaching figures or links to KB messages	2,57	7	0,54	2,33	3	1,16	2,75	4	0,50	2,57	14	0,65
Jamming	1,25	4	0,50	2,00	2	0,00	1,50	2	0,71	1,50	8	0,54

Table 4
Effectiveness for collaboration per functionality of FLE3

On the average, there is a reasonable agreement among the teachers on almost all statements of the questionnaire, indicating that FLE3 was easy to use for collaborative work. For example: the scores on the statements "While working in FLE3, the students understood how the process of inquiry goes on", "The students were evaluating together the inquiry process during the project", and "It was easy for the students to collaborate with other students via FLE3" were high or above average (M D 4.14; SD D 0.69, M D 4.14; SD D 1.07, respectively M D 3.67; SD D 0.82).

The scores on the statements "I guided the students to write research problems related to their topic of study to FLE3" (M D 4.27; SD D 0.80) and "I guided the students to make deepening questions to FLE3 during the process" (M D 4.0; SD D 0.76) indicate that the task for teachers to support and scaffold this process was easy as well.

5
Discussion

From the results, it is encouraging to observe that teachers rated the IT-COLE software fair (on average), even though they were new to it in both a technological and a pedagogical way. Collaboration between technical and pedagogical experts resulted in software that offers new possibilities to teachers that they seem to like and that are user friendly. Collaborative learning can be supported by computers in such a way that knowledge building becomes a real possibility.

A point of discussion is whether there is a relationship between the familiarity of teachers with theoretical frameworks such as progressive inquiry and knowledge building in general, and the user satisfaction of the CLE. If a teacher is familiar with social-constructivist approaches, this could influence his judgment on the used CLE (positively or negatively). For example: the Dutch teachers had few experiences with collaborative learning in general. Second, it is an open question whether there is a relationship between the familiarity of teachers with ICT in general (or even other virtual learning environments), and user satisfaction of the CLE. The teachers' judgment of the currently used CLE could be influenced – positively or negatively – by his or her experiences with another virtual learning environment (e.g. BlackBoard). Finally, an interesting question is whether the concept of collaborative learning of researchers and teachers match. A more qualitative analysis has to be done to study how teachers define "collaborative learning". Furthermore, a comparison could be made of the concepts of teachers and researchers.

6 Conclusions

In this study we focused on the evaluation of the ITCOLE-software from the point of view of user friendliness and user satisfaction concerning the various functionalities (especially the pedagogical usability), as far as the involved teachers are concerned.

Most teachers claim that the environments are easy to use, and (after you had some training with it), it is easy to find your way in the environments. In some cases, teachers reacted more negatively. This may partly be caused by slow Internet connections and partly by too little training before actually starting to work with the environment. In general, however, the teachers are positive. Overall, the ratings for screen design, information presentation and aesthetics are high.

It is likely that teachers need training beforehand, both on the technical aspects of the environment, but especially in the pedagogical use – collaborative learning – of a CLE. For teachers, it is important that they have some (pedagogical) guidelines to get started.

Concerning the second research question "Are the involved teachers satisfied with the functionality provided by the system?" it can be said that both the users of FLE3 and Synergeia are satisfied with these tools. The overall functionality is rated as good, and the various functionalities individually are rated good as well. Some functionalities are rated as average (Jamming for FLE3; MapTool and instant messaging for Synergeia). For Synergeia, this is partly caused by general technical difficulties especially in the case of the MapTool, resulting in lower ratings in some testing sites.

Concerning the pedagogical usability, the teachers think that the combination of functionalities in the tools provides a good environment for collaboration. It can be concluded that all functionalities have added value for the CLEs.

Based on the experiences of the ITCOLE-project it becomes clear that it should be stimulated to develop CLEs, using pedagogical principles as starting point. Software developers and pedagogical researchers succeeded in the development of CLEs that where user friendly and pedagogical useful. Because of the interaction with end users they managed to design and development collaborative software systems, which maintain synchronous as well as asynchronous collaboration that can be integrated in a web-educational environment. Since this was one of the main challenges of the ITCOLE-project, it can be concluded that this European research and development project was successful. Nevertheless, we mentioned two points of discussion that are related to the paradigm of collaborative learning, using ICT (see Section 6). If there is no match between the concepts of teachers and researchers on collaborative learning, the user satisfaction concerning the pedagogical usability could be questioned. In the introduction of Section 3 we mentioned that the design of a CLE is only partially a software design challenge. It is also a matter of designing appropriate pedagogical and epistemological infrastructures. These infrastructures could be important influential factors on the pedagogical usability of a CLE.

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MOBILED – MOBILE TOOLS AND SERVICES PLATFORM FOR FORMAL AND INFORMAL LEARNING

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Abstract

MobilED is a South African initiative aimed at designing teaching and learning environments that are meaningfully enhanced with mobile technologies and services. The deliverables are the development of a set of scenarios and guidelines on how mobile technologies could be used for teaching and learning within and outside the school context. The applicability of mobile phones in an educational environment is examined, with a specific focus on the differences and similarities between the developing and developed worlds. The first phase of the project in South Africa focused on the use of low-cost mobile phones, which are readily available in the developing world, and the second phase examined the use of more advanced mobile phones with multimedia capabilities. Pilot projects in South Africa are being replicated in Finland, India, and Brazil to explore the cultural, social and organizational context of the utilization of mobile phones in and out of school in a developing and developed world context.

1
Introduction

Mobile technologies, particularly the mobile phone, are set to play a major role in the development of the information society in developing countries. According to the International Telecommunications Union (ITU), Africa's mobile cellular growth rate has been the highest of any region over the past five years, averaging close to 60 per cent year on year. The continent-wide total number of mobile phone subscribers at the end of 2004 was seventy-six million (ITU Report 2006). The economic and social benefits of mobile phones are evident at all socio-economic levels of society and the penetration rate of mobile phones is significant, especially given the fact that access to these devices is often shared.

Contrary to trends in the developed world, where PC and Internet connectivity is almost ubiquitous, mobile phones are currently the most important networked knowledge-exchange technology used in the developing world. From a developing country perspective, features such as limited or no dependence on permanent electricity supply, easy maintenance, easy-to-use audio and text interfaces, affordability and accessibility are the most important considerations for using mobile phones as potential learning tools (Masters 2005; Mutula 2002; Stone et al. 2003). The contention that a "socially and educationally responsible definition (of mobile learning) must view the learner as the one being mobile and not his/her devices" (Laouris and Eteokleous 2005), and the ability for "anytime, anywhere" learning is still applicable in the developing world, but more as a positive side-effect. If we separate "mobile learning" into "mobile" and "learning," the learning aspect is the most important concept in the developing world. The computing device just happens to be mobile.

These mobile devices are becoming increasingly powerful computers, with built-in advanced multimedia facilities. It is interesting to note that today's high-end mobile phones have the computing power of a mid-1990s PC – while consuming only one-hundredth of the energy (Oelofse et al. 2006). Even the simplest, voice-only phones have more complex and powerful chips than the 1969 on-board computer that landed a spaceship on the moon (Prensky 2005). In addition, if we have a closer look at the whole mobile phone infrastructure, we will realize that the actual device can be seen as a terminal for using several computers in a network. When making a simple call or sending an SMS message we use (1) the "computer" of the mobile phone, (2) the server computers of the operators, and (3) the "computer" of the receiver's mobile phone. When mobile phones are perceived as terminals for using computers, we open up a new perspective for the design and development of practices relating to how mobile phones could be used in different human operations and processes, including formal and informal learning.

2
Context: ICT in Education in South Africa

South Africa's education system has undergone a dramatic change over the past ten years, with the introduction of "outcomes-based education" (OBE). Spady (1994) defines OBE as a "comprehensive approach to organizing and operating an education system that is focused on and defined by the successful demonstrations of learning sought from each student. Outcomes are clear learning results that we want students to demonstrate at the end of significant learning experiences and are actions and performances that embody and reflect learner competence in using content, information, ideas, and tools successfully." South Africa's education policy is thus one of the most forward-thinking in the world. However, the implementation of this policy has put tremendous pressures on the education system, and especially on teachers. This focus, combined with a lack of infrastructure and insufficient funds, has resulted in very little use being made of modern technologies in South Africa's government schools (Oelofse et al. 2006).

In order to drive a strategy for implementing ICTs in South African schools, the Department of Education published the national e-education white paper in November 2004. In this context, e-education is defined as the use of ICTs to accelerate teaching and learning goals, particularly in a developing world context. ICT is seen as an enabler rather than an end in itself. It enables teachers and learners to connect to better information, ideas and to one another via appropriate and effective combinations of pedagogy in support of learning goals (White Paper on E-education 2004).

There has been a concerted attempt to introduce computer technology into schools in South Africa, with mixed results. Many have been PC-specific, sporadic, and have often adopted unsustainable models. Hence, scalability is a major consideration. Issues that are prevalent include (White Paper on E-education 2004):

- Lack of ICT literacy at a general level amongst teachers.
- Stringent and structured forms of teaching with little or no scope for lateral thinking.
- Realization of the importance of technology but inability to incorporate this due to lack of training, adequate infrastructure and integration with the current curriculum. This is more apparent as we move from the urban to the rural centers.
- In most places, there is a gender skew in access to education and this gets reflected in access to information technology.

Even in developed countries where computer technology has been used for educational purposes for several decades, the delivery has rarely met the expectation. Teachers have used computers for drill and practice, automated tutoring and instruction and only lately as a tool for communication, collaboration and problem-solving (Statham and Torrell 1996). The use of technology or media does not in itself improve learners' learning achievements. Learning is influenced more by the instructional strategy than by the type of medium used (Clark 1985).

There is thus a desperate need for a new approach to integrating technology into the classroom, particularly in the developing world environment. The model needs to take into account issues of usability, accessibility, and affordability, while ensuring that appropriate pedagogical models are adhered to.

3
MobilED
Philosophy and Principles

Currently, mobile phones do not play an active role in formal education in South Africa. In fact, most schools ban the use of mobile phones during school hours. In an informal learning context, however, mobile phones are widely used. We call our colleagues and friends to seek information and reciprocally help them with their knowledge acquisition and problem-solving. Simultaneously, we build up our social networks and strengthen the links that are considered very important in modern theories of learning (see Senge 1990). In African traditional culture, "Umuntu ngmuntu ngabantu" means literally, "a person is a person because of other people." In other words, "you are who you are because of others." Expressed variously as "Botho" in Sesotho and "Setswana" and "Umbabtu" in the Nguni languages, this concept is about a strong sense of community where people co-exist in a mutually supportive lifestyle.

The idea of the MobilED project is to create technology that supports existing social infrastructures and increases the potential of current practices with mobile phones by introducing new opportunities for knowledge-sharing, community-building, and shared creation of knowledge in the authentic context of studying and learning. With this technology the participants may be encouraged to increase the value of their current practices through knowledge-sharing and collaboration across boundaries of time and place. Freedom from the constraints of time and place enables the timely use of technology wherever knowledge acquisition and problem-solving are situational and contextual.

The approach of the MobilED project is to integrate research-based ideas of using mobile technologies in teaching/learning with active scenarios of real learning programmes. The project includes the design, development, and piloting of prototype applications where multimedia and language technologies (voice, text, images) will be used via the mobile phone as tools in the learning process. In order to work within a contextual framework, the project will rely on the advances made in the psychology of learning, which emphasize the collective nature of human intellectual achievements and the use of local languages in the learning process. The aim will be to enable all members of society (especially those in the developing world) to become active participants in the information society by being contributors to, and not just passive recipients of, information.

From a technology perspective, all tools and platforms developed will be made available as Open Source Software (OSS) in support of the collaborative, knowledge-sharing philosophy of this project. Probably the most important benefit of OSS is that it stimulates the local IT sector in a country, which is crucial in developing countries to ensure full participation in the information society. From the social angle, OSS is highly beneficial because it allows software to be customized to local conditions by the communities themselves.

4
MobilED Objectives

The MobilED project has four key scientific, technical, and developmental objectives:

- To explore and comprehend the cultural, social, and organizational context of young people in and out of school in three developing countries (South Africa, India, Brazil) and in a developed country (Finland) in their utilisation of mobile technologies, particularly mobile phones.
- To develop research-based models and scenarios of how mobile technologies could be used for teaching, learning and empowerment of students within and outside the school context.
- To develop concepts, prototypes, and platforms that will facilitate and support the models and scenarios developed.
- To test, evaluate, and disseminate the scenarios, models, concepts, prototypes, and platforms in the four countries.

The project aims to contribute to scientific and technical know-how by learning about how groups of young people in and out of school environments are using mobile devices in their everyday knowledge-acquisition and problem-solving situations. It also aims to uncover user innovations and concepts relating to mobile devices through a participatory design process with users. Within the research work that the project implements will be several prototypes that can be tested and disseminated in real environments, which includes schools, youth clubs, and other informal groups.

5
Project Participants

The current principal partners of MobilED are the Meraka Institute of the CSIR, South Africa, and the Media Lab of the University of Art and Design in Helsinki, Finland. The network of associated partners and advisers includes Nokia (Finland), the Centre for Research on Networked Learning and Knowledge Building, University of Helsinki (Finland), the Tshwane University of Technology (South Africa, the University of Pretoria (South Africa), the Escola do Futuro Universidade de São Paulo (Brazil), the WikiMedia Foundation (U.S.A.), and the Centre for Knowledge Societies (India). For the pilots, handsets were donated by Nokia and airtime was donated by MTN (a South African network operator).

6
MobilED
Research Framework and Process

The strength of the multidisciplinary nature of the consortium, as well as deep roots of participants in cognitive, learning, and design sciences, lends a multi-pronged perspective to this initiative. In order to ensure cohesion and understanding between the different disciplines (including teachers, educational researchers, educational psychologists, designers, and technologists), a research framework was developed and is shown in Figure 1.1.

Each intervention needs to be grounded in the local context. Central to the intervention is the design process, which is fed by both the appropriate pedagogical models and the potential of the technology itself. Since South Africa is a developing country, any intervention needs to take cognizance of the developmental and societal outcomes. The outcome mapping methodology (as designed by IDRC in consultation with Dr Barry Kibel of the Pacific Institute for Research and Evaluation as an adaptation of the outcome engineering approach) is being employed here, and this methodology looks at the results of an intervention as a behavioral change in the project participants. Outcomes are seen as desired changes indicating progress towards large-scale development goals. At the heart of outcome mapping is documenting contribution rather than attribution, and seeking to understand the ways in which communities contribute to change rather than trying to attribute change to a single intervention (Smutyo 2001).

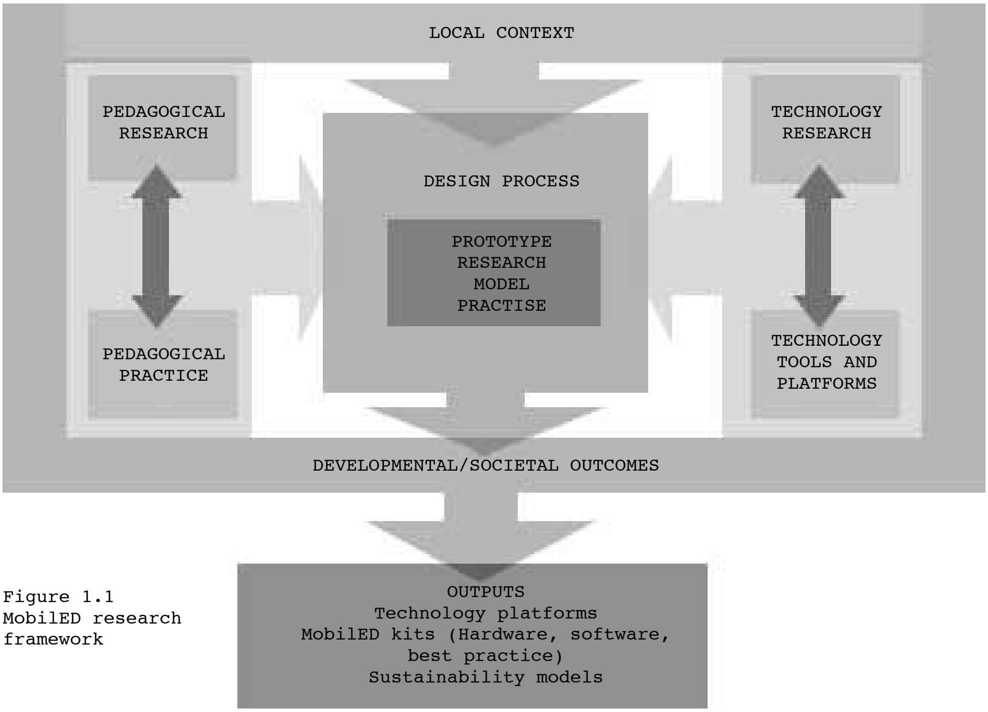

Figure 1.1
MobilED research framework

7
Technology Used

The basic technology components being used in the project are:

- Mobile devices and network(s): GSM/SMS phones, multimedia phones, Internet tablets, PDAS, the US$100 laptop (OLPC project of MIT), etc.
- Wikipedia: The free encyclopedia.
- Social software: Mediawiki, blogs, knowledge-building tools, etc.
- Open Source language technologies: speech interfaces, audio usage, etc.
- Open Source telephony and software frameworks and platforms.

8
MobilED Pilots

The first phase of the project included the design, development, and piloting of a prototype platform in which multimedia and language technologies (voice, text, images) are used via the mobile phone as tools in the learning process. A scenario-based approach was adopted to develop potential uses of the technology in formal learning environments. One of the main problems in South African schools is access to learning and reference materials for both learners and teachers. The focus was on how to use low-cost mobile phones, which are readily available in the developing world, while ensuring that participants not only access information, but also contribute information. Based on these prerequisites, we developed the concept of a mobile audio wikipedia, using SMS and text-to-speech technologies to enable access to information, as well as the contribution of information using voice. The mobile audio wikipedia works as follows:

1 A user can search for a term by sending an SMS message to the server.
2 The server then calls the user.
3 A speech synthesizer will read the article found in the wikipedia.
4 If the term is not found in the wikipedia, then the user can submit his/her contribution by dictating it to the system.

9
Prototype Platform

Based on the scenarios developed, the technology development team built the version 1 MobilEd platform. MobilEd employs three main technology platforms to achieve its goal:

1 An SMS communication interface/gateway, such as Kannel (http:// www.kannel.org) or Alamin (http://www.alamin.org/) to send and receive SMSs.
2 The Asterisk Open Source PBX (http://www.asterisk.org/) for audio telephony communications.
3 A media wiki (http://www.mediawiki.org/) server with suitable content, such as http://www.en.wikipedia.org (Leinonen et al. 2006)

A typical case of a high-level use of the system is provided in Figure 1.2.

PILOT 1

The first pilot was conducted at a private school, Cornwall Hill College, in South Africa. The learners ranged from age fifteen to sixteen. The theme of the pilot was HIV/AIDS. The project followed the principles of the "jigsaw cooperative learning technique" (Aronson et al. 1978), where each learner is a member of two types of groups. The first kind of group

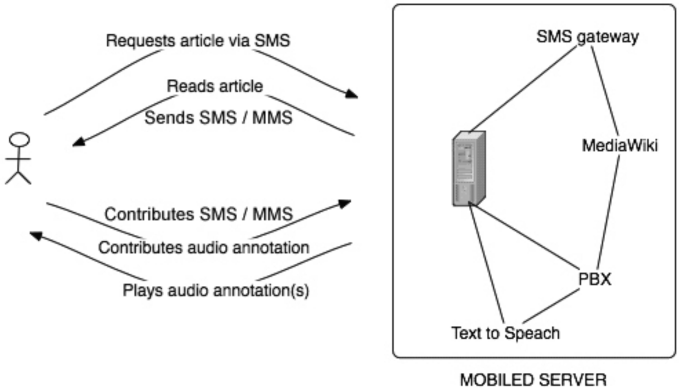

Figure 1.2 Simple high-level usage scenario (user's perspective) (Leinonen et al. 2006)

is the "home group"; in our case we called them the "audiocasting groups," referring to the idea of podcasting. The second kind of group is the "thematic expert group." Each thematic group consists of one member from each home group.

The thematic group discussed different aspects of HIV and used the MobilED server with the English wikipedia content to search for information related to their theme.

Learners could navigate through the audio of the article as follows:

- Fast forward: skips ahead one sentence in the same section.
- Rewind: skips back one sentence in the same section.
- Next section: skips to the next section of the article.
- Previous section: skips to the previous section of the article.
- Pause: pauses playback – if any other DTMF key is then pressed, playback continues from where it was paused. Figure 1.3 shows the use of the audio wikipedia.

Figure 1.3 Using the audio Wikipedia

The results of the information retrieval and discussions were reported back to each audiocasting group. The audiocasting group then discussed the most relevant issues of HIV/AIDS for their own age groups and communicated the results to the school community as an audiocast recorded via MobilED onto the wiki. To access the audio encyclopedia and the audiocasting service, the students used shared Nokia 3230 phones with speakers.

The learners from Cornwall Hill College were all from affluent homes and most already owned a mobile phone. They were also fully ICT-literate. It was decided to test the service with these learners before testing with learners from disadvantaged backgrounds so that we could improve the platform based on their more experienced input. The learners were given very little time to experiment with the phones before the pilot started, and although they supported each other and figured out all the main functions of the phones in a short period of time, they felt they needed more time to "play" with the devices. It was not necessary to "teach" the learners how to use a phone – it was an everyday skill that they had already mastered. In addition, these learners did not like the fact that the phones were shared in the group – each said they would have preferred their own phone. However, the use of shared phones with speakers supported collaboration in the shared task. Based on the observation and the video data, it was obvious that the use of the shared phone made it possible to distribute the cognitive load related to the use of the technology and to fulfill the study tasks. Peer support and learning were obvious.

We also noted that the boys tended to dominate the technology usage. During the pilot there were a few technology hiccups, and at one stage a temporary measure was instituted to record their audiocasts onto an analogue tape recorder – it was most interesting to note that more learners were challenged figuring out how to use a tape recorder than how to use the MobilED service. Other input we received from these learners was that the "voice" used for the text-to-speech engine was very difficult to understand and that the speakers did not work very well. Overall, however, there was overwhelming official support and student enthusiasm for using mobile phones in the classroom.

An unexpected consequence of the first pilot was that the school requested another pilot. Although this was not planned as part of the original intervention, an additional pilot (Pilot 1A) was run. In this pilot learners went on a trip to a theme park as part of a science lesson on energy. All interactions between the teachers and learners were via SMS. Some content was "seeded" on the wiki and the MobilED platform was expanded to include information retrieval via SMS as well. The learners used their own mobile phones and there was spontaneous sharing of mobile phone capabilities (such as photos, audio, and video). Once again, there was much excitement about and support for the concept by the learners (Botha et al. 2006).

PILOT 2

Pilot 2 was run at a local government (or previously disadvantaged) school, Irene Middle School. The learners were from very poor backgrounds and most travelled long distances from outlying rural areas on a daily basis to get to school. Most learners did not own their own mobile phones, and many had never used a mobile phone. Although the school did have a computer lab, the computers had been stolen and the learners were not at all ICT-literate. The learners do not speak English as a home language, but are educated in English from Grade 4.

The MobilED platform was significantly enhanced and upgraded to version 2, based on the results of Pilots 1 and 1A. The Irene Middle School learners had a lesson on HIV/AIDS based on the same lesson plan developed for Cornwall Hill College, but here the learners were given a longer period of time to familiarize themselves with the mobile phones, and they were also given a printout of a typical wikipedia article. Since very few articles exist on wikipedia in their home languages (Sepedi, Setswana, and isiZulu), the lesson was given in English. They were divided into groups as with the first pilot.

This MobilED pilot was once again a success, with wholehearted support from both learners and teachers. Learners were motivated and energized and clearly enjoyed the learning process. In fact, the server logs showed that many of the learners spontaneously used the service to get information about many other topics (particularly World War II and Adolf Hitler, which was the current topic in their history lessons). Figures 1.4 and 1.5 below show the groups "playing" with the mobile phone and accessing the MobilED service. Although the learners were not ICT-literate and very few had access to mobile phones, they took only a very short time to familiarize themselves with the technology. Since many mobile phones are shared in their culture, they did not have a problem with sharing the mobile phone during the lesson and enjoyed the collaborative aspects of the tasks. In addition, it was interesting to note that the boys did not dominate the technology as in the previous pilot – there was equal use by both sexes.

They were also less critical of the artificial voice (which had been improved in the interim). When asked about their language of choice for learning, every group chose English – they see English as the "academic" language and the gateway to opportunities later in life. It was interesting to note that interactions between participants were in their home languages, but most produced audiocasts in English. They were excited that their contributions could potentially reach a huge worldwide audience. It was obvious, though, that using English as the language of instruction was a major problem for some of the learners, as evidenced by the written responses to some of our questionnaires, which were in poor and broken English.

Figure 1.4
Trying out the MobilED service

During this pilot there were very few technology problems and this contributed to a much better experience for these learners. The audiocasts were passionate and uninhibited and included spontaneous harmonizing of songs, including rap songs. As part of the outcomes mapping methodology, some mobile phones were left at the school for the teachers and learners to use, with the idea of monitoring the use of the service over the next few months.

Figure 1.5
Hard at "play"

Figure 1.6 Learners from Cornwall Hill College and Irene Middle School

PILOT 3

In pilot 3 we wanted to observe the collaborative behavior of groups of children from different cultural and socio-economic backgrounds when using the mobile phone as a tool for learning. We also wanted to introduce and test the use of MMS/SMS technology as part of the MobilED platform.

Another aim was to test the platform with younger children. The first part of the pilot consisted of ten learners (aged thirteen to fourteen) from Irene Middle School and from Cornwall Hill College who were invited to the Meraka Institute as part of a learning activity to create a reusable multimedia slide show about three technology projects developed by the institute. The photo in Figure 1.6 shows some of the learners who were involved in the pilot.

The learners were divided into groups of two comprised of one learner from each school, and an icebreaker activity was used to familiarize the learners with each other. Thereafter they were given a short period of time to "play" with the mobile phones and experiment with sending SMS and MMS messages. Their task was to use the mobile phone for the following purposes:

- capturing information
- taking photos
- recording and storing
- compiling a slide presentation with all the above and MMSing to the server

The learners seemed to enjoy the activities and were extremely creative with their photographs. There was a marked difference at the beginning of the pilot with regard to usage of the mobile phones, but the less-experienced learners soon "caught up" and were able to do most of the tasks with ease. Most pairs worked well in their groups, although there were instances of incompatibilities. On the whole, the girls tended to work better in their groups and there was spontaneous sharing of knowledge in these pairs. This pilot is still incomplete and data is in the process of being analyzed. Figures 1.7A and 1.7B shows the good spirit of cooperation that existed between the participants.

Figure 1.7A
Collaboration
and peer
learning

Figure 1.7B
Collaboration
and peer
learning

10
Discussion

Will the MobilED technology transform the way in which teaching and learning can take place in schools, particularly in Africa and the rest of the developing world? It certainly has the potential to enhance existing practices and extend the capabilities of currently established forms of technology without any special redesigning of the basic tool. It also extends the use of mobile phones to incorporate a particular learning project – this was accomplished with relative confidence and ease (Ford et al. 2007).

The results of the pilots show that the use of a mobile phone as technology tool to aid the learning process can work extremely well. The barrier of entry was very low – the learners themselves were very open to using the technology and the teachers could focus on facilitating the learning process, rather than having to grapple with new, unfamiliar technologies (as is the case with traditional computers). Thus both learners and teachers felt empowered and confident in using the phones as learning tools. In addition, a mobile phone is a portable device and can be used anywhere, anytime – the teacher does not need to take her learners to the technology (as per the computer lab model), but is able to take the technology to the learner. A mobile phone also opens up the possibility of using the technology on fieldtrips and out of typical classroom environments, thus demonstrating again the potential to use the mobile phone as a complementary tool to a traditional computer.

The concept of a mobile audio-wikipedia is particularly of interest in Africa, where the access to information, both paper-based and electronic, is limited. It also supports the strong African oral tradition. Since the mobile phones used were basic models and only needed to support the ability to send an SMS, the cost factor for the handset was small. However, the network costs (sending an SMS and providing the content via a phone call) could become prohibitive if the service were to be provided widely in South Africa and Africa more broadly. The issue of sustainability and affordability will need to be clearly understood and various models explored as part of subsequent phases in years two and three of the MobilED project. It seems obvious that some kind of support would be needed from the mobile network operators in the various countries where MobilED could be implemented (Ford et al. 2007).

With regard to potential models for making the technology of practical use in schools, especially in the light of many schools in South Africa banning mobile phones, some initial ideas have been developed by the MobilED team. One such idea is the creation of a MobilED "kit" – a secure and rugged box that contains a set of mobile phones with places for charging them, speakers to attach to them, pedagogical guidebooks with descriptions of learning events, some reusable physical "learning objects" (for example, laminated paper sheets) that will help teachers and learners implement mobile learning events, and a DVD with video footage of example projects. The MobilED kit could be part of the school's facilities, just like blackboards, overhead projectors, computers, etc. When a teacher wants to implement a mobile learning project it will be easy to take the MobilED kit to the classroom and when the project is over to return it to a secure environment (such as the teacher's room or school library).

Further development of MobilED will include the integration of more advanced technologies (such as MMS and data services) and the development of additional scenarios, concepts, models, and processes for formal learning environments. It will focus on massification strategies to cost-effectively implement the platform in as many schools as possible in South Africa, and exploring what would be needed to expand into the rest of Africa. This will include a strategy to collaboratively develop a set of lesson plans for teachers to include in their teaching activities, using the open source model for content creation.

11
Conclusion

The MobilED consortium will be reflecting on the results of these pilots and will use the results to develop future strategy. Some of the ideas that have been suggested in South Africa include:

1. Using the service to disseminate ideas and lesson plans to teachers by creating slide shows of lessons with audio narrations in all eleven of South Africa's official languages. A teacher could send an SMS with the title of the lesson to the server and this would be sent the slideshow (if they have an MMS-capable phone) or he/she would be phoned back and the audio played.
   The teacher could add an audio/video annotation to add his/her ideas to the lesson plan.
2. Making existing educational video/animation "bytes" available to teachers and learners via MMS and data services.

Worldwide interest in the project has been overwhelming: Brazil will start its own MobilED pilots in the near future, and Colombia and Mexico are also planning pilots. Even comparatively wealthy countries like New Zealand are showing interest. For more information on the status of the project and future plans, refer to the MobilED website (http:// mobiled.uiah.fi).

Despite this enthusiasm, however, a major problem being faced in trying to institutionalize the use of mobile phones is the current negative publicity regarding their illicit use in schools. There is no question that currently there is a lot of "under the table" use of mobile phones in classrooms and that they can be distracting influences. This came out very strongly in many of the interviews held while we were collecting data for MobilED. After the pilots, Cornwall Hill decided to champion the use of mobile phones in their school and started developing a strategy for institutionalizing the phones. Additional work needs to be done, but some of the results are discussed below.

Because mobile phone use is difficult to monitor in a classroom setting, the appropriate use of these instruments can be encouraged through values-based principles, instead of managing it on a rules-based system. Values must be clearly defined, understood, communicated, and practiced. Individual responsibility and accountability can be stipulated and its acceptance is to be encouraged amongst all stakeholders. Well established communication channels can also help ensure proper participant behavior.

Developing a clear strategy for the formal use of these instruments to facilitate learning is paramount to the success of adoption, and this strategy can be divided into three different phases. The first phase focuses on creating awareness amongst the various stakeholders in a school setting. This can be achieved by creating an atmosphere of informed curiosity by running pilots and publishing the results in a local and global context. The second phase consists of an adjustment and developing period where competencies are identified and policies drafted. It is crucial at this stage to offer support to those who want to come on board to keep the momentum and growing interest going. The final phase involves the identification of mentors to coach and form ongoing relationships with those already involved in the initiative. Their role is to have a clear understanding of organizational context and to give advice on how to move forward. The crucial factor in determining successful implementation of new strategies is to create cause champions in the process. It is the role of the champion to demystify the mobile instruments and to create an environment in which it can be viewed as just another tool in the toolbox of the educator to help them in their efforts to facilitate lifelong learning (Ford et al. 2007).

The MobilED technology developed in the first year of the project (the mobile audio encyclopedia) has many different possible applications beyond that of education. Since the basic content source in the pilots is a wiki (specifically the wikipedia implementation), this mobile audio wiki can be seen as a community information system that can be used with a mobile phone, which would be of tremendous importance in places where there is a strong culture of mobile phones, but where the Internet and World Wide Web are not widely used (Leinonen et al. 2006). Thus, the platform could be used for e-government, e-health, NGO support, SMME support, etc., in developing countries – all aspects integral to socio-economic growth.

The MobilED platform enables all people in the developing world not only to access information, but also to contribute information back – thus becoming active participants in the information society. It is making a significant step towards bridging the "digital divide."

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INFORMATION ARCHITECTURE AND DESIGN SOLUTIONS SCAFFOLDING AUTHORING OF OPEN EDUCATIONAL RESOURCES

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Abstract

This article presents the open learning object repository and collaborative authoring platform LeMill (http://lemill.net), which has over 7500 members and over 8500 reusable learning resources (situation in October 30th, 2009), all created by the community members. The design of LeMill has tackled numerous challenges that hinder the authoring and sharing of educational resources by communities of teachers. This article describes the research-based design process that was used to solve these challenges. The information architecture of LeMill scaffolds authors towards collaboration and sharing. The licensing scheme encourages reusing and remixing of educational content. In order to make LeMill easy to learn and use we have avoided technical terminology and complicated metadata forms in the user interface. As an open community we have also tackled multicultural and multilingual issues. In this article we present the information architecture and design of LeMill, including the technical solutions. We believe that our design solutions will contribute to the goal of creating an open educational resource ecosystem.

1
Introduction

There is something deceptively simple in open educational resources (OER). Almost anything can be used as an educational resource [1] and anything that is offered for free and without major social or economic expectations can be understood to be open. It can look like the internet is full of open educational resources, ready for teachers to adopt and to use. In reality this doesn't seem to happen. To get people to use open educational resources, there have been projects to define, package, and share them. Currently, research in educational technology has proposed several definitions on what OERs are [2], [3], there are some generally shared standards on how to represent them, and numerous repositories for collecting and sharing them.

As far as we can see, there are still a few missing links before the adoption of OERs can take place in everyday teaching and learning. The most important missing link is that there is no room for OERs in the everyday activities of a median teacher. To fix this, we would need to fix the daily activities of teachers, and we cannot do that directly. However, what we can do is design tools that will support new kinds of everyday practices of teachers and learners.

Because we cannot simply push OERs and the changes they necessitate on teachers and learners, we should try to minimize the required conceptual shifts and changes in learning activities. LeMill (Learning Mill) is a web community for finding, authoring and sharing educational resources, designed for easy integration with teachers' existing meaningful tasks and needs. LeMill was developed in 2005–2008 within an EU funded CALIBRATE project (http://calibrate.eun.org/), with an initial premise of providing a toolbox for collaborative authoring of learning resources. After CALIBRATE, further development and dissemination has been done in the contexts of the Estonian Tiger Leap Foundation and the EU funded Finnish AVO project (Open Networks for Learning, 2008-2011).

There are implicit and explicit assumptions about what good OERS are: They should be relevant to the learner and thus easily modified to fit the learner's needs. They should be of good quality and contain no factual errors. They should be disclose their point of view and in the case of science be free from bias. They should not have hidden costs or prohibiting limitations on use. A good learning resource should also be able to 'travel well', to be easily translated and recontextualised [4].

We believe that these requirements can be met by having the resources edited collaboratively and freely online with no restrictions on participation. If OERS can be freely edited, they can be customized for the needs of individual teachers and learners. If they have multiple editors working on them, versions will evolve, making errors and biases easier to find and correct. The license scheme must permit all this: free editing, sharing of edited versions and combining versions to form new resources. These requirements point towards a uniform and non-restrictive licensing scheme for all resources.

Since we want LeMill to have good OERS and collaborative authoring seems to be the way to do it, but teachers' existing activities, tasks and skills do not necessarily include collaborative authoring, we designed LeMill to provide scaffolding for teachers, so that what they do with their existing skills becomes directed towards collaborative creation.

The main research question of this article is: How can a web service design promote use and creation of OERS?

This article will start by presenting the general challenges related to the design of open educational resource systems, which are not only technological but also social systems. The article continues by defining relatively concrete design challenges that are part of the overall 'wicked problem' landscape. Wicked problem is a concept used by Rittel [5] when referring to the nature of problems common in planning and design practice.

After presenting the design challenges, we introduce the design methodology used in the process. We call the methodology a research-based design process with focus on software as hypothesis [6]. We continue by presenting design solutions that scaffold authoring of open educational resources. The solutions are mainly decisions related to information architecture: ways of organizing, structuring, and enabling collaborative authoring and sharing of educational resources online. We conclude by comparing LeMill's design solutions to other popular repositories and learning resource authoring services.

2
Design Challenges

When starting the LeMill project our initial design challenge was the assumption that European teachers do not share their learning materials nor do they improve them in a collaborative way. Beyond this challenge we can see more general challenges related to European and international educational politics. These are, for instance, differences in the results of educational systems in different countries, which cause problems in recognizing educational degrees in other countries. Not recognizing educational degrees in a pan-European level hinders the free movement of people, which is one of the basic components of the European Union and acknowledged as a fundamental right for EU citizens.

While our task was not to solve the problems related to the rights of EU citizens, as designers we considered it important that we are aware of the big picture. Focusing is not possible if one does not know the context. When narrowing down the design challenge to problems related to sharing of learning materials and improving them in a collaborative way, we already implicitly defined the general design solution. This is common in design thinking where the fact that problems are wickedly incomplete and often contradictory is taken for granted [7], [5], [8]. A designer's way of approaching a problem includes the idea that all problems have multiple solutions and every formulation of a problem is simultaneously an attempt to solve it. According to Nelson and Stolterman, ordinary problem solving is reactive to unwanted states, while designing is about creating a positive addition to the present state [7]. The designer cannot assume that the truth about optimal design is there to be found. Instead, the designer can point a way and say that choosing this way has some benefits.

We chose to work with teachers because they are the part of each country's educational system that has direct effects on learning outcomes. Within the educational system, changes in teaching are easier to track than changes in learning. If we had worked outside of the educational system (self-learning, open learning, networked learning) we would have positioned ourselves as outsiders to our pan-European problem, that of recognizing educational outcomes from different educational systems.

During design and development the main design challenge broke down into smaller, often more urgent sub-challenges. These sub-challenges represent recurring themes in LeMill's design and we think they can be expressed as general design problems in OER repositories and services. These sub-challenges are:

1 Lack of collaboration and peer production of learning materials
2 Lack of reuse and remixing
3 Limited access and poor usability
4 Barriers related to multilingualism
5 Poor use of the underlying principles of the web,
such as openness and 'linkedness'

In section 4, we will argue for and explain our solutions to these sub-challenges.

3
Methodology and Design Process

Our design methodology is called 'Research-based design with software as hypothesis' [6]. In several earlier design and research projects aiming to develop new learning technology (FLE, Fle2, Fle3, MobilED, Hauki, Kuha) we have noticed that people create meaningful ways of using the tools that surround them, and, from the perspective of tool design, often do not know beforehand what tools they really need. The consequences and the affordances of the tools are realized only when they are used in the real world. With LeMill, our aim was to design learning technology in an open dialogue between designers and the target group (in this case teachers) and provide them with software prototypes. With these prototypes we can design affordances (as understood by Norman [9]) that will likely make sense for the teachers at first glimpse.

The relationship between meaning created in action and tools can be illustrated with an example from school architecture. An auditorium and a teacher's podium are tools that form learning spaces. The architecture, fixtures, furniture, and props in the space quite openly communicate and support certain types of teaching and learning. In complex social activity systems, all new tools bring changes to existing activity systems. A new tool should communicate the changes needed in the system. In our context of educational technology, this means that the designed tools and artifacts are always also communicating what teaching and learning with

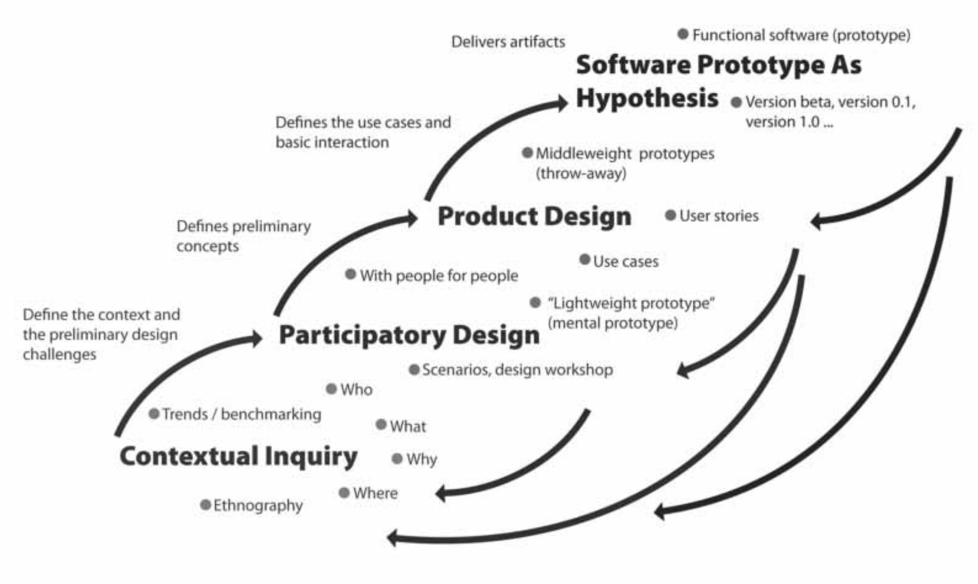

Figure 1. Research-based design process [6]

them could be like. In this sense, software tools can be presented as hypotheses about teachers' activities. They can succeed or fail at inducing activities that teachers are willing to integrate into their everyday teaching.

Research-based design with software as hypothesis is not to be confused with design-based research. In design-based research [10], [11], the aim is to do research with designed interventions into real-world situations [6]. In design-based research design interventions are a research method. In research-based design, the design is the main outcome and anthropological (or quasi-anthropological) research helps to draw routes to that outcome[1]. Our process of research-based design aiming to design a new tool is divided into four iterative phases which happen partly in parallel: (1) contextual inquiry, (2) participatory design, (3) product design, and (4) production of software as hypothesis (see Fig. 1). The process resembles a hermeneutic circle where all research and design operations increase the researchers' and the designers' understanding of each other and the context [6].

1 Other sources of confusion are that sometimes a design that is based on results of any usability research is called research-based design and in an educational context any design that implements a researched instructional theory or pedagogy can be called research-based design.

As part of the research-based design process, LeMill was developed by using the principles of scenario based design [12] and agile software development methods [13]. The design process was carried out and documented in a publicly available software development environment, called Trac (http://lemill.org).

The contextual inquiry phase included observation of teachers' computer use with a special focus on searching of online learning materials. In addition, we benchmarked several other online services. These were MediaWiki (http://www.mediawiki.org), MIT's Open Courseware (http://ocw.mit.edu/), Connexions, (http://cnx.org/), MERLOT (http://www.merlot.org), Pachyderm (http://www.nmc.org/pachyderm), and eduCommons (http://cosl.usu.edu/projects/educommons/). Teachers were also asked to use these systems and relate their experiences.

In the contextual inquiry phase, our impression was that median teachers in the year 2005 hardly used online learning materials. According to a study conducted in 2006 in European countries [14], 40–85% (depending on country) of teachers have used computers in class in the last 12 months, 70–90% consider themselves competent in using ICT, and 70–95% have used material retrieved from the internet. However, in our observations, most of the teachers used very limited computing skills to produce learning resources: a basic knowledge of office software and using copy-paste to add internet resources was enough for most of the teachers.

Participatory design sessions with one researcher-designer and 2–3 teachers were organized in Estonia, Finland, Hungary, and Norway. The teachers read prepared scenarios and then discussed each scenario in a structured group interview led by the researcher-designer. The participants were then asked to visualize the proposed system as they imagined it and explain their drawing. The researchers recorded the sessions and wrote summaries of them into the Trac system.

During product design we realized that we were designing and developing a new tool: something to which none of the existing learning resource authoring tools could contribute. When analyzing the participatory design sessions, we noticed that teachers often do not know what kind of tools they really need and their wishes are influenced by tools that they currently use. We had to balance this reliance on existing tools and their frameworks with the affordances of the new tool. This balancing was an iterative process with teachers, as we gradually became better at understanding the perceived usefulness of each feature.

Our software as hypothesis is the LeMill service. We believe that with it — a simple web-based tool that provides a clear structure for learning resources — teachers can create communities of practice that share and create open educational resources.

4
Design Solutions

This section presents our solutions to the design challenges outlined in section 2.

4.1 Scaffolding Collaboration and Peer Production

The lack of collaboration and peer production of learning materials was the first of the design challenges. The issue was considered from several points of view, including the basic structure of the service, the level of 'wikiness' that would rather benefit than become an obstacle for collaboration, basic concepts and their relations, and the workflows of collaboration and peer production.

The overall tasks that teachers should be doing in LeMill were deduced from participatory design sessions (http://lemill.org/trac/wiki/DesignSessionResults) and later from workshops with teachers. The structure of LeMill and the available features on each page should provide scaffolding for these tasks. The main tasks were defined as (1) finding resources to use (illustrations and exercises), (2) finding new teaching methods, and (3) modifying resources to better suit a particular learning context. In the participatory design sessions we noticed that when planning their teaching, teachers are primarily interested in using some new teaching or learning methods or tools and only secondarily are interested in the curriculum in which these could be utilized. Based on this discovery, we decided that the top level navigation in LeMill should be split into four segments: Content, Methods, Tools, and Community.

Also apparent from the design sessions was that teachers are generally wary of collaboration and resource creation, pointing out problems with copyright, motivation, and high threshold for joining a new community. While from a workflow perspective LeMill resembles a wiki, its user interface is quite far removed from that of Wikipedia for instance. While a traditional wiki-like interface promotes co-editing among a community of technologically savvy users, this is not sufficient to encourage teachers to collaborate, as participation in wikis requires mastering a relatively complex syntax and the environment requires joint continuous efforts to maintain a coherent structure. To support collaboration and peer-production among teachers we noticed that on top of the 'wikiness' we must have additional scaffolding that presents the information architecture and the concepts in a language that teachers already know and are comfortable with.

For instance, Methods and Tools are familiar concepts for pedagogically minded teachers. Methods are descriptions of various pedagogical methods, activities, games, and other ways of teaching and learning. Methods also represent LeMill's unique take on Learning Objects (LOs) and Learning Design (LD). While most online LO repositories primarily contain learning objects for learners, LeMill focuses on resources that teachers can utilize to improve their teaching. LOs have been criticized for their unfounded promise of Lego-like combinatorics, which would only be possible if they were instructionally empty [15]. Learning Design (LD, [16]) on the other hand adds instruction theory to learning objects, but the level of description required for IMS-LD modeling is too cumbersome for our needs of easy access and online editing, and on the other hand is incapable of representing some advanced pedagogical models [17]. In LeMill methods are treated like other learning resources and it is up to the teachers to decide how a certain method should be used with certain content. LeMill's LOs are not supposed to be fully machine readable or used in automated instructional sequences. It is assumed that there is always a teacher to decide how resources are to be used. If a teacher is there to contextualise the resources, the decontextualized nature of LOs is not a problem [18].

The Content section contains more typical learning resources. Content resources are built on one of six available templates. The templates are basic scaffolding tools that make it easier for people to create web content [19], [20]. Our templates are: web page, presentation, exercise, lesson plan, school project, and PILOT (Progressive Inquiry Learning Object Template [21]). The main concepts and divisions of LeMill are described in Fig. 2.

An important aspect of LeMill is the authoring workflow. We would have preferred to keep the authoring workflow as simple as possible, but participatory design sessions revealed that teachers had many reservations about releasing unfinished or partial resources. So there had to be a division to drafts and published content. However, that division does not need to apply to resource types that don't have a precedent for such division. Our judgment has been that methods, tools, references, PDFs, learning stories, and media pieces do not need to have a draft version. Only template based content types should have drafts (see Fig 2).

Drafts were initially created as public to encourage collaboration but without prominent author information to lower the threshold of creating unfinished content. Because of feedback of teachers, we had to make drafts private by default and made a third option of 'public draft'. Publishing a resource is encouraged by allowing only published resources to have cover images. When resources are published, they are visible for all and editable by all.

We initially designed the communities in LeMill to form around collaborative learning resource creation. Each resource can be adopted by a group. Anybody can join a group, but joining a group is the precondition for editing a resource. Later, when we noticed that groups were also used to form courses or workshops, and that these groups collected interesting learning resources, we allowed resources to be adopted by several groups. Discussion about learning resources was initially limited to happen within groups, but as these discussions were rare, the threshold to start one stayed high. We tried linking these discussions to resources with similar 'discussion' links as seen in Wikipedia, but the concept became complicated when resources could belong to several groups. Finally, we migrated all discussions about resources to happen within the resources themselves and having groups only aggregate these discussions.

We have also tried two solutions for branching different versions of a resource, but we are not satisfied with either. At first we allowed versioning, but found that teachers were too eager to use it in avoiding modifying each other's works, with a detrimental effect to collaboration. The second attempt was when there was an existing biology textbook that an author wanted to publish in LeMill, but didn't want it to be changed by anyone. We allowed the locking down of resources so that only author can edit them, but with the condition that there can be new branches. This feature also seems to be misused, and we are planning in removing it.

Authoring of learning resources and collaboration around them is encouraged by a teacher's portfolio. For every teacher it keeps track of where the teacher has participated in creation or editing of resources and aggregates these resources. The portfolio also has room for profile and personal information and interests, and these can be used to find other teachers with similar interests.

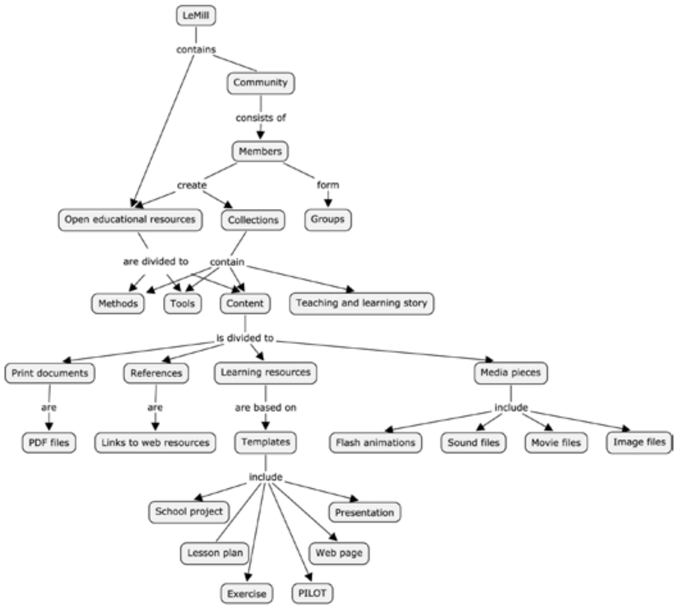

Figure 2. The central LeMill concepts and their relations.

Individual teachers are also encouraged to collect interesting or high quality resources into their personal collections, which are visible to others. These collections can be formed around any theme, such as 'interesting math resources', 'good pedagogical advice', etc. A collection can also be used to create a lesson or course plan: by adding content, methods, and tools into a collection, a teacher can create a package that has much of the information that is needed to teach a lesson or a course (Fig. 3).

Teachers can also add 'teaching and learning stories' to their collections. These are simple free form descriptions of a collection explaining how the teacher plans to use them or has used them in teaching. Resources that are used in teaching and learning stories automatically and prominently link back to them so as to provide examples and ideas on how to use them. This design addresses the common problem of learning objects not having contextual information about how they should be used [22], [18].

4.2 SCAFFOLDING REUSE AND REMIXING

Reusability of learning resources has both technical and legal aspects one must consider when designing a service and a tool for this purpose. In the participatory design sessions we found out that teachers are aware of the copyright issues but many of them have a rather practical stand on them. The principle seems to be that if some online content is found useful in teaching and learning it can be used for this purpose freely, including copying, printing, remixing, distributing etc. However, teachers perceived it as a plus if they could do so legally.

Figure 3. An example collection from LeMill

Traditional copyright laws give the creator of an original work the exclusive right to decide how their work is distributed and if it can be adapted. This is a major obstacle for the reuse of learning resources. Learning resources that teachers find from the web may often need to be adapted to a certain learning context and target group. Doing this for personal learning purposes poses no problem, but distributing the adapted version is a conundrum. According to copyright laws, teachers need an agreement from the holder of the copyright before they can adapt and distribute the learning resource. These legal obstacles can be solved when learning resources are published under an open content license.

From the beginning of the project it was clear that all the content created in LeMill must be published under an open license. However, it was important to choose a licensing scheme that will both protect teachers and give them the possibility to reuse content created by other people. In 2005 when we were pondering this, several licenses were used for educational content. Some systems used GNU Free Documentation License (Wikipedia and other initiatives of the Wikimedia Foundation), some used Creative Commons licenses with non-commercial restriction (MIT OpenCourseWare) and some allowed users to choose between different Creative Commons licenses or all rights reserved (Flickr).

The first important decision was to use the same license for all resources that are created in LeMill. This enables teachers to remix all the resources that they find in LeMill without having to think about license compatibility issues. Secondly we decided to choose one of the Creative Commons licenses because their licensing scheme is developed to be understandable by a wide audience. Finally we were considering between Attribution-Noncommercial-Share Alike (BY-NC-SA) and Attribution-Share Alike (BY-SA) licenses. The non-commercial restriction limits the possibilities of reuse. In the educational context it is problematic for many meaningful ways of reusing content [23]. Therefore we decided to choose the Creative Commons Attribution-Share Alike license for all content created in LeMill. Back in 2005 it was not the most popular choice for educational content, but recent developments in the field show that it was the right decision. The Wikimedia Foundation has migrated from GNU FDL license to Creative Commons BY-SA license [24]. This made it possible to remix Wikipedia (and other Wikimedia projects') content with LeMill content.

In addition to the new possibilities with Wikipedia and Wikimedia Commons, Connexions has all their content under a compatible CC Attribution (BY) license. The popular photo sharing site Flickr has millions of images under CC BY and BY-SA licenses. A growing number of content with licenses compatible with CC BY-SA makes LeMill part of a larger OER ecosystem, while content that is under complete copyright can be used by linking or embedding under the Fair Use conventions. For example it is possible to embed videos from YouTube to learning resources in LeMill.

While there are no legal restrictions for remixing the content that is created in LeMill there are still some technical limitations in order to keep the system simple. With remixing we understand the combination of two or more learning resources. So far we have not developed special tools for combining parts of learning resources, but one content type — the media piece — is intended to be used with and within other resources. Web pages, exercises, presentations and PILOTS can all include media pieces. When adding a media piece to a resource, the author can search from existing media pieces or upload a new piece.

The remixing culture makes it easier for us to concentrate on our main focus by outsourcing some of the difficult parts of content creation to services specialized for them. For example, we have had trouble designing and implementing a fast and easy way to create presentations or slide shows as learning resources. Building them from media pieces is cumbersome and leads to dozens of uploaded slides with minimal reuse value. Teachers also want to upload existing Microsoft PowerPoint slide sets as learning resources, which leads to additional problems because then online editing and improving is not possible. Our current solution is to run OpenOffice.org as daemon to export PowerPoint slides into images once they are uploaded and thus create editable and 'granular' presentations from uploaded material. In addition to putting presentation into LeMill users may use any of the external presentation hosting and creation services like SlideShare (http://www.slideshare.net) or 280 Slides (http://280slides.com) and embed slideshows from there into resources.

Embedding media from another site is actually another popular way to remix content in LeMill. The common method for embedding is to copy and paste an 'embed code', a piece of HTML, into a page or blog post. In workshops, we have noticed that many teachers are accustomed to office software paradigm for creating content. In office software copying and pasting is the most common solution for moving pieces of text or images from one document to another. Thus we assume that copying an embed code from a site is the cleanest and most versatile way to embed content. The simplicity of copy and paste outweighs the additional user interface clutter that graphical remixing tools would add.

4.3 SCAFFOLDING ACCESS WITH MINIMAL METADATA

We suspect that the problem of limited access and poor usability of educational repositories in general is related to different perceptions of what is important for repository curators and repository users [25]. In the participatory design sessions we noticed that average teachers do not know what 'metadata' is or see how it could be important to them. Nevertheless, teachers use different kinds of metadata in their daily work. From a technical perspective metadata is important to have, but for teachers it should be invisible, implicit or obviously useful [26].

LeMill is a repository of educational resources. Repositories store objects and metadata, and metadata is there to help find relevant data objects and communicate to other systems about their existence. There are several metadata schemes for educational resources. The Learning Resource Exchange (LRE) Metadata Application Profile v3.0 [27] of the IEEE Learning Object Metadata (LOM) standard [28] defines the metadata that European learning resource repositories should support. These standards can provide a solid base for designing an educational resource repository.

LeMill is built on Zope (http://www.zope.org/), a transactional object database. Using an object database allowed us to be very flexible with the actual data model and start with a very minimalistic object scheme. Object schemata are easily updated to have new or changed fields. Having an architecture based on custom object types suggests using adapters to accommodate them to different metadata schemata instead of trying to keep the data structures themselves uniform and compatible. Educational resources from LeMill can be harvested with the Open Archive Initiative Protocol for Metadata Harvesting v2.0 (OAI-PMH) [29] as LRE LOM objects or using DublinCore metadata. In short, the actual data model is there to reflect the priorities of teachers creating content as far as we know them, while satisfying metadata harvesters and queries from other systems comes secondary and is done with adapters. Technically this has proved to be feasible and can be seen as a local mapping solution to problems of metadata interoperability [30].

In LeMill's user interface we altogether avoid the word 'metadata', because teachers' existing workflows for preparing material for classes do not use the term. Teachers have a very contextualized short-term need, whereas curators think about the general form and future accessibility of data [25]. If metadata is not perceived as essential for finding resources [25], [31], [32], then we suspect that adding such metadata to content will be perceived as an extraneous and unnecessary task.

To make some metadata relevant, we encourage teachers to browse LeMill. For example, the Content section's front page has emphasized links to browse by language, subject area, target groups, and tags, with links to the three most popular tokens for each. Internally all these browsing options are metadata categories. All of them except tags come naturally from teachers' needs. Free form tagging is a concept familiar from social software and it has been found that teachers adopt it well [33]. After limiting results with one criterion, the browsing view allows the addition of other criteria from drop-down menus so that teachers can end up browsing for example resources in English that are about History and suitable for 10th grade students and have the tag media.

We assume that the usefulness of metadata in browsing encourages teachers to enter similar metadata to their resources. The data that LeMill collects that can be understood as metadata is presented in table 1. Only the first four are explicitly asked from teachers and they are all optional. The rest of the fields are created automatically. The teachers may enter metadata when creating the resource, or they may complement them later. Complementation — the 'wiki-way' — can be done by any user. LeMill is integrating flexible community-based metadata creation to automated metadata gathering, as described by Duval [26].

Table 1
Metadata fields

FIELD NAME	TEACHER'S INPUT
Tags	free text
Subject area	multiple selection
Target group	multiple selection
Language	suggestion based on the teacher profile's languages, single selection
Publication status	for most resources 'published' or 'deleted', for Content types also 'draft' or 'private'; altered by actions 'publish', 'delete', 'undelete' or 'retract' shown when applicable
Cover image	asked when publishing a resource, can be changed later; for media pieces that are images, automatically use thumbnail image
Creators	automatically added as creator, order of authors depend on size of contribution
Rights	CC BY-SA automatically for most; with references and media pieces several options that refer to original license
CreationDate	automatically added
ModificationDate	automatically updated
Id	automatically generated from resource's title

When presenting metadata fields to teachers we have to use the same terminology as teachers do. For example, in workshops we found out that teachers prefer to use grades instead of a typical age range. Because of this we combined three elements from LRE LOM ('Educational.Intended End User Role', 'Educational.Learning Context' and 'Educational.Typical Age Range') into a new element named 'Target group'. Vocabulary values for this element include all the primary education grade levels, preschool education, higher education, adult education, special education and teachers. In the OAI-PMH script we map these values back to LRE LOM. Instead of 'General.Keyword' we use 'Tags' in the user interface. We also avoided using technical terminology such as 'learning objects' and 'learning assets' in the user interface. Instead of these we decided to use 'learning resources' and 'media pieces'.

During the development of LeMill, the data model has gone through several minor changes and adjustments. For instance, we have removed fields that have not been used or have often been misunderstood. One example of an unused field was the link to a video, to demonstrate a method. An example of a confusing field was 'learning resource type', a field that was based on LRE LOM element 'Educational.Learning Resource Type' and used for references to determine which kind of resource is referenced. We noticed that teachers were uncertain as to what kind of element to choose when the resource was, for example a website with simulations and quizzes. We observed that the description texts were providing the same information in an easier way and decided to remove the field altogether.

One example of the difference between metadata for teachers and standardized metadata is the learning resource's cover image. When browsing resources, a cover image can tell a lot about the resource and the effort that has been put into creating it. Metadata standards do not recognize such information. We try to encourage teachers to add cover images to resources by making it a mandatory step in the publication process. Cover images can reuse thumbnail-sized versions of existing media pieces or be newly uploaded images.

In a repository with thousands of objects, it is crucial to have metadata that supports finding quality content. One way of ranking resources would be to have a simple rating system. However, our design sessions have indicated that because of variance in teachers' needs, simple five star rating systems are not objective enough. In addition, the editable nature of LeMill resources makes ratings counterproductive, as bad ratings follow resources even when their causes are fixed. Instead of a rating system teachers can use a discussion page to give meaningful feedback about the resource. This approach is being used in LeMill, but conclusive results have not yet been gathered. One aspect of this approach is that it blurs the line between commenting and editing content. If you have a constructive comment on a resource, will you write it into the discussion page as a comment, or directly edit the resource itself to reflect the changes, or both?

We have developed ranking algorithms for calculating scores for content, methods, and tools. The score will depend on the way people work on the resource and on the actions that other people have with it. Each object will get initial points when it is published. The score will rise when it is edited further, illustrations are added and external resources are embedded. Since our aim is to support collaborative authoring, we will give more points when the resource is edited by more than one member. Points will be added to the score each time other people bookmark the resource into their collections. As a result, resources that are edited by several people and belong to several collections have a higher score. The scores are used to sort search results, generate tag clouds, and display featured resources on the section front pages. These algorithms are modified periodically as we try to balance results to both encourage collaboration and to reward individual efforts.

In a similar way, we calculate scores for community members. The member score consists of three parts. First, we sum up the scores for all content, methods, and tools that the member has created. Then the social activities such as sharing teaching and learning stories, participating in the groups, and being added as a contact are scored. Finally, the member will receive additional points for fully filling the member profile.

4.4 SCAFFOLDING MULTILINGUAL USE

The participatory design sessions were carried out in four European countries — Estonia, Finland, Hungary, and Norway — in four different languages. From the very beginning it was clear that we were designing a multi-lingual and multi-cultural tool and service. The results should include ways to translate and localize itself to whatever language. The content should also be easily translatable. Different languages in the site should not confuse the people using the site.

For a multilingual site, there are basically two options: either keep the languages separate, or mix them up in one pool. As LeMill developed from an empty repository, we started with everything in the same pool, and gradually added functionality to allow for different languages to separate to their own resource pools. The upside of keeping everything together is that the repository doesn't appear empty to a representative of a minor language, while the downside is that search results may be flooded with resources in a language that the teacher doesn't understand.

From the beginning each teacher was able to define in their profile the languages that they are fluent in, in the order they think is most suitable, usually placing their native language first, followed by other languages that they can use. This became a very important tool as we noticed that LeMill was starting to be dominated by a few small languages.

Nearly all resources in LeMill have a specified language, and those that don't are causing problems, so in the future they will need to be tagged with a language as well. We use teachers' profile language information to customize both the user interface and the listed resources in search results, featured resources, and browsing views. The list of matching resources is sorted by languages, and then by the individual resource's popularity score. Thus in search and browsing results, teachers will first see matching entries in their native language, in popularity order, followed by resources in their secondary languages, in popularity order, language by language, and finally in English, if English was not already included.

Resources in languages that the teacher has not listed in their profile will not be shown at all unless explicitly searched for. Teachers can of course access them if they find them. This feature acts to form language clusters within the repository, as the language skills of the teachers define the borders surrounding clusters. Multilingual teachers will of course be positioned as mediators between language clusters.

LeMill encourages translation of resources. Each resource has a link to translate it, and the resource has links to already existing translations. Translations are not assumed to be identical, and certainly cannot be, as the original and the translation can both be further developed by other teachers. The intention is to facilitate the spread of good resources and teaching ideas.

We've identified some specific problems regarding resource languages. Images don't usually have any language content, but their descriptions and titles are written in some language. Would it make sense to tag an image with the language of its description? While it is informative, teachers could easily reuse images regardless of their description language.

Another problem concerns collections, which can contain resources in multiple languages, in addition to the collection's title and its own description. What should the language of a collection be, if its title and description are in Estonian, but all or most resources are in English?

A third problem concerns resources related to language studies. If a resource contains text in English, and instructions in Estonian, which language should it be tagged with? English teachers in Estonia will most likely try to find material for their courses by looking into the pool of English resources, but having a resource that is partly in Estonian will be quite problematic for English teachers in other countries. Short of having separate metadata fields for 'teaching language' and 'content language', this issue is still unresolved, partly because there is a similar problem with referencing to resources outside LeMill. The referenced resource can be in a different language than the actual reference description and explanation, but there is an ambiguity about what the language field is referring to. LRE LOM's approach of asking for language in 'General.Language', 'Meta-metadata.Language' and 'Educational.Language' allows all of these specifications. However, in most of the cases selecting the language of a resource is obvious, and having these three fields would feel like an unnecessary complication.

A fourth problem is the issue of tags and their languages. Currently tags carry no language information, which means that tag clouds are quite multi-lingual. It would be technically possible for us to convert all our tags to tuples of tag and language code, but keeping the process of adding tags simple would then be a formidable design challenge. Tag language could be inferred from the language of the resource, except that many content resources are about foreign language learning and thus contain two languages and are labeled in differing ways (see previous paragraph). Inferring tag language from the user's profile would require each tag to have a language specified separately, as tags can be edited by anyone and adding a few tags in your own language shouldn't change the language of other tags. Even a dictionary-based solution has its limitations, as some words can occur in multiple languages and mean either the same thing, or different things.

A multilingual site attracts users from multiple countries and cultures. At the time of writing this article, LeMill has teachers from 56 countries. Each group of sufficient size seems to form its own codes of conduct and practices of using LeMill. Teachers in some countries have started to write individual course plans as method descriptions, while others have written them into the content section. In some countries teachers need to be able to present their lesson plans and show how they connect to accepted learning goals, where as in other countries there is no need for such detailed plans. As a response new content types were added to the content section: lesson plans and school project plans. One example of cultural differences is the popularity of history as a subject area in Georgian resources, where in other languages it is one of the least used categories. A more detailed comparison of community practices is difficult because of language barriers, which also forces us to trust in community self-organization and self-policing.

4.5 SCAFFOLDING CREATION OF SMALL PIECES LOOSELY JOINED

Our fifth design challenge was the poor use of the underlying principles of the web, such as openness and 'linkedness'. What we mean with openness is that anyone can join the system, create new resources, have them link to any resource anywhere, and to link to these resources from anywhere on the web. Because of its elective, haphazard, and unlimited fashion of linking, the web is said to be formed from small pieces loosely joined [34]. A powerful side effect of ideological linkedness is that because search engines index resources by following links, resources in highly linked and openly traversable repositories are very visible in general search results.

As noted before, our approach to standards is not to build from standards, but to build from teachers' needs and have the result adapt to standards when necessary. All textual resources in LeMill are presented as XHTML. Multimedia uses the normal web-acceptable image formats, and some rich media are displayed using Flash, which can be considered a de facto standard. As previously discussed, we considered IMS Learning Design (IMS LD) [16] to provide an interesting and advanced description language for pedagogy, but we found it too complicated for easy access and also that it had important restrictions in covering dynamic group behaviors and other advanced iterative methods [17].

If the resources in a repository cannot be exported and transferred to other infrastructures, it cannot claim to be truly open. The most popular LO transfer format is SCORM, and collections from LeMill can be exported as SCORM sequences, stand-alone web file packages, or pdf booklets. These allow teachers to export their collections and set them up on a web server, import them to any SCORM compatible LMS, or to print them as handouts.

Table 2. Provided protocols and views

READER	PROVIDED PROTOCOLS AND VIEWS
teacher	web page, 'student view', zipped offline web pages, SCORM-package, PDF
RSS-reader	RSS 2.0
metarepository	OAI-PMH, supported formats LRE LOM and DublinCore

Referratories or metarepositories that only store the metadata of resources have lately been quite popular, and any open repository should acknowledge them and provide access to them. OAI-PMH [29] support was built into LeMill, as it seemed to be the leading protocol in querying repository contents, had sufficient support for LO metadata, and was already supported by other platforms. LeMill also provides RSS feeds for search results and other dynamic pages. A summary of currently supported protocols and views is presented in Table 2.

To prevent LeMill from becoming a closed silo it is important to make it clear that LeMill is open and readable by anyone, by not hiding information inside members-only areas and by publishing the content with open licenses that make it clear to authors that their creations will be openly available. When LeMill resources are readable in general then technical support for existing open standards and for upcoming new standards is relatively simple to add.

5
Comparison of design solutions to other learning resource repositories

Teachers' expectations for online services in general have been about time and effort savings in finding resources and preparing resources for classes [35], [31], [25], [32]. Peer production is not in the teachers' goals, but should come as a byproduct of resource finding and preparation. OER repositories and LeMill share the same purpose of supporting teachers in finding resources. Yet, because LeMill's main design goal is to foster peer production, LeMill omits a few common OER repository features in order to make participation and co-creation easier. LeMill differs from major repositories like Connexions (http://cnx.org), MERLOT (http://www. merlot.org) OER Commons (http://www.oer-commons. org/) and its sister project Learning Resource Exchange for Schools (http://lreforschools.eun.org/) by keeping the user interface much more simple. The resources cannot be rated and they have less visible metadata.

Simplicity in browsing makes simplicity in editing easier to achieve. In Connexions, creating Modules is done in their own CNXML language; in MERLOT, OERCommons and LRE-for-Schools, resources are submitted by providing a link and entering metadata, after which the resource goes through a review process. Even as resources are often published with open licenses, only the author or editor can modify the resource. Only wiki-based OER projects like Wikiversity (http: //wikiversity.org), Wikieducator (http://wikieducator. org), and LeMill expect collaborative editing to be the default.

Mixing languages is also typical for LeMill, but as a site wide feature it may be a passing phase, as content in foreign languages are only displayed when enough resources in familiar languages are not found. MERLOT and Connexions use English as the only user interface language. Connexions has ≈90% of resources in English and MERLOT's ratio is unknown, although probably in the same region. Wikiversity and Wikieducator use separate subsites for every language, with courses linking to other languages if the translations are available. There is also a multilingual beta. wikiversity.org for languages that have not reached critical mass of active users. LRE-for-Schools uses the same principles as LeMill for dealing with languages: the user interface is translated into several languages and the content is syndicated from several languages. LRE-for-Schools has a special tag for 'Travel well'-resources that do not rely on language.

Encouraging creation of small resources is a goal that is related to reuse and remixing. For finding images and pieces to use in teaching, teachers can rely on Flickr and similar services, but for the purpose of composing a new resource to be shared with other teachers, the parts should have a license that permits that. Hosting suitable media pieces inside the repository facilitates remixing and allows automated attribution. While Wikiversity uses resources from Wikimedia Commons quite naturally, other repositories expect authors to have prepared material that is clear from copyright issues.

5.1 AUTHORING TOOLS

In addition to OER repositories, there are authoring tools for learning resources that have repository-like features. Their focus is on creating resources in a certain presentation format, which then can be downloaded or played on site.

LAMS is a tool for authoring IMS LD compliant learning sequences and has a community where sequences are published and shared (http://www.lamscommunity. org/). Playing LAMS sequences requires a dedicated server. Building a sequence is done with a drag-and-drop editor, but as the task is to model a learning scenario, the entry barrier is quite high. Furthermore, viewing a learning sequence requires the creation of a demo account. The RELOAD editor allows offline editing of IMS LD and SCORM sequences, but it is aimed for more technical users. While IMS LD has promise, modeling learning sequences is beyond LeMill's goals of supporting teachers in their first steps at collaborative authoring.

5.2 OTHER APPROACHES

ALOCOM is an innovative approach for reusing learning objects. ALOCOM is a model about content of learning objects, but instead of providing an online service for composing LOs from LOs, it is used by plugins within popular office software [36]. These plugins try to search the ALOCOM repository for smaller 'Content Fragments' that could be useful for the LO that the teacher is trying to create. The LO can then be sent to the repository where it will get automatically parsed into Content Fragments usable by other teachers. By using office software that the teachers already know well, it bypasses many usability issues and in a way provides scaffolding. This approach is highly dependent on automated parsing of LOs and would be less effective for the very heterogenous needs of European teachers. However, doing ALOCOM ontology parsing in LeMill, uploading LeMill content to the ALOCOM repository and fetching Content Fragments from ALOCOM could be a future option.

Also of note is eduCommons (http://educommons. com), a content management system for OpenCourseWare projects. The idea is that a school can have an eduCommons server and host its courses there. These hosted courses are syndicated to other OpenCourseWare servers and repositories. This is a great approach for institutions that can commit to the OpenCourseWare Consortium, as each eduCommons site can set up its workflows and practices as they see fit. But as the consortium targets only higher education, modifying an eduCommons site to serve primary or secondary school teachers would be a design project of its own. In one phase of the project, LeMill was perceived to provide a similar service for basic education: LeMill installations were supposed to form a network with syndicated searches. However, as a lively initial community was a necessity, we concentrated our efforts to one LeMill site.

6
Conclusions

The design of LeMill aims to combine many aspects that are important in authoring and sharing of open educational resources. We have tried to solve several fundamental challenges that hinder European teachers from creating and sharing open educational resources. The information architecture presented in LeMill can be part of the solution helping European teachers share more their learning materials and improve them in a collaborative way.

Thorough validation and evaluation work has shown that LeMill is at least a partial success. From the very beginning of the project, we aimed to create a living community — or actually make it a platform for communities. Today LeMill has more than 7500 members from 56 countries. Teachers from some countries, such as Georgia or Estonia, have their own strong communities, while teachers from some countries like Hungary or Finland have not yet formed a self-sustaining community. Together with Connexions, Wikiversity, and WikiEducator LeMill is currently one of the largest OER initiatives based on peer-produced content.

LeMill has currently over 8500 learning resources. In November 2007 Ochoa and Duval [37] calculated that average growth for Connexions to be 1.8, for MIT OCW 1.0, and for MERLOT 4.6 new resources per day. In the same time period LeMill's growth was 3.4 resources per day and in the fall of 2009 the growth rate was 8.0 (not including media pieces).

LeMill has been evaluated by pedagogical researchers working in close cooperation with teachers [38]. The evaluation included authentic trials in schools, national focus group discussions in six European countries, pre-pilots, workshops, and evaluation exercises with teachers between 2005 and 2008. The results were compared to the general ICT capabilities of the teachers with the SIPTEC framework. During the evaluation, one hypothesis concerned LeMill successfully supporting computer supported collaborative learning in knowledge building communities and trialogical learning. This hypothesis was supported by the findings of the study, mentioning the emergence of national communities, peer learning among teachers, extra-cognitive mechanisms, social presence, and the importance of co-evolutionary methods in the development of LeMill. Another hypothesis concerning long-term impact of LeMill showed promise, but could not be verified in the study as more time was needed to truly see the long-term effects [38].

However, the main question for this article is what part the design of LeMill has played in achieving these results. The design solutions have been (1) making social activities like building collections, building portfolios, discussing and forming groups centered on resources, and having reuse and remixing an explicit part of resource creation, (2) publishing all resources under a license that permits remixing (3) making metadata creation implicit and manual entry of metadata minimal, (4) mixing languages together and personalizing views based on language preferences, and (5) encouraging the creation of small resources and keeping them open to the larger web.

In discussions with teachers from several countries one of the main reasons why LeMill has been taken into use by the teachers is its ease of use. It is said to be simple and elegant, while at the same time showing respect for freedom of expression, freedom of assembly, and the existence of different languages and cultures.

However, by looking at the actual amount of collaborative editing in LeMill, the numbers are low. Only 5.5% (270 of 4890) of resources (excluding media pieces and resources that are clearly stubs, have no tags or language information) have been edited by more than one author. For those resources that are assigned to groups, 9.7% (128 of 1326) have been edited by more than one author. It is a positive finding that assigning resources to groups has a noticeable effect. There are some known factors influencing these numbers. One is that collaborative editing is defined quite strictly: only changes in the actual body text of a resource count; adding tags or fixing missing metadata doesn't count. Another is that many of the resources are created in teacher training sessions and while we now try to delete them afterwards, there are still large amounts of low quality content that is generally not visible, but affects these statistics. Our design solutions for supporting collaboration have not created a major change in teachers' behavior in this aspect.

We may also have been mistaken in our assumption that the smaller granularity of resources lowers the threshold of resource creation. Ochoa and Duval [37] found that repositories that feature full courses have a more active user base than repositories that concentrate on resources of smaller granularity. A course is a natural context for teachers to return and work on. Instead we have had to rely on workshops, competitions, and teacher training sessions to provide temporary meaningful contexts for resource creation.

We have found that it is difficult to maintain the separation between design work in LeMill and 'community gardening'. In social software, a design solution can create affordances, but community conventions and introduced rules can override and replace the designers' intentions. Design can be used to resist certain habits, like the teachers' preference of keeping unfinished resources private. A designer as a community moderator can do the same thing with a simple discussion post. In LeMill dissemination, one of the designers has held the majority of teacher workshops and gained many important insights into the design problems from teachers. This learning has been mutual: teachers in the workshops have learned about LeMill's design intentions and in turn adapted to them. This is typical for a 'wicked problem' — even when there seems to be progress towards solving it, it is difficult to point out which of the multiple solution attempts actually worked. In the spirit of openness, we have here presented our attempts.

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LEARNING IN AND WITH AN OPEN WIKI PROJECT: WIKIVERSITY'S POTENTIAL IN GLOBAL CAPACITY BUILDING

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Abstract

There is a chance that *Wikiversity* will become the Internet's free university just as *Wikipedia* is the free encyclopedia on the Internet. The building of an educational entity demands considering a number of philosophical and practical questions such as pedagogy and organization. In this paper, we will address some of these, starting by introducing several earlier approaches and ideas related to wikis' potential for education. We continue by presenting three commonly used metaphors of learning: acquisition, participation and knowledge creation. Then we will present the main principles of two existing alternative educational approaches: free adult education and free school movement. To test these educational approaches and practices on *Wikiversity* and increase our understanding of the possibilities of this initiative, in the spring of 2008 we implemented an experimental course in *Wikiversity*. We conclude with several recommendations essentially advocating for *Wikiversity* and the use of wikis in education. However, more than just presenting our opinions, as authors we aim to make an educated — traditionally and in the wiki way — contribution to the international discussion about the future of education for all in the digital era.

1
Introduction

Wikiversity is a project of the Wikimedia community and a sister project of the *Wikipedia* project. The Wikimedia community is an international online community born and expanding around *Wikipedia*. *Wikiversity* was launched in June 2006 after an extensive online discussion on the mission, vision and objectives of the project. According to the approved project proposal *Wikiversity* is: "a repository of free, multilingual educational resources; a network of communities to create and use these resources; and group effort to learn, which may or may not be led by an instructor, who may or may not be an expert on the topic." Furthermore, the *Wikiversity* community has defined *Wikiversity* to be "a centre for the creation and use of free learning materials and activities." Its priorities and goals are to: "Create and host a range of free–content, multilingual learning materials/resources, for all age groups in all languages; Host scholarly/learning projects and communities that support these materials; and Complement and develop existing Wikimedia projects (e.g., a project devoted to finding good sources for *Wikipedia* articles)" (*Wikiversity*, 2007)

Open wiki projects, such as *Wikipedia* and *Wikiversity*, take their form over time. They are, first of all, online communities that are responsible of building their own culture and way of operating. Because of this, when an open wiki project is started, it is hard to know what it will finally become. Still, open wiki projects do not develop independently because they are embedded in specific socio–cultural contexts. Because of their free and open nature — anyone may join — their context changes over time depending on the socio–cultural demographics of active community members.

At the time we write this, *Wikiversity* is still developing. It looks like the community is not yet exactly sure about its identity. At one level, *Wikiversity* is already a Web site for real online learning communities — kinds of educational entities. One may even see some signs of it becoming an educational institution. The slogans used within the *Wikiversity* project promise a great deal: "Free learning community" and "set learning free".

There is a chance that *Wikiversity* will become one of the most important online education sites on the Internet with a great impact on global capacity building. But it is possible that *Wikiversity* will slowly vanish when the first pioneering volunteers realize that running an online education site requires more than masses of editors of wiki pages.

As *Wikiversity* evolves, one must consider what will be the underlying educational ideologies driving its development. From the history of education we know that some radical approaches to education, especially the ideas surrounding free and liberal education, have played an important role in capacity building in many societies around the world. We argue that by learning from the free and liberal educational tradition, *Wikiversity* could become an entity with a great impact on human capacity building on a global scale.

In this paper, we first present several different approaches to evaluate the potential of wikis for education. Then we will introduce three metaphors of learning that are common in the West. These are: acquisition, participation and knowledge creation (Paavola, et al., 2004). These metaphors strongly affect the ways we organize education today. We will then present the history and practical implementation of free and liberal education, more precisely focusing on free adult education and the free school movement. Free adult education will be discussed in the Scandinavian tradition. The ideas of empowering education and implementations of the free school are based on number of pedagogical thinkers around the world such as Paulo Freire (1993), Henry Giroux (2007), bell hooks (1994), Ivan Illich (1971) and Peter McLaren (2004). To test educational approaches presented in this article, we organized and facilitated in late 2007 and early 2008 an open and free class. This ten–week interactive course with more than 70 students was used to gather data and test the idea of making Wikiversity an open and free platform for education in the tradition of free adult education and the free school movement.

Based on earlier attempts at using wikis in education, three metaphors of learning, two traditions of free and liberal education, and our research, we'll present several recommendations for the possible future direction of *Wikiversity*. Our arguments are based on the belief that *Wikiversity* — as well as the other open wiki projects — should aim for the highest possible potential intrinsic in their unique combination of free content, volunteer collaboration and massive distribution of labor. Wikiversity should be build on a two–fold foundation: (1) the open wiki project forces genuinely new forms and results in education; and, (2) the tradition of free and liberal educational philosophy and practice.

2
The potential of wikis for education

When aiming to clarify wikis' potential for education, we must recognize the difference between learning with the wiki platform and learning in an open wiki project. The former refers to the use of wiki engine (such as Mediawiki) in an educational situation occurring in some existing social and organizational context, such as in a school. The later discusses the educational impact of participation in open wiki projects such as *Wikipedia*.

In the last few years, a number of researchers and educators in various educational institutions at all levels — from primary to higher education — have experimented with wikis in many different ways. Wikis have been tested as a tool for collaborative note–taking, for making annotated bibliographies, for collaborative writing in students' research projects, and in distance learning to publish course resources such as syllabi and handouts (e.g., Lamb, 2004; Duffy and Bruns, 2006; Grant, 2006).

Several educators and educational researchers have considered wikis as a tool to promote change in pedagogy and educational practices. For instance, Lydsay Grant (2006) has pointed out wikis' potential to provide structures supporting community of practice (Wenger, 1998). Grant also sees wikis as one possible platform to implement collaborative knowledge–building models of learning (Scardamalia and Bereiter, 1994). Experiments and research about educational wikis has mainly focused on situations where the wiki platform is used in a traditional, institutional educational context. In these cases, the wiki has been brought to the educational institution as a tool to enrich the learners' experience.

Learning in and with an open wiki project, such as *Wikipedia*, is very different from the use of wikis in institutional educational settings. In an open wiki project the participants focus on building shared resources that will be available for all. To reach this, open wiki projects have positioned themselves in a digital economy of share and share–alike. This economy means that resources created together are freely available for all, as long as new contributions are also shared under the same terms.

Open wiki projects have borrowed this economic model from free/libre/open source software projects. In a manner similar to that of an open source project, open wiki projects rely a great deal on volunteers. One could argue that this form of collaboration, for open source and open wiki projects, provides new input for the Habermasian ideal of democratic communication and, on the other hand, as completely new forms of civic self–organization and self–management[1]. The nature of democratic collaboration, self–organization and self–management requires from the participants very different kinds of behavior and skills than participation in a study project using wikis inside an educational institution.

Open source and open content projects operate in a second economy[2], also called the amateur economy, sharing economy, social–production economy, non–commercial economy, p2p economy, and the gift economy. The conditions and modes of operation in the traditional commercial first economy and in the second economy differ greatly from each other. The first economy and the second economy work in symbiosis where both need each other. One may claim that the second economy, providing infrastructure, is always serving the first economy.

We may, however, see all of this in a completely different light. It makes sense to claim that the only task of the first economy is to provide individuals resources to participate in the second economy. The differences and relationship between the first and the second economies should be kept in mind when we consider the potential of wikis for education. Thus, to understand this, we should briefly examine the economy of education.

1 For theories on hacker communities, see Castells (1996) and Himanen (2001).
2 For an overview, see Lessig (2004).

Basic education has been considered fundamental to all economies. For instance, Article 26 of the U.N. (1948) Universal Declaration of Human Rights states: "Everyone has the right to education. Education shall be free, at least in the elementary and fundamental stage." Hence education is defined as a human right because it affects peaceful and sustainable development. Education is seen as a vehicle to provide humankind with the tools to meet other human rights.

Locating education in the second economy becomes more obvious when we compare it to more traditional commodities, such as physical products or raw materials. In economic terms education is a service, but even as a service it is significantly different. When you educate someone you enrich your commodity instead of losing it. Every time you increase someone's intellectual capacity you also increase your own intellectual capacity. When you give someone a physical product, you no longer possess it.

Open source and open content projects base their existence in similar positions within the second economy. As a commodity, GNU/Linux does not carry a great deal of exchange value but it has tremendous value to users. Freely available *Wikipedia* might be difficult to sell. Still, millions find *Wikipedia* extremely useful every day. When we think more in terms of 'the use value of education' and in terms of 'exchange value' we start to see education in a very different light.

In order to increase use value, it becomes natural to think about students as teachers, and teachers as students. In an optimal system, everyone will learn and everyone will find results useful. The real potential of an open wiki project is support education as a form of a commons, not as isolated activities operated by experts in institutions. This type of education may also aid the growth of native skills and wisdom already possessed in communities.

3
Metaphors of learning

Sfard (1998) points out that there are basically two metaphors that dominate our thinking about learning — learning as *acquisition* and learning as *participation*. Paavola, et al. (2004) added a third metaphor; learning as knowledge–creation.

In the *acquisition* metaphor, the human mind is seen as a container of knowledge and learning is a process where the learner (or her teachers) fill the container with knowledge (Paavola, et al., 2004). The historical roots of this metaphor can be traced to a time when information was scarce — the production and reproduction of information was expensive. Recently, the trend of considering education as a for–profit activity has strengthened this metaphor. Many individuals have been taught that education has a specific cost. Implementations relying on this metaphor include standardized certification courses with standard materials and tests.

Suppose we examine a family operating a farm. The children in this family would learn from their parents through a process of acquisition. The parents might provide for their children a guidebook and a series of lectures explaining tricks and tips on how to run a farm. Then the parents would arrange a test, giving the farm to their children only when the test results reached a certain specific goal.

In the case of *Wikipedia*, first a person would acquire access to *Wikipedia*. Then she would study some parts of it carefully, and take a test to prove that she was familiar with that specific content. Finally, *Wikipedia* would provide a certificate stating that this individual is knowledgeable in certain, very specific topics.

The *participation* metaphor emphasizes involvement in various cultural practices and shared learning activities (Paavola, et al., 2004). In this metaphor knowledge and learning are situated in individual lives in specific socio–cultural contexts. In this metaphor, knowledge is accessible only by cultural mediation, such as learning by doing and dialogues within the learning community.

In the case of *Wikipedia* it would mean that an individual would start to edit articles and take part in discussions in talk pages. Slowly, she become familiar with the practices of the wiki community and gradually know more Wikipedians. She would learn from more experienced and mature Wikipedians, understaning eventually the culture of *Wikipedia* insiders. At some point she would be given administrator's rights[3]. In sociology, this process is termed cultural socialization.

The knowledge–creation metaphor (Paavola, et al., 2004) is partly based on the works of Nonaka and Takeuchi (1995), Engeström (1987) and Bereiter (2002). All emphasized the creation of conceptual and material cultural knowledge artifacts in communities. Knowledge artifacts are, at same time, part of a community's and all of humankind's collective knowledge. This knowledge is always situated in time and space. Because the situations and contexts of learning change, knowledge artifacts are always unique. What I learned and created today in my knowledge–creation community is different from what someone else learned and created in her community.

Scardamalia (2002) proposed some principles for knowledge–creation communities. First of all the community must focus on authentic problems and real ideas. These ideas should be considered as ideas that can be improved; the diversity of ideas should be seen as a necessity. Work around a set of ideas should be progressive so that the community should create some higher level concepts. All participants have a right to contribute; new knowledge hence is commonly owned. In knowledge–creation, participants should use a variety of information sources and understand these sources critically. In this way the *knowledge–creation* metaphor com-

3 See http://en.wikipedia.org/wiki/Wikipedia_administrator.

bines the acquisition and participation metaphors, but at the same time goes beyond them. The *knowledge–creation* metaphor invites individuals to participate in processes where they not only acquire knowledge, but also create new knowledge usable for a broad spectrum of people.

With the example of the farmer family, knowledge–creation would mean that children could learn farming with their family in the fields, but would also have access to different kind of materials about farming in general (theoretical information), and discussions with other farmers farming in different kind of environments and conditions. In the farming community the participants would share their unique experiences (cases) and native skills. Based on their *participation* when farming, their *acquisition* of theoretical information about farming and their *participation* in discussions with other farmers, the new generation would *create new knowledge* in the context of their own farm. They could evaluate what practices in their parents' way of doing things were good and should be kept and what new ways of farming could be implemented. During the learning process they would also participate in the process of creating collective knowledge, presenting their case and their theories, and in this way, contribute to common knowledge.

In the case of *Wikipedia*, a person would participate in *Wikipedia* editing and administration of the site, but would also aim to do research with others in areas she finds interesting but in which she does not have well structured conceptions. This research would involve developing real study problems as well as hypotheses aimed at solving them, searching for evidence to support these hypotheses and eventually developing conclusions.

As a platform for learning, wikis have the potential to cover all three metaphors. When it comes to the acquisition metaphor, the free/libre nature of wiki content guarantees access and reduces scarcity. This in itself is a great benefit, and promises to equalize and democratize learning when technological and ideological barriers of access are removed. The second metaphor, participation, is the forte of wikis, and could prove to be a similar boon for education and capacity building as it has been for building online encyclopedias. The knowledge creation metaphor is also present in wikis. However in *Wikipedia* the focus is on encyclopedic knowledge — to document and to create content from already existing sources[4].

4 See http://en.wikipedia.org/wiki/Wikipedia:No_original_research.

4
Free and liberal education and wikis

The participation metaphor of learning captures some of the essential parts of free and liberal education. For instance, free and liberal adult education is first and foremost a participatory activity. It is goal oriented and collaborative, and it aims at social as well as individual transformation. For instance Raymond Williams, a British cultural theorist and adult educator, emphasized that education belongs to everyone: "that it is, before everything else, the process of giving to the ordinary members of society its full common meanings, in the light of their personal and common experience." [5]

Free and liberal adult education is always based on and embedded in understanding social circumstances and local realities. Thus it has a direct connection to everyday lives. It stems from a need to solve practical problems by finding solutions together. Three common characteristics for free and liberal adult education are: (1) the diversity of curricula; (2) voluntary nature of participation; and, (3) learner–based study methods. Free and liberal education is often open–ended. It has no ready–made goals, only a problem–based starting point. Thus it has nothing to do with formal curricula "from above" as in formal schooling systems. The other element separating free and liberal adult education from formal schooling is

5 Williams, 1989, p. 14.

voluntary participation. Individuals are not forced to join forces in adult education. Voluntary participation implies study methods which respect participants' experience and ideas. The most common study method has been the study circle. In it, adults share their world views and experiences, building insights in dialogue.

Historically, free and liberal adult education has occurred in many places. Among these are folk high schools, workers' educational centers and civic centers. Additionally public libraries, museums and the free press can be seen as part of a liberal adult education system. Free and liberal adult education is also often linked with social movements in their task of tackling burning social or ecological issues of the time.

In Scandinavia and the Nordic countries, free and liberal adult education has played important role in socio–economical and cultural development. The liberal adult education movement's ideological father was N.F.S. Grundtvig (1783–1872), Danish teacher, poet and philosopher who founded the first Folk High School in Denmark in 1844. Originally Grundtvig wanted to reform existing higher education in Denmark which he saw as educating only scholars who didn't have any connection to the everyday life of ordinary people. He claimed that the university did not serve society. In the Folk High School the aim was to educate people to actively participate in society and popular life. The focus of studies was on practical skills, history and national poetry. The studies were a combination of practical science and humanities with an emphasis on wisdom and equality. "Grundtvigian" educational thinking took over quickly in other Nordic countries where a number of Folk High Schools, "workers educational centers" and "adult education centers" were founded in late 1800s and early 1900s. In 1960s the free and liberal education's significance for socio–economical development, cultural life and people's well–being was widely recognized and various institutions started to receive state subsidies. Today taking voluntary studies in free and liberal adult education institutions is very popular in the Nordic countries. In Finland in 2004, about one million adults (total population of 5.2 million) took some studies in one of the many liberal adult education institutions. Seventy percent of the participants were women (Toiviainen, 1997; Toiviainen, n.d.).

Besides free and liberal adult education there have been several initiatives to reformulate university studies to be more free, liberal, responsible and accessible for their surrounding community. For example, Bertell

Ollman (1985) argued that the university should primarily contribute to the community. According to Ollman, the university should stay true to its critical function to do autonomous research by involving the entire university community in shared, collective, cooperative and multidisciplinary research projects. Ollman continues his idea further in the context of the City University of New York (CUNY): "Why should research be an individual and small group activity? Let 150,000 people take to their pencils and wits together about something worthwhile. Put mass scholarship into motion."

The free school movement is a "second cousin" of free and liberal adult education, for they share many, if not all, of their characteristics such as open–ended curriculum, contextualization in everyday life and problem–based and dialogical study methods. The free school movement has its roots in the critique of national, "closed" schooling systems. These closed systems were seen as central "ideological state apparatuses" with national political bias and direction, and sometimes, as in the Nordic countries, a comprehensive national curriculum. In other words schooling was defined as politically directed with a Western emphasis. According to critics, like Ivan Illich (1971), schooling is harnessed on the wagons of economical utility, and it is directed by the control of content. This control is identified in national and supranational educational policies. In the era of economic globalization, it has been claimed that the main aim has been the production of prolonged exchange value of well–educated citizens. Teachers and students are defined as state subjects and their learning means merely "having" more knowledge and more production and consumption power (Suoranta and Vadén, 2008).

On the contrary, in the free school movement education was not defined as a state–governed "thing" located in institutions like schools. Instead, it was maintained that education was a naturally evolving activity, belonging to people, not to governments. Furthermore education's main aim was to enhance individual, social and spiritual faculties, as well as increase capabilities for self–direction and self–government. One of the early critics of the state–led schooling system, Ivan Illich (1971), examined the ways in which learning was expanding across everyday lives: to the streets and small study corners where one could watch a film or listen a record, and have an educative discussion about it with others. This idea breaks the old dichotomy between masters and students and creates a space where former teachers become students and former students as teachers. No one is seen as a passive, empty vessel. Instead individuals are seen as active creators capable of sharing and absorbing their experiences as well as gradually learning how to assess external information.

It is interesting that already in 1971 llich talks about "learning webs", where people are exchanging teaching and learning based on their needs. In Illich's own words: "The current search for new educational funnels must be reversed into the search for their institutional inverse: educational webs which heighten the opportunity for each one to transform each moment of his living into one of learning, sharing and caring."

Furthermore, Illich defines the good educational system in this fashion:

> *"A good education system should have three purposes: it should provide all who want to learn with access to available resources at any time in their lives; empower all who want to share what they know to find those who want to learn it from them; and finally furnish all who want to present an issue to the public with the opportunity to make their challenge known."*

From Illich's dream, access to resources at any time is becoming real thanks to the Internet, Wikimedia community and other online free/libre content initiatives. In a few years, learning materials in most basic study subjects, in a number of language, will be available online for all for free. At the same time, blogs and other tools provide the means to present issues to the public, just like in Illich's third purpose of a good educational system. The Illich's notion of a free and open "marketplace" has not yet materialized online. However, certain conventions — such as the wiki way of doing things — can be seen as initial steps in that direction.

5
Case study: Experimental course on Wikiversity

To study how *Wikiversity* works and to test the educational approaches presented earlier in this paper we implemented a design experiment in the spirit of Lewinian action research. Action research is relatively commonly used method in social sciences and educational research. An action research starts with fact–finding and planning an intervention in a community, such as a workplace or classroom. Once the intervention is implemented, data is collected, analyzed and discussed with those involved in the experiment.

Design experiments test new ways of teaching or learning in authentic learning environments. The aim is not only to find out what teaching arrangements are most functional or feasible but also to guide theory building on learning. This way design experiments are pragmatic as well as theoretical.

The experiment on *Wikiversity* was started in November 2007 by setting up in the English *Wikiversity* a draft plan for a course described as "Composing Free and open online educational resources". The experiment was designed so that the course could model teaching and learning — that is, combining elements from acquisition, participation and knowledge–building metaphors of learning. From the organizational perspective, the course relied in many ways on conventions common in free adult education.

During the experiment we collected quantitative data from the server logs of the wiki server and qualitative research data from participants. The emphasis was on qualitative data gathered by close contacts with those participating in the experiment. The data collection methods included observations with detailed note–taking, and structured feedback discussion on a wiki page and in a videoconference session.

On 10 December 2007 the first course schedule for nine weeks was released with a start for class on 3 March 2008. This schedule included an introduction to the course, an explanation of target groups, objectives, and information about class meetings, assignments and a draft weekly program with titles. Also, the names of class facilitators and their blogs were included.

In the first draft description of the course we stated that it was open for all. We emphasized that it was not self–study, like many courses in *Wikiversity*. Indeed this course was akin to other online classes with pre–defined weekly content and assignments. Individuals interested in the course could simply register by adding their names/nicknames, e–mail and blog addresses to the wiki page.

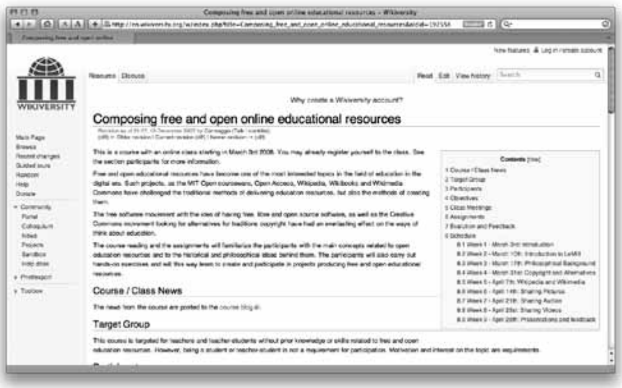


Figure 1: Experimental course on Wikiversity.

Releasing this course description immediately sparked some attention in the Wikiversity community and online communities at large. The news was fast replicated in several mailing lists and blogs. By 3 February 2008, a month before the course was scheduled to start, there were 17 registered participants. By 23 February, 10 days before in advance of the course, there were 51 registered participants; on 3 March, there were 72 registered participants.

All of the course pages on *Wikiversity* were publicly compiled and changes to the pages were made live. This public alteration of the course allowed anyone to follow the course as it evolved. The open wiki way invited individuals to contribute to course planning. However, we did not make it explicit.

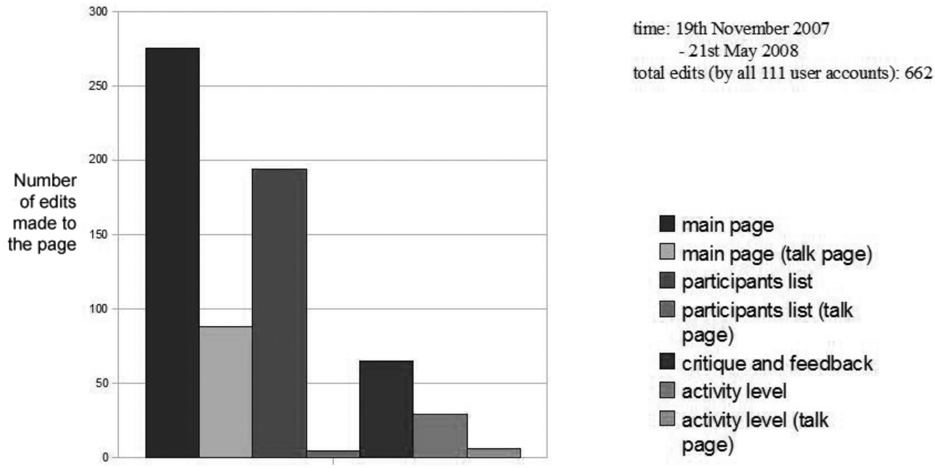
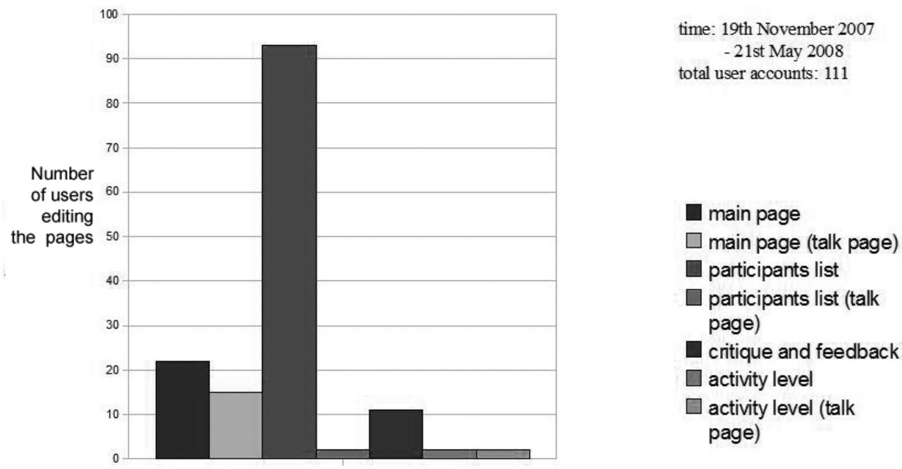


Figure 2: Number of edits for different pages about the course.

Figure 3: Number of users editing different pages of the course.

Data from course editing provides some insights into about the activities of participants during the planning period and the actual course. The main page was edited more than 250 times (see Figure 2). Most of the edits were done during course planning. The page with a list of participants was edited almost 200 times. The talk pages of each wiki page were not very active, though they received several comments and questions related to practicalities about the course. However, it is worth mentioning that the main social interaction in the actual course was not intended to take place in Wikiversity but on the participants' own blogs.



The main course page was edited by over 20 people (see Figure 3). Based on the revision history, most edits were small language corrections and formatting. Still, three participants, in addition to the two facilitators, contributed strongly to course content, program and assignments. In discussions with those three participants who contributed a great deal to course planning we discovered that two were contemplating a similar course, whereas one was an active *Wikiversity* community member.

The total number of users editing the participants' list was more than 90 (see Figure 3). When the course started, the list contained 72 registered participants. After the first week of the course we counted 39 participants working on the course and in the end of the first week 25 participants had completed their first assignments.

Participants' feedback regarding the course was in general positive. The original structure divided the course in two parts: 1) theoretical introduction to the topic with reading and assignments related to them; and, 2) hands–on exercises — where participants were asked to make open educational resources — was found meaningful and useful.

> *"I liked the mixture of theory and practice — so I not only got to know the concept of OER, I also saw some very good examples & I applied my gained knowledge."* (Participant A)

> *"The most satisfying experience was the 'The learning by doing' part of the course. I was looking forward to the following week's assignment, as it was becoming more and more interesting, however more challenging."* (Participant B)

The communication tools used in the course — blogs and wiki — were found by most participants rather confusing and sometime frustrating. Also, the facilitators found it difficult to follow all of the different blogs. Although some participants tried to improve communication by providing guidelines on how to add all of the blogs into a single blog reader, the complexity of communicating with blogs was widely recognized as a major challenge. The use of blogs, however, supported the idea of individual learning diaries. They were easy tools to post and share assignments among participants, but did not facilitate community building. One participant noted:

> *"Probably the lack of class community. Most of us (all?) are still strangers, despite our use of public blogs."* (Participant C)

To improve the course, participants proposed more collaboration and live events with video or audio conferencing. Group work assignments were considered to be one way to build a community and allow participants to learn more about each other.

> *"The videoconference at the end of the course was nice — it personalized some of the participants and made me think that it would have been nice to have met this way in the middle of the course."* (Participant D)

> *"I think that a synchronous meeting in the beginning or half way through would have been awesome — I know it's hard still I would have liked to get that feeling."* (Participant A)

As a result of this experiment, we think that an open course with a program and weekly assignments on *Wikiversity* is feasible. The course can be very useful to participants. The open nature of course planning allows a larger group of individuals to bring their expertise into the course.

6
Discussion and conclusion

The Internet is forcing educators to reconsider their thinking about education. Wiki technologies are challenging traditional metaphors of learning. Online collaboration and publishing with Web forums, blogs, and wikis seems to favor more participation and knowledge–creation metaphors than the acquisition metaphor.

Both free and liberal education and open–wiki projects emphasize community, democracy and communities' ownership. Both see individuals as active participants in communities with responsibility to their development. In this way free and liberal education and open–wiki projects share many common values and practices.

There are, however, also areas where free and liberal education differs from existing open–wiki projects. With our experimental course we tested the open–wiki project's ability to move from its current practices to present some of the practices of free and liberal education. We found that it can happen but may require widely accepted conceptual change in the Wikiversity community. Based on the analyses of the differences and similarities of open–wiki projects and free and liberal education as well as the results from the experiment, we conclude with the following recommendations:

PEOPLE FIRST. Probably the main difference between free and liberal education and open–wiki projects relates to focus. In classical free and liberal education, people are the center of educational efforts. The aim of the community is to have an impact on the lives of individuals. In a "classical" open–wiki project the focus is on the wiki site. The aim is to build wiki pages.

This difference is remarkable. It can be illustrated with an example. The aim of the *Wikipedia* community is to create the world's best, free, multilingual encyclopedia. The focus in on content. In the case of a free school, the focus on content could mean that the school's objective would be to create the world's best school library. In a similar way, the free school's objective of offering people possibilities to develop as human beings — to fulfill their psychological, social, emotional, intellectual and spiritual needs — is not the main objective of *Wikipedia*, though it obviously has this effect on many lives, too. Still, the aim is to make an encyclopedia. In *Wikiversity* it should be different and make its community members the center of its activities in order to ultimately assist individuals to develop and grow.

CLASSES. Putting members of the *Wikiversity* community in a central role provides an opportunity to develop new options. To increase the accessibility of *Wikiversity*, a new option could be organize study projects or classes. The structure of a *Wikiversity* class could include traditional elements such as a title, introduction, list of participants, schedule, syllabus, objectives, and possible means of evaluation — if these elements are important to participants in a given class. Ultimately a given class should reflect the needs of the community since the community will propose, develop and accept classes over time.

SOCIAL INTERVENTIONS. The *Wikiversity* community should actively recognize groups that would most benefit from further developments in the diversity of offerings in *Wikiversity*. Indeed *Wikiversity* should be pro–active in reaching new audiences, such as those with reduced opportunities for education. In free and liberal education, the focus is on those who have less favorable combinations of circumstances in their lives and in society. *Wikiversity* can assist the disadvantaged in a variety of roles much like free and liberal education has served social change globally.

COMMUNICATION TOOLS. *Wikiversity* needs to diversify its suite of options for communication. Integration of free/libre VoIP online conference tools would open *Wikiversity* to group work, assisting a larger number of individuals in creating additional content and offerings online.

TRANSPARENCY OF AUTHORSHIP. In the case of *Wikipedia* the idea of developing content without visible attribution as a collaboratively edited system makes sense. In the case of *Wikiversity* this does not make sense. With classes it will be more important for participants to literally know other participants and their instructors.

FREEDOM OF POINT OF VIEW, NON–VERIFIABILITY AND ORIGINAL RESEARCH. Crucial *Wikipedia* policies — neutral point of view, verifiability and non–original research — should not tie *Wikiversity*. In a class participants should be free to take whatever point of view and use whatever sources they need. Participants should be encouraged to use unconventional forms of communication and representations of knowledge including music, dance, paintings, and poetry. The community as a whole, however, should hold final word on the value and virtue of different sub–communities working in *Wikiversity*.

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SOFTWARE AS HYPOTHESIS: RESEARCH-BASED DESIGN METHODOLOGY

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Abstract

KEYWORDS:
Design methodology, method, human-centered, education, learning, software

Recently design has been discussed in areas of research outside the traditional fields of art and design and engineering. Meanwhile design practitioners increasingly use methods from social sciences. Completing three design cases dealing with educational technology we have developed a human-centered research-based design methodology where software prototypes play an important role. Although the methodology builds on theories and methods from social sciences and educational research the context is design. Through analyses of the patterns identified in the cases we conceptualized the intentions of the methodology and created a model of an iterative research-based design process. Research-based design emphasizes serving users and the iterative process consists of four partly overlapping phases: contextual inquiry, participatory design, product design, and production of software as hypotheses. In the hermeneutic cycle all research and design operations increase researchers' and designers' understanding of the context and factors in all the phases. Firstly this article contributes to the discussion of using design in educational research. Secondly it contributes to the philosophical discussion of designing tools for complex social systems. Thirdly it presents a model of a design process for practitioners interested in carrying out research-based design with software prototypes.

1
Introduction

The word "design" can be understood as both a verb and a noun. An example of the former is Archer's [1] concept of design as the process of thinking and communicating. According to Victor Papanek [41] "all men are designers". For him design is basic to all human activity: "The planning and patterning of any act toward a desired, foreseeable end constitutes the design process".

The result of design is a product: design as a noun. The product, an artifact or a tool, is the end of the design process. In art and design tradition the product — how it behaves and what it communicates — is in the center of the activity. As the focus is on product and its affordances [20, 39], the process of designing things becomes extremely important. The big question is how do you create meaningful products?

In this article we will present a type of design research in which social studies, playfulness and product prototyping, in our case software, all plays an important role. Our way of doing design research can be considered a design methodology but also a wider philosophical approach to design. It has been developed in three research and design processes, all carried out in the field of educational technology, more precisely, educational software. The focus, however, is not only the software, but also, how it affects the environment in which the software is used.

In the design of tools we are interested in understanding how people live, work and play with them. We consider the tools and people from a range of perspectives, involving psychological, socio-psychological, sociological, ethical and aesthetic points of view. The theories used in the design process come from these domains.

The aim of the design research methodology discussed in this article has been, to develop novel and unique educational tools that will enhance learning. The tools designed are:

- Fle3 - Future Learning Environment: Virtual learning environment for Progressive Inquiry learning (http://fle3.uiah.fi),
- MobilED - Audio wiki / encyclopedia for mobile phones (http://mobiled.uiah.fi), and
- LeMill - Web community and platform for finding, authoring and sharing open and free learning resources (http://lemill.net).

In the three design cases, we have based our work on a view of social reality in which people are active in shaping the social conditions they live in. People affect their environment and design artifacts, tools, spaces and practices that have an effect on their relations with each other. From the point of view of designing new tools, this means that often people do not know what kind of tools they really need. The significance, the meaning and the opportunities of the tools, are realized in the real world only. For this reason, the new tools should be created in open communication between the designers and the people, where people become designers and designers become people. In this respect the approach is indebted to Jurgen Habermas's conception of life world-supporting communicative rationality [22, 23].

We also want to emphasize the word "research", even though we practice design. First of all, research in design means that we are experimental. Our experiments may result in the failure of the product. This makes design research different from design for customers, where failures are tolerated much less. Secondly, research means that in the process we are as systematic and analytical as possible. Still, we try to keep ourselves open to serendipity. Sometimes the outcome can be something entirely different than expected. The solution designed may actually solve a design challenge we did not even see when starting the process. This can be compared to pharmacological research, where the discovery of a new medicine has positive effects on something entirely different that what it was originally thought to cure.

2
Theoretical foundation for design

This section presents several theoretical research approaches in social sciences and educational research, and their effect on design research that is focusing on designing tools. The traditions of action research and developmental work research will be discussed first as they are important theoretical foundations closely related to each other, and in part the basis of our methodology.

2.1. ACTION RESEARCH AND DEVELOPMENTAL WORK RESEARCH

The main principle of action research is that the targets of the research also participate in the research process. [30]. The principles of action research are opposite to the view that researcher in behavioral and social sciences should be neutral and not interfere with the processes taking place in his or her target of research [17].

An essential part of action research, according to Lewin [33, 34], is the change experiments [17]. Engeström points out that a change experiment differs from a traditional laboratory experiment in many ways. The former does not even try to standardize all possible variables affecting the situation. A change experiment makes it possible to gain a deeper understanding of a phenomenon, and explore the mechanisms that cause phenomena and discover paths that can lead to change.

A Lewinian change experiment starts with fact finding. The planning of the intervention is served by mapping the present situation, including the difficulties of action and how people perceive their situation. The intervention and any changes occurring are thoroughly documented, after which a final mapping takes place [33].

The findings of the change experiments are evaluated and discussed among the researchers and participants. Alongside the field notes, theoretical interpretations are made of every sequence in the change experiment [17]. The process of research can be described as a spiral, where every case consists of planning, interventions, observation and data collection, analysis and conclusions. The research frame is not constant; it changes along with the research process and the constant evaluation and re-evaluation process [33].

Developmental Work research argues that to analyze work processes one should focus on the whole system of action instead of just the accomplishment of a task [17]. According to Engeström, who based his theories on Vygotsky [53], Leontjev [31,32] and Luria [36], tools and language shape human beings while they also provide opportunities to influence and create the world.

Developmental Work Research has developed a theory of an activity system consisting of a subject, an object and a tool, and the context in which the activity takes place. The context is the community with a division of labor and rules affecting the subjects. The introduction of a new tool influences the whole activity system. However, the effects are hard to predict because human beings are reflective actors. In a human activity system there are different perspectives and different voices. The community, which the individual belongs to shapes the voices, but at the same time, the individual himself forms his own voice. A diversity of voices — the different ways of acting and thinking — is not allowed when there exists a sharp division of labor and everybody is strongly attached to their own place in the community. In an expanding learning process, on the other hand, the diverse ways and models of action and thinking in a community are shared and developed into reciprocal interaction and evaluation [17].

2.2. THE DESIGN-BASED RESEARCH APPROACH AND DESIGN EXPERIMENTS IN EDUCATIONAL SCIENCE

In the last twenty years design has been discussed in many areas of research. In the field of learning science, design-based research has been introduced as a new approach to research on teaching and learning [5,7]. According to the Design-Based Research Collective [12], the focus is on innovations and interventions, which can abstract entities such as activity structures. Thus the focus goes beyond merely designing and testing innovations the "interventions embody specific theoretical claims about teaching and learning" [12].

Design-based research differs from psychological experimentations in many ways. The former should take place in an authentic situation. According to Barab and Squire [2], who base their arguments on Collins [9], the focus should be on the learning process and interaction among the participants. This requires a new kind of data collection and methods of analysis. Design-based research often implements "design experiments", which are presenting new ways of teaching and learning that are then tested in a real learning environment [51]. On a more general level the design-based research approach seems to ask for a change from quantitative laboratory studies to studies taking place in authentic situations.

Design-based research differs from basic research in that it always focuses on producing concrete changes in the real world instead of simply testing a theory [2]. Therefore, design-based research shares some common features with action research. However, design-based research also tries to create formative evaluation methods that could prove some practices or "design" to be usable in other settings. The aim is to create theory and the design is used as a means to achieve this. Barab & Squire base their arguments on a pragmatic philosophical approach according to the thinking of John Dewey [14], in which the value of a theory is its ability to produce changes in the real world.

For us designers — for whom the product is the end result — design-based research results look tame. The product should first communicate the theoretical findings made during the design process. Even if the process is developing a new theory or concept, the design or product should communicate these in an innovative, sophisticated and clear way. The design can be an extensive combination of process and system descriptions as well as collections of tools and artifacts. Design, for us, is the end. In comparison, for design-based research, design is a means, not an end. In design-based research design is an instrument used in the research.

3
Design and design research

It seems that science is about thinking, and design about acting. However, if we go back to the pre-Socratic era we will see that the concept of wisdom (sophia) actually meant both thinking and acting. Only later were they separated from each other. Today, thinking without doing has a higher status than making things. Establishing the academic foundations for the design tradition is an attempt to create a renaissance of sophia, that is, an "integration of reason with observation, reflection, imagination, action and production" [37].

3.1. DESIGN THINKING

As an academic discipline design and design research are young. As a practice design is as old as humankind. Today design is not an established form of inquiry such as science and even art. However, design practices share features in common with both science and art. The main difference is that while science attempts to investigate the world to gain a universal and general understanding of it, art always carries the intention to produce changes in the world: to offer new perspectives and interpretations.

The processes of inquiry in science and art are different in terms of their emphasis on the importance of the path to the goal. In science, the methods, the way to gain the results, is extremely important, while that is not necessarily the case in art [29,21]. In artistic research the focus is on the work of art and its audience. The aim is to offer people new meanings [21]. The contemporary art community stresses the originality and genius of the artist rather than scholarly acquired handicraft skills [35]. In this respect, strict science with a commitment to certain scholarly methods is actually closer to handicraft than art is.

Design is somewhere between art, science and handicraft. Design has methods, but at the same time, the originality and ingeniousness of the work is highly appreciated. Also the designer's way of achieving the end product is practically irrelevant as long as the product is good.

Problem solving is an important part of the practice of both science and design. There are, however, many differences between the two approaches to problem solving. In design, the fact that problems are wicked incomplete and often contradictory is taken for granted [37, 44, 45]. Designers can see that a problem has multiple solutions and that every formulation of a problem is at the same time an attempt to solve it. Wicked problems are difficult to recognize, and often an attempt to solve one creates another, even more complex problem. According to Nelson and Stolterman, ordinary problem solving is reactive to unwanted states, while designing is about creating a positive addition to the present state. The designer cannot assume that the "perfect design" is there, waiting for someone to discover it. Instead, the design is achieved by intentional action.

According to Archer [1] design thinking is "as powerful as scientific and scholarly methods of inquiry when applied to its own kind of problem". Design is a holistic activity where the smaller units of the design process must be preformed with the whole design in mind. In Donal Schön's words it requires the skills to "recognize and appreciate desirable or undesirable design qualities" [50]. For Schön, the activity of design is a "reflective conversation with the materials of a situation" [50]. This means that the designer partly invents her own way of doing things every time she begins a new design process.

Despite the limitations of scientific methods in solving design problems, we should not underestimate the value of scientific information and methods in design inquiry. One should be able to move smoothly between design thinking and "scientific thinking", which we can use to inform us of meaningful problems. The challenges should come up from a reality that is complex and only partly understood with the scientific method. From the "scientific facts" one may then move to intuitive design thinking, looking for new artifacts that could be placed in complex reality. Donald Schön calls it artistry [50].

3.2. PLAY IN DESIGN

Design thinking requires freedom to play with ideas. Innovations seem to be born more often in a process of playfulness and curiosity rather than with rational thinking. The initial phase in the design of a new tool is closer to play than real use. Later it is standardized. It becomes more rational and begins to have instrumental value. In the next phase the functions of the tool are redefined, and it becomes transformed into a piece of art. This seems to be the case with many new technologies. At first the mobile phone was a "yuppie toy" which nobody really needed. In the second phase, people started to see its value in everyday life. Today mobile phones are widely used as a material in modern art.

In practice we have seen that design benefits from environments that enhance playfulness. Play enhances learning by evoking zones of proximal development [28]. It is important to engage the playfulness of those who are expected to use the tool being designed.

Two practices of inquiry, art and science, contain elements of what Csíkszentmihályi [10] calls autotelic reward. These activities are rewarding for their own sake. Both art and science promote playfulness, and a combination of these can increase the benefits of play even more. This includes playful experiments that give researchers, artists and designers time for creative work; that is, the testing of various ideas and concepts in practice [52].

Software programmers working on free and open source software have said that their main reason for work is not money but their passion to program. This attitude has been called "hacker ethics" [26]. Hackers programming online are like children playing in a playground. In practice hackers simply solve puzzles in a collaborative environment. Naturally, playfulness requires at least some degree of freedom from urgent necessities. It flourishes best in conditions that resemble a child's situation [4]. The hacker's work ethic has its roots in the idea of a passion that guides intellectual activity. This can be seen as derived from Plato's Academy, where intellectual activity was guided for it s own sake, for the love of wisdom: sophia [26]. Despite its imperfections, the modern academic environment can provide some degree of freedom for playfulness, which is an important factor in research-based design.

3.3. HUMAN-CENTERED DESIGN METHODS

Human-centered design — often called user- or customer-centered design — is a design approach in which designers primarily focus on the user's needs [39], moment when using it. The human-centered design trend has partly heated up some methodological discussion on how the user can be put in the center of design process.

Several writers [38, 27] have called design to move from the focus on the user of some product to the human activity system as a whole where the product will be used. The discussion, however, has been mostly theoretical and has not brought much input to the practice of daily design.

Several researchers have pointed out the interdependency between software and the working process. Pelle Ehn already stated in the 1980s that design of computer support for work was in fact designing the labor process [3]. Ehn is often referred to as one of the earliest practitioners of participatory design. Consequently, we see that the design of educational technology is therefore the design of the learning process. It is not just about providing products to preexisting learning processes.

In participatory design those using technology are recognized as the prime source of innovation. Design ideas arise in the collaboration of participants with different backgrounds and expertise. This is why designers prefer to spend time with people in their everyday life situations rather than test prototypes in laboratories. Problems arise from the real context of people's lives. The problems are then defined and articulated in collaboration with a number of stakeholders. Neither the problems nor the solution should ever be imposed from the outside.

This means that during the design process the artifact is seen as a hypothesis of the kind of tool that could work in the actual context, situation and process. The hypothesis is aligned closely with research on the situations and in collaboration with the people who are going to use the product. In part, the process of using a tool is designed simultaneously with the design of the tool itself. In this way diverse ways of action and thinking that already exist in the community are strongly linked to and communicated in that process.

When a wider group of practitioners is asked to take part in the designing process, they will bring their tacit knowledge [42] into the process. This knowledge can also be seen as community-based instead individually based. The aim is to make the tacit knowledge as explicit as possible. This happens by producing documentation of the design sessions in the form of videos, pictures, audio and written texts.

On the other hand, tacit knowledge is also transferred among the participants in very informal and implicit ways. For instance, Pelle Ehn used to organize football matches with the office workers and computer scientists designing computer systems for them [16].

While working, playing and living together, people will slowly start to understand each other's values, preferences, ethics and aesthetics. The designers designing and developing the actual tool will become more than simply visitors in the "culture" whom they are designing for. The design is ultimately done by a group, where the designers are just members. At its best the final product will embody the tacit knowledge [42] of the practitioners.

4
Three cases of designing software as hypothesis

In this section we will briefly present three design cases and the final products. Each tool designed is novel, though there are a number of projects that have developed products with similar functionality and aims. For instance, in the design of Fle3 we have been greatly influenced by the Bereiter's and Scardamalia's Computer-Supported International Learning Environment [48]. In the design of MobilED audio wiki we have taken a close look at several experimental audio information services and applications developed previously by a number of people [18, 47]. In the design of LeMill we have been inspired by such products as the MediaWiki (http://www.mediawiki.org) MIT's Open Courseware (http://ocw.mit.edu/), Connexions (http://cnx.org/), MERLOT (http://www.merlot.org), Pachyderm (http://www.nmc.org/pachyderm), and Educommons (http://cosl.usu.edu/projects/educommons/).

4.1. FLE3 - FUTURE LEARNING ENVIRONMENT

Fle3 - Future Learning Environment (http://fle3.uiah.fi) is a virtual learning environment designed to support the Progressive Inquiry pedagogical method [24, 25, 51]. The design challenge was defined to be a lack of student-centered knowledge building activities in schools. The hypothesis was that a computer supported collaborative learning tool could help teachers and students to change their pedagogical practices.

Fle3's main tools are: personal Webtops for learners to collect information; Knowledge Building area for collaborative, constructive discussion whose aim is to increase the group's level of knowledge and understanding about the topic; and Jamming for collaboration in designing digital artifacts.

The theoretical foundation of Fle3 is social constructivist learning and Lev Vygotsky's idea of zones of proximal development [53]. Fle3 aims to increase students' and teachers' quantity and quality of discussion, argumentation and negotiation on topics under study [11] and this way help them to reach new zones of development.

The main development of Fle3 took place during 2001-2002, and continued the work done on Fle2 (2000-2001) and FLE (1998-1999). During this development of the design a number of participatory design sessions took place with teachers, pupils and educational experts. Three prototypes (FLE, Fle2, Fle3) with each tens of versions were developed and offered to teachers and pupils for testing, evaluation, and actual use at different levels of education. Activities and feedback from users were then analyzed and acted upon by the designers and developers in producing the next iteration of the tool.

Parallel with the design and development of Fle3, concrete learning and teaching methods have been developed on the basis of collaborative and social constructivist learning theories. This way one of Fle3's main purposes was to facilitate and support the development of the Progressive Inquiry method and to help in validating the pedagogical approach.

Fle3 is used on all the major continents and has been translated into more than 20 languages. It is being used at primary, secondary and university level education, as well as in informal learning.

4.2 MOBILED - MOBILE LEARNING TOOL AND SERVICE

MobilED (http://mobiled.uiah.fi) is a mobile learning tool and service originally designed in a context of formal learning in schools in developing countries. The design challenge recognized was a lack of quality learning materials and creative way of using information and communication technologies.

MobilED platform design offers an access to audio wiki – a collaborative information system. The server makes it possible to use MediaWiki server as the Content Management System of audio information system. Mediawiki is a feature-rich Open Source wiki engine written primarily for Wikipedia, the Free Encyclopedia. Wikipedia defines wikis as "a type of website that allows users to easily add, remove, or otherwise edit all content, very quickly and easily, sometimes without the need for registration".

MobilED tool was designed in a number of participatory design sessions taking place in India, South Africa and Finland. The iterative process was started in 2004. The first prototype was tested in two schools in South Africa in March-July 2006. A large part of the work took place in two South African schools, where teachers were involved in planning of pilots, video recording of classroom activities and semi-structure interviews of pupils.

As the process continued, we reformulated the original design challenges. We found out that the tool developed could fit better to the lack of independent, community-run information systems. We realized that community-run information system such as MobilED could help communities in informal learning. In this way the original design challenges were redefined along with the contextual inquiry taking place in the design process [19].

4.3 LeMill - Web Community for Authoring and Sharing Learning Resources

LeMill (http://lemill.net) is a web community for finding, authoring and sharing open educational resources. The design challenge recognized was that European teachers do not share their learning materials and do not improve them hem in a collaborative way.

LeMill software is similar to a wiki: all learning resources can be edited and improved by other people. In addition to editing learning materials LeMill offers tools for social networking and matching of interests among the participating teachers.

LeMill was designed and developed by an international team located in four European countries. The work started in 2005 with participatory design sessions in Estonia, Finland, Hungary and Norway and the first functional prototype was released in 2006. The prototypes were discussed in focus group interviews in Hungary and Estonia. The first phase of school evaluations was carried out in 2007 in Estonia, Hungary and Lithuania.

The design process was carried out using the principles of scenario-based design [6] and agile software development methods [49]. Designers wrote short scenarios describing how teachers could use the potential system. Participatory design sessions with one researcher-designer and two or three teachers were organized in Estonia, Finland, Hungary and Norway. At these sessions the teachers read the scenarios, and then discussed each scenario in a structured discussion led by the researcher-designer. Then the participants were asked to visualize the planned system as they imagined it and explain their drawing. The researchers recorded the sessions with an audio recorder and wrote summaries of them.

During the design process we kept in mind that we were designing unique software and that there was not much that could be copied from existing learning resource authoring tools. When analyzing the feedback from users, we had to take into account that often people do not know what kind of tools they really need and their wishes are influenced by tools that they are currently using. Our hypothesis with LeMill has been that learning resources can be created by communities of practice, if they have simple web-based tools that provide a clear structure for learning resources.

5
Research-based design: software as hypothesis

During the three design processes we realized that our research-based design is closer to artistic research than to science. Similarly to artistic research, the aim of the research-based design is not only to produce new artifacts, but also to produce new knowledge about the formation of these artifacts, and at the same time, knowledge of the particular research subjects the artifacts are related to. Our software prototypes have been the new artifacts communicating the hypothesis: their aim has been to answer to the design challenges. Within the design process we have been able to relate our practice to difference dimensions of design and conceptualize our research-based design process.

5.1 DIMENSIONS OF RESEARCH-BASED DESIGN

To illustrate the research-based design approach we have compared it to the Nelson and Stolterman's model of contract intentions in a design [37]. They divide the contract intentions in a design into the four main categories as seen in the Figure 1.

Nelson and Stolterman make a distinction between, helping (or fixing) and service. Connecting their arguments to Remen [43] they claim that "in a helping relationship all power and resources reside within the 'helper', leaving the 'helpee' in a position of being indebted." [37]

Remen [43] sees fixing as a process, which is motivated by a reaction to a perceived inadequate state. A service relationship is instead a relationship between equal parties, between the designers and the people who will benefit from the design. Thus a component of service should be to define the design process. Other intentions are present to various extent, depending on the situation. Without the service-relationship, however, Nelson and Stolterman claim there is no process of design.

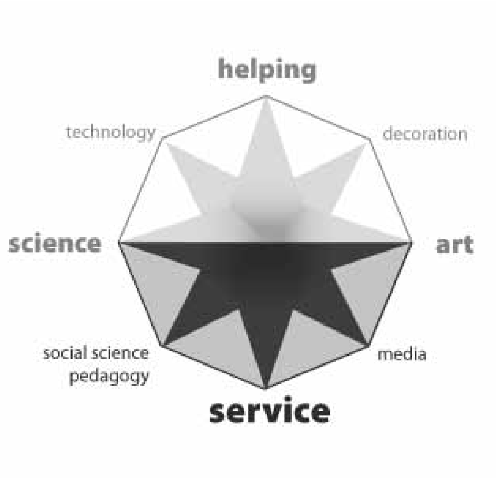

Figure 1: Intentions of research-based design.

Research-based design has a "service" approach to the people who are going to use the artifact. This can be clarified with the help of Jurgen Habermas' distinction between a cognitive technical form of rationality and a communicative rationality. The former is focused on developing the means to achieve given goals while communicative rationality is focused on forming a shared understanding of meaning and on which goals are worthy of achieving [22, 23].

In our research-based design methodology, there are more dimensions present besides the service, science, art and helping elements. Within the three design experiments we have noticed that we often work with something that can be located between these main dimensions. We have named the half-cardinal dimensions to be media, social sciences/pedagogy, technology and decoration.

From all eight dimensions we emphasis service, science and art, but special attention is also given for the hard-cardinal points between then: (1) social sciences and pedagogy, and (2) media. The service approach means that our aim is not to produce knowledge or artifacts on behalf of the people who participate in the study, but in collaboration with them. The researcher-designers therefore do not have a monopoly on defining the challenges for research.

The results from the contextual inquiry build on the social sciences and pedagogy and partly contribute to them, too. We also want to produce knowledge about how the use of ethnographic methods can influence design process.

Media is situated between service and art. Media is close to service because the idea of what the recipient wants is never fixed nor one-dimensional. The role of the recipient in the creation of media is a subject-position. The media that the designers provide can influence this subject, but he can also legitimately challenge, redefine or reject the views that the media offers him.

Technology is situated between science and helping. In the tradition of technology (defined as the scientific and systematic way of developing techniques), the emphasis has been on the means to achieve a goal instead of contemplating which goal to achieve [35]. The application of scientific knowledge is a defining feature of modern technology. Relatively little attention to technology "per se" is one of the principles of human-centered development, which starts with users and their needs rather than with technology [40].

Decoration is situated between helping and art. The goal of decoration, like technology, is to achieve a given goal: to increase "beauty", for example. Instead of the application of scientific principles, decoration applies artistic principles: imagination, creativity and genius. But often, decoration is tied-up with a fixed view of the beautiful, the pleasant, or the desired, as well as on view of the needs of the recipients. Therefore, it is hard to leave an original legacy behind. In decoration, as well as in technology, the needs of the users are perceived one-dimensionally. If the users reject decoration or technology, a redefinition of the goal does not occur. Instead, the fault is found in the singular user's "taste" or in the (technical) skills of the accomplisher of the tool or the artifact.

5.2 RESEARCH-BASED DESIGN PROCESS

Within the three design processes described earlier we have noticed that people create meaningful ways of using the tools that surround them, and, from the perspective of tool design, often do not know beforehand what tools they really need. The significance, the meaning, and the opportunities of the tools are realized only in the real world. Thus we aim to design tools in an open dialogue between designers and participants and provide them with software prototypes.

The relationship between social action and tools can be illustrated with an example from school architecture. An auditorium and a teacher's podium are tools that form learning spaces. They quite openly communicate and support certain type of teaching and learning. In complex social activity systems, new tools bring changes to existing activity systems. A new tool should communicate the chances needed in the system. In our context of educational technology this means that our artifacts in part communicate what learning could be.

Our process of research-based design is divided into four iterative phases, which happen partly in parallel: (1) contextual inquiry, (2) participatory design, (3) product design, and (4) production of software as hypothesis (see Figure 2). The process is deepening, hermeneutic circle where all research and design operations that are carried out increase researchers and designers' understanding of each other.

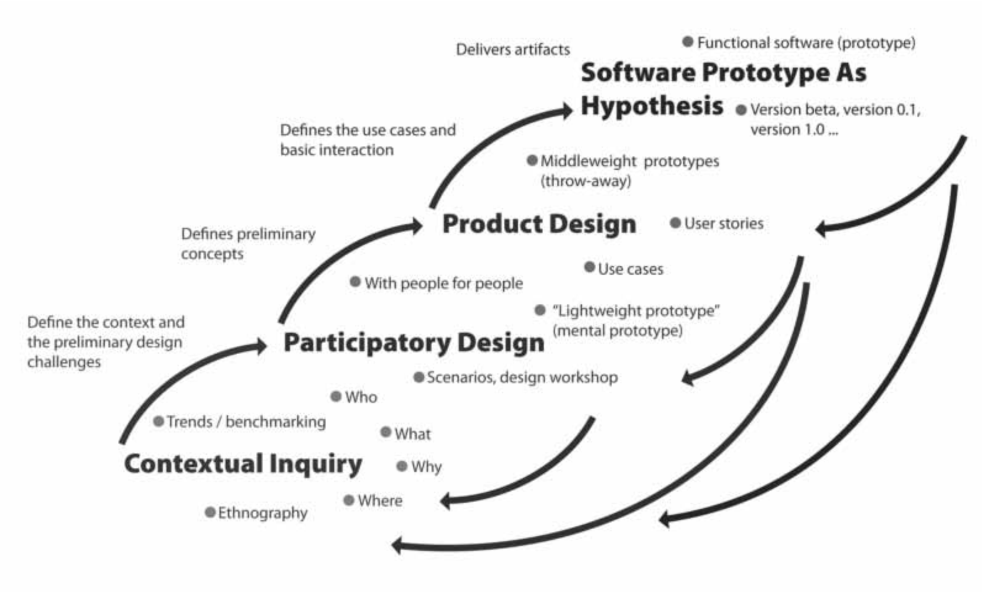

Figure 2: Research-based design process: contextual inquiry, participatory design, product design, and production of software as hypothesis.

CONTEXTUAL INQUIRY. The process begins with a contextual inquiry in which the context and preliminary design challenges are defined. This means a clarification of whom we are designing for and with, what the design challenges are, and why they should be solved. We use ethnographic methods and benchmarking of the environment and the "landscape" to recognize preliminary design challenges.

In the case of Fle3 - Future Learning Environment, the context included a Progressive Inquiry into school learning and the use of computer network systems to facilitate qualitative learning. In the design of MobilED the original context was school learning in developing countries, but later in the process the context changed to communities in general, all with a need of self-organized community media services. In the case of LeMill the context was the need of European schools for more efficient exchange of learning materials, as well as the use of teachers' expertise to build new and novel learning materials, and to promote an exchange across Europe of the best teaching methods and tools.

PARTICIPATORY DESIGN. In the second phase we use participatory design methods to involve people in the design process in artistic and playful ways in design workshops. We prepare scenarios, sketches, and mental and light physical prototypes. The goal is to define the design challenges and the preliminary design concepts.

In Fle3 design process, we organized a number of sessions with teachers and pupils from several European countries. The sessions included looking at paper prototypes and writing user stories. Furthermore, tens of teachers and hundreds of students have been using Fle3; from these pilots we have collected both quantitative and qualitative data from server logs and interviews with the participants. In the design of MobilED we were in close contact with many experts in Finland and South Africa, including teachers and their pupils. Most of the design workshops — including discussions, scenario building and testing in a real school context — were observed and documented with pictures and videos. In LeMill design we worked with groups of teachers from Finland, Estonia and Hungary, carrying out participatory design sessions with scenarios and paper prototypes as well as thematic interviews and discussions. The sessions were audio recorded and later analyzed by the designers.

PRODUCT DESIGN. Based on the participatory design sessions, the third phase attempts to define use cases and basic interactions using user stories and throwaway prototypes. The aim is to give more concrete form to the ideas presented in the participatory design sessions.

In Fle3 design we used a number of paper prototypes as well as screen prototypes to share the early ideas with teachers and other experts. Based on the feedback we continued writing user stories which were then used in the functional software prototype development stage. In MobilED design we produced video prototypes with use scenarios to share the design ideas and concepts with a wider community of stakeholders. In LeMill, we wrote user stories and made prototypes to conceptualize the ideas from the participatory design sessions. In both Fle3 and LeMill, we often released an early beta version for people to take a look at and give us feedback on the direction we should take in further development.

PRODUCTION OF SOFTWARE AS HYPOTHESIS. In the last phase a number of artifacts are delivered: from early functional prototypes to more feature-rich applications. The aim is to build functional software prototypes for and with the community and to see what effect they have on the environment and the community using them. The prototypes are hypotheses, potential solutions to the design challenges defined in the process.

Each of the design cases described earlier has produced functional prototype software that has been tested with a number of users in different contexts. The testing and feedback gathered from the pilots in which the prototypes have been tested have increased our understanding of the context and also resulted in changes in it. Simultaneously, this has had an effect on the design process and the final product under development. The focus of the design has not been on the artifact alone, but on the whole system of people and their activities. Thus, our research-based design focuses on people and their activities, but also on the tools around them. Tools carry affordances. As designers we are interested in designing affordances into the tools, which reflect the visions of social reality the community is aspiring to achieve.

6
Conclusions

The research-based design methodology described in this article builds on traditions of qualitative research in social science, more precisely on action research and development work research. We feel that the description of the methodology can be useful for designers and design researchers working with complex social systems, but also for social scientists interested in developing their design-thinking skills.

Research-based design is a multi-disciplinary activity. It needs input from a number of disciplines to be successful. For the best results participants should share some common language(s) and understanding of each other's expertise on some level. We hope this article will partly contribute to cross-disciplinary discussions aiming at social change through research.

The methods of the social sciences are widely used in design and research-based design. However, design thinking is not a widely known or commonly used approach in social research. We believe that the social sciences could benefit from designers. We also see the potentiality that social scientists working with designers, could solve real world problems in a much more creative way than when working independently.

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