Educational Software in Engineering Education

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Doktorsavhandlingar från Institutionen för pedagogik och didaktik

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ISBN 978-91-7649-205-5

Printed in Sweden by Holmbergs, Malmö 2015
Distributor: Department of Education, Stockholm University

Previous series of Doctoral Theses: ”Avhandlingar från Institutionen för didaktik och pedagogiskt arbete” no 1-10 and ”Doktorsavhandlingar från Pedagogiska institutionen no 1-171”.

Con agradecimiento a las personas que me han ayudado de forma decisiva en mi desarrollo académico:

Lena Nordholm
Karin Renblad
Tomas Pettersson
Antonio Pulgarin

Abstract

This thesis contributes to the quality of engineering education and the accessibility of education worldwide by promoting computer-enhanced teaching and learning. It uses the epistemology of John Dewey (1859-1952) and the action research methodology first advanced by Kurt Lewin (1890-1947). A mixed methods approach that combines qualitative case studies with quantitative research methods is used.

In the first of three case studies engineering students working on their final degree projects participated. To elicit interaction, a learning management system (LMS) was used and the students were strongly encouraged to discuss various aspects of their work.

The second case focused on the barriers to a wider utilization of educational software in engineering education. The case is delimited to lecturers at the School of Engineering at the University of Borås. The investigation focuses on the lecturers' reluctance to use educational technology and the slow uptake of new pedagogical methods in engineering education.

The third case study covers three subsets of participants. A course intended to improve lecturers handling skills and motivation to utilize educational software in a pedagogically sound manner was given in Cuba, Guatemala and Peru.

The first case demonstrated that computer-enhanced collaborative learning can improve the learning experience and performance of engineering students. The second case showed that LMS tools that facilitate traditional methods are used routinely, whereas lecturers often refrain from using features intended to facilitate collaboration and the creation of communities of learners.

The third case study investigated the use of a complete course package, with all course material and software contained on the same USB drive (LiveUSB Mediated Education, LUME). It is asserted that LUME can facilitate constructivist pedagogical methods and help overcome the reluctance of lecturers to utilize educational software in a pedagogical sound way.

Keywords: Higher Education, E-learning, Learning Management Systems, Engineering Education, Educational Technology, Pedagogical Use of ICT, Staff Development, Developing Countries

Abstrakt

Denna avhandling syftar till att förbättra utbildningen av ingenjörer samt öka tillgängligheten till utbildning i hela världen genom att främja användningen av datorstödd undervisning och lärande. Den använder epistemologi från John Dewey (1859-1952) och den forskningsmodell, action research, som först lades fram av Kurt Lewin (1890-1947). Undersökningarna blandar kvalitativa och kvantitativa metoder.

I den första av tre fallstudier deltog teknologer som arbetade på sina examensprojekt. För att locka fram ökad interaktion, användes en lärplattform (Learning Management System; LMS) och eleverna uppmuntrades att diskutera olika aspekter på sitt arbete.

Det andra fallet fokuserade på hinder för en bredare användning av informations- och kommunikationsteknik (IKT) i ingenjörsutbildningen och orsakerna till det långsamma upptag av nya pedagogiska metoder i ingenjörsutbildning. Undersökningarna genomfördes vid Ingenjörshögskolan, en institution vid Högskolan i Borås.

Den tredje fallstudien presenteras som en fallstudie med tre undergrupper av deltagare. En kurs som syftade till att ge de deltagande lärarna teknisk kompetens i att hantera ett LMS och motivera dem att utnyttja IT på ett pedagogiskt sätt gavs i Kuba, Guatemala och Peru.

Det första fallet visade att dator-stött kollaborativt lärande kan förbättra studenternas resultat och upplevelse av lärandet. Den andra fallstudien visar att LMS verktyg som underlättar traditionella undervisningsmetoder används rutinmässigt, medan funktioner som syftar till att underlätta samarbete och stimulera skapandet av aktiva studiegrupper sällan utnyttjas.

Den tredje fallstudien undersöker användningen av ett komplett packet med allt kursmaterial och portabla program tillsammans på ett USB-minne (Live-USB Mediated Education, LUME). Det framhålls att LUME kan underlätta tillämpningen av konstruktivistiska pedagogiska metoder, och därmed bidra till en utvidgad användning av pedagogisk mjukvara.

List of Articles

This thesis is based on the following articles, which are referred to in the text by Roman numeral. These articles can be found at the end of this thesis, in the appendix.

I. Garrote Jurado, R., & Pettersson, T. (2007). Lecturers' Attitudes about the Use of Learning Management Systems in Engineering Education: A Swedish Case Study. Australasian Journal of Educational Technology (AJET), 23(3), 327-349.

II. Garrote Jurado, R., & Pettersson, T. (2011). The use of Learning Management Systems: A Longitudinal Case Study. e-learning and education (eleed), 8(1).

III. Garrote Jurado, R., (2012). Barriers to a wider Implementation of LMS in Higher Education: a Swedish case study, 2006-2011. e-learning and education (eleed), Vol. 9(1).

IV. Garrote, R., Pettersson, T., & Christie, M. (2011). LiveUSB Mediated Education: A method to facilitate computer supported education. Australasian Journal of Educational Technology (AJET), 27(4), 610-632.

Comments on my contributions

I. I am first author and formulated the general research idea, analysis and presentation. Tomas Pettersson assisted with background research, editorial comments and help in the publishing process.

II. I am the first author, and I formulated the research idea and collected and analysed the data. Tomas Pettersson made significant contributions, helping to collect the data and write the paper.

III. I am the sole author.

IV. I am the first author and I formulated the general research idea and collected and analysed the data. Tomas Pettersson collaborated with me in the data analysis and provided editorial advice. Professor Michael Christie provided important suggestions during the writing process.

Preface

From 2001 to 2007 I was responsible for a Learning Management Systems (LMS) at the engineering department at University of Borås. In order to improve the way educational software was utilized I needed to examine how teachers used the LMS and outline the factors that are restricting the use.

Two projects have had particular impact on my understanding of engineering education and problems surrounding Higher education in developing countries. The Asia Link project (Helgesson et al., 2006), took me to Indonesia on three occasions in 2004-06 to teach and train lecturers at the University of Gadjah Mada, Yogyakarta, Indonesia, how to use an LMS.

In the project Universidad, Sociedad e Innovación, (USO+i) (Campo Montalvo & Espinoza Montenegro, 2011) I took part as technical coordinator and lecturer. The project objectives were to facilitate the adaption of Engineering Education to the need of the society in Latin-American countries. During this project I visited 6 countries and gave a course to engineering educators on three separated occasions, in Cuba, Guatemala and Peru.

Participants in Cuba, Guatemala and Peru. All of them were Engineering educators at different universities.

Of course a credo of action research is "no action without research and no research without action" (Adelman, 1993, p. 8). The ideas of John Dewey and Kurt Lewin have been important to me, both the idea of action research and their insistence on collaborative efforts to improve praxis.

My research and my work as an educator have developed together and I feel confident that I am a better, more dedicated teacher due to my research efforts, as well as a more insightful researcher due to my teaching experiences. My aim is to contribute to the efforts to implement the right to education worldwide, as stated in the declaration of human rights that "…Technical and professional education shall be made generally available and higher education shall be equally accessible to all on the basis of merit." (Assembly, 1948). I believe it is possible, but only if educational institutions utilize modern technology and adopt a wide range of pedagogical practices to fully exploit the technology. Therefore I have focused my efforts on bringing together modern technology, pedagogical methods and open educational resources.

The action part of my action research consisted of the planning and implementation of courses for university teachers in Latin America. An important part of that work was the development of LUME (LiveUSB Mediated Education, see chapter 4 of this thesis). The course and the LUME concept were well received and I have given the course two more times, in Guatemala and Brazil.

Also my material has been utilized by some of the participants to give the

Participants in the course in Brazil, they came from different departments at the university in Orleans.

course in their turn. I have received two awards for my work in Latin America; 'El sello de la CUJAE' awarded by Instituto Superior Politécnico José Antonio Echebarria (ISPJAE) 2012 and the 'Innovative and Creative Teaching', awarded by the Rede International e Escolas Criativas, 2012, Orleans, Brazil.

The research presented in this thesis evolved over time, with new questions

Above I receive 'El sello de la CUJAE' and the 'Innovative and Creative Teaching' awards for my work in Latin America

emerging as a result of the research process, my work experiences and reflections. Michael Christie, then professor at the University of Gothenburg encouraged me to disseminate my results and before I was accepted into the PhD program at the Department of Education at Stockholm University in the autumn of 2010 I had published a number of papers, a book chapter and one of the journal articles included in the thesis (with Tomas Pettersson). Looking at my research as part of an action research project I hope that sharing my results and experiences will inspire other teachers to engage in action research, thus improving educational practice.

Abbreviations

ABET:	The Accreditation Board for Engineering and Technology United States of America
ASIIN:	Agency for Degree Programs in Engineering, Informatics/Computer – Germany
CDIO:	Conceive, Design, Implement and Operate
ECTS:	European Credit Transfer System
EERC:	Engineering Education Research Colloquies
ICT:	Information and Communication Technology
LMS:	Learning Management System
LP:	Learning Platforms
LUME:	LiveUSB-Mediated Education
MOODLE:	Modular Object-Oriented Dynamic Learning Environment
NS&E:	Natural Science and Engineering
OAD:	Online Asynchronous Discussion
OER:	Open Educational Resources
PBL:	Problem-Based Learning
PLE:	Personal Learning Environment
USB:	Universal Serial Bus
VLE:	Virtual Learning Environments

Contents

List of figures

1. Outline of the thesis

The publications that are incorporated into this thesis are listed in the first section with comments on my role as author. The introduction, Chapter 2, presents the scope of my research.

Chapter 3 is an overview of engineering education, including its history, structure and current trends. It is asserted that engineering education is very similar throughout the world, a result of both design and educational traditions. It is demonstrated that the numbers of engineering students is constant in most developed countries but increasing rapidly in some other parts of the world.

The development of the concept LiveUSB-Mediated Education (LUME) is presented in Chapter 4. LUME is suggested as a feasible way to instigate a wider use of educational software in higher education.

The research questions and their relation to each of the three case studies are presented in Chapter 5. Here the progression of my research can be followed, with new questions arising as the result of my experiences.

Chapter 6 provides a general description of theories of learning that accentuate the importance of students' activities, interactions and collaboration. This chapter also provides the background of engineering education research in general and the theoretical context in which this thesis is founded.

Next, Chapter 7 delineates the three case studies that comprise this thesis and gives an overview of how the data were obtained and analysed. Much attention is given to the concept action research, as a process of fact-finding, planning and action, first described by Lewin.

Each of the three case studies is presented in Chapter 8. The results and conclusions are presented. The development of the LUME method as a response to the findings of the first two case studies is described.

Chapter 9 is a summary of the findings, including the answers to the four research questions that were presented earlier. The last chapter (10) begins with a discussion about the findings reported in this thesis. The future of ICT and LMS in higher education is discussed, and it is asserted that LMS will be

a part of the educational practice for the foreseeable future. Some considerations and concerns about the future of engineering education research are discussed.

2. Introduction

This thesis focuses on the utilization of educational software in engineering education and it aims to demonstrate ways in which engineering education can be improved and made more accessible worldwide by the proper application of Information and Communication Technology (ICT). The research is intended to add to the knowledge about the pedagogical use of ICT in higher education and staff development within educational institutions. It makes an original contribution by introducing and explaining the practical uses of LiveUSB-Mediated Education (LUME). The concept behind LUME is explained later in this thesis (see Chapter 4).

When the use of ICT in education is discussed it is common to make a distinction between hardware and software. If the hardware is ordinary computers and peripheral equipment, then the term computer enhanced, or computer facilitated education is appropriate.

Computer programs, used for teaching and learning, are sometimes called "educational technology" but in this thesis the term "educational software" is used to avoid the possible confusion with other technical devices. Another issue with the term "educational software" is computer programs that are designed with a specific subject in mind, such as virtual laboratory or Computer Aided Design & Manufacturing (CAD/CAM), may be used in education but are foremost intended as practical tools or professional training.

The term "educational software" is hence used for computer programs intended to facilitate teaching, learning and course administration, but not for software designed for specific fields, such as medicine, engineering or computer science. Educational software are often put together in a package called a learning management system (LMS), see section 3.2.1.

In all organized enterprises, the people involved must work together, giving each other encouragement, support and feedback. The teachers' job is to facilitate learning, and they can be most effective by ensuring that their course material motivates students to learn and be active participants in the learning process. Since the smooth use of educational software requires support from administrators, educational technologists and technicians, teachers must learn to work with a new network of people. In an age in which there is increasing use of the internet for educational purposes (Kargidis et al., 2003), changing

one's teaching and learning paradigm can be both challenging and rewarding (Scott, 1999).

There are both differences and similarities between developed and developing countries with respect to the uptake of new technology in education. My interest in the pedagogical use of ICT in teaching and learning has deepened as a result of my work experiences in developing countries. In 2004-2006, I visited Indonesia on three separate occasions to educate lecturers about learning management systems (LMSes). Later I visited many Latin-American countries and taught courses in Cuba, Guatemala, Peru and Brazil.

This thesis research combines qualitative and quantitative research methods and consists of three case studies. Together, these three case studies form an action research project, inspired by the works of John Dewey and Kurt Lewin (Adelman, 1993; Argyris et al., 1985; Dewey, 1910; Lewin, 1946).

According to Shaw & Marlow (1999), ICT has the potential to provide study material that is not only constructively aligned but also varied in its content and levels of difficulty. It can appeal to different learning styles and types of intelligences, which is especially important in an area such as engineering education where teaching and learning methods tend to rely on a traditional mix of lecture, tutorial and/or laboratory and closed book end-of-course exams. In such situations, ICT may be used mostly to facilitate an existing educational practice.

A recurring theme in the literature is that while new technologies create new possibilities for learning, they also require significant changes in learning attitudes and pedagogy (Scott, 1999). It follows that preparing faculty for future changes and challenges in teaching (e.g., flexible learning, distance education, etc.) is an important issue for educational institutions, including schools of engineering and universities of technology & science. The development of new working procedures based both on pedagogic and technical methods used in distance education and web-based learning as well as the knowledge of how students learn outside school and university environments is recognized as the key to optimizing engineering education and attracting a wider range of students (UNESCO, 2010, p. 47-49; 2011, p. 17; 2013, p. 4-7).

3. Engineering Education

3.1 Two centuries of Engineering Education

The term "engineer" has been used for about 200 years. The model for western engineering education was first developed with the establishment of the first technical university in Europe, the L'Ecole Polytechnique in France (1794). This model has influenced institutions worldwide (Grayson, 1993, p. 15-23; UNESCO, 2010, p. 31). From the beginning of formal engineering education, instructional laboratories have been an essential part of teaching and learning (Feisel & Rosa, 2005). Experiments and practical projects have been used to help students learn to handle real-world problems and gain practical experience (Gustavsson et al., 2006).

Today, engineering education is a well-established field in higher education throughout the world. During my work, I mainly viewed engineering education as a practical endeavour, with the aim of providing society with highly trained professionals and at the same time facilitating the students' intellectual and personal development. My work is based on the assumption that there will be a growing demand for good engineers in the foreseeable future and that it is in the interest of humankind to improve the educational methods and adapt the curriculum as society changes.

A lot of research and discussions have focused on learning and/or teaching paradigms in higher education. However, it has had relatively little impact on engineering education because much of engineering education is hierarchical and linear, e.g., traditional face-to-face lectures combined with laboratory work (UNESCO, 2010). Only during the latter part of their education do students conduct an application-oriented final project (Bissell & Endean, 2007).

3.1.1 The structure of Engineering Education

Engineering education programs throughout the world are very similar to each other (Campo Montalvo et al., 2012, p. 29-69). Engineering education is commonly divided into three blocks. During the first block, engineering students primarily study core science subjects, such as mathematics, physics and chemistry. In the second block, students begin with elementary courses in their chosen engineering branch, and during the third block, students participate in

courses that provide in-depth knowledge of the engineering area of their choice. It is during this last phase that the majority of the laboratory work is completed. Students typically complete their practical degree project, working independently to gather information and present their work in a final report (Blicblau & Steiner, 1998; Ku & Goh, 2010).

3.1.2 International perspective on Engineering Education

In Europe, the Bologna process is used to compare and standardize the quality of education. Using this process, countries are working towards a system to facilitate knowledge transfer and progression throughout the European community, in which two main cycles, undergraduate and graduate, should be recognized for international comparison and equivalence using European Credit Transfer System (ECTS) credits. One academic year corresponds to 60 ECTS credits (1500 to 1800 hours of study). This process began in 1998 with the aim of ensuring that our students are provided with the best education opportunities so that they are competitive in the job market (Allegre et al., 1998).

Worldwide, the similarities in engineering education increases as a result of the practice in many developing countries to employ accreditation agencies from Europe or the USA, such as the Agency for Degree Programs in Engineering, Informatics/Computer (ASIIN) in Germany and the Accreditation Board for Engineering and Technology (ABET) in the USA (Jones, 2003; Ortiz-Marcos et al., 2011), to evaluate their engineering education programs or via accreditation projects financed by various organizations that help universities develop their curriculum (Campo Montalvo & Espinoza Montenegro, 2011).

3.2 Current trends in Engineering Education

During my tenure as a lecturer at the School of Engineering at the University of Borås, I often heard my colleagues discuss the difficulty of recruiting engineering students and their concerns that the number of engineering students decreases each year. At that time, I too believed that the number of engineering students was declining. However, when I later studied the available statistics, I found that the number of students in engineering in Sweden increased from 64,634 in the year 1999 to 68,846 in 2006 (UNESCO, 2010, p. 82).

The trend of increasing numbers of students in the natural sciences and engineering (NS&E) has continued. According to the Swedish Higher Education Authority, the number of registered engineering students rose from 86,533 in the autumn of 2007 to 104,791 in the autumn of 2012, an increase of ca 21%. The number of science students increased by 17% (Universitetskanslersämbetet, 2013).

Concern about declining interest in natural science and technology is not limited to Sweden. In Spain, I found that people were also worried about declining student enrolment in natural science and technology. However, as demonstrated in a study from 2011, the concerns were unfounded (Blazquez et al., 2011). Apparently such concerns are almost universal despite the fact that the number of engineering students has remained the same or increased in most developed countries (see below, fig. 1). According to Science and Engineering Indicators 2012, '*Governments in many Western countries and in Japan are concerned about lagging student interest in studying NS&E fields they believe convey technical skills and knowledge that are essential for knowledge-intensive economies*' (*Science and Engineering Indicators 2012*, 2012, p. O-7). One clear expression of how serious those concerns are taken in the USA is contained in a special report published in the Journal of Engineering Education ("The National Engineering Education Research Colloquies," 2006) by the US-based Engineering Education Research Colloquies (EERC). In the report, they outline the intentions for a National Science Foundation grant provided to support the EERC's work in designing a research framework to help coordinate research in engineering education.

A viable explanation of the apparent contradiction between "lagging interest" and actual enrolment is that perhaps engineering and science are less attractive to the most talented students today than was the case for previous generations. That issue is outside the scope of this thesis but surely emphasizes the importance of pedagogical development in engineering education.

Each year approximately 2 million students around the world receive a degree in engineering (figure 1), accounting for about 13% of all degrees awarded in higher education (*Science and Engineering Indicators 2012*, 2012, table. 2-32). A first university degree in engineering is comparable to a U.S. baccalaureate or 180 ECTS credits in Europe; this represents approximately three years of full-time studies. Hence, we can estimate the number of engineering students as well above 6 million. In most countries in the Western world, the number of graduating engineers increased from 1998 to 2008 (UNESCO, 2010, p. 79-93), and in many developing countries, the number of engineering students has increased rapidly (UNESCO, 2010, p. 79-93).

Figure 2 below shows that the number of engineering degrees received in

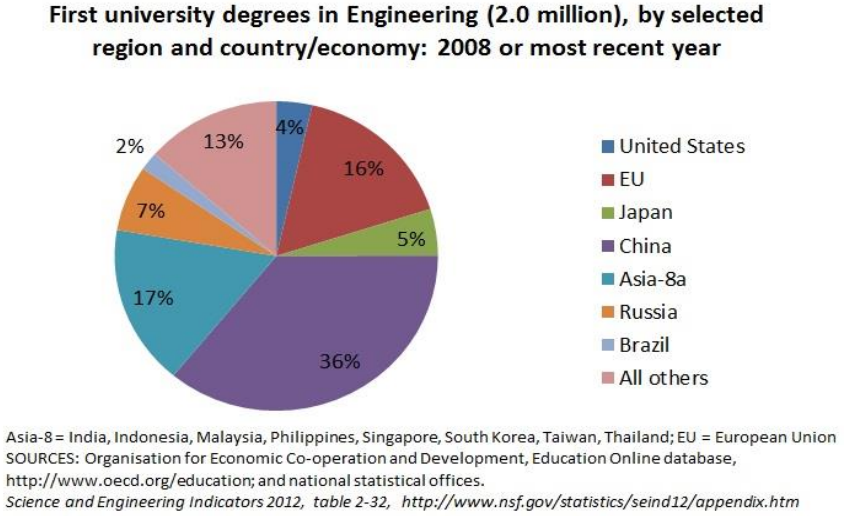

Figure 1: Number of university degrees in Engineering

seven of the biggest economies in the world is constant over time with the exception of China, in which the number of engineering degrees has increased from about 200,000 in the year 1998 to about 700,000 ten years later (*Science and Engineering Indicators 2012*, 2012, p. O-9); the dramatic increase in China can be explained by targeted governmental intervention.

The Chinese government actions included reform in the public science and technology institutions, financial policy, business innovation support structure, human resource policy and legislative actions (Huang et al., 2004).

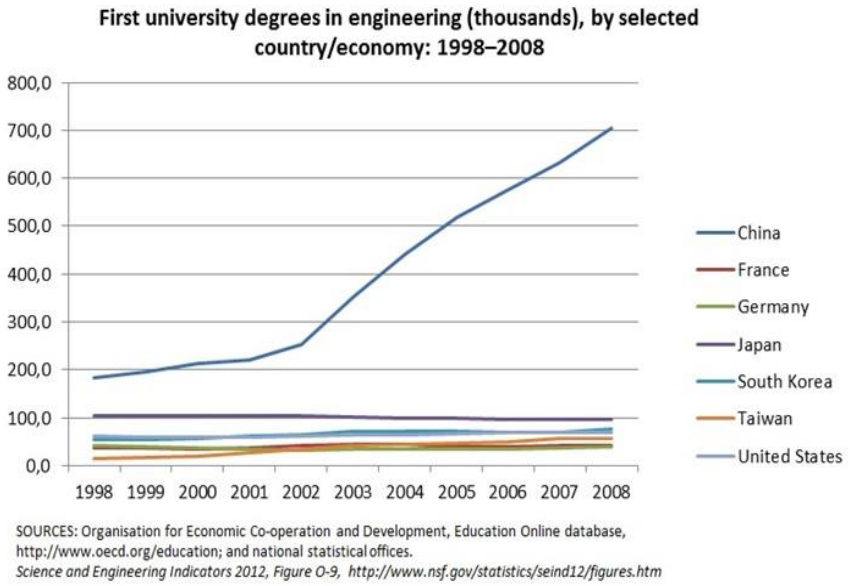

Figure 2: Number of first university degrees in engineering 1998-2008

3.2.1 Technical development

Engineering education is affected by the development of technology (Christie et al., 2002). Less obvious but equally important is the way production processes are organized and information is handled in the surrounding society. Changes in those aspects of civilization are reflected in the way engineering education has changed in the last several decades (Korhonen-Yrjänheikki et al., 2007).

ICT plays an increasing role in both engineering and society, and the application of ICT for educational purposes is a growing concern for educational institutions. The demands on engineers to keep pace with rapid changes in technology are growing, in particular their ability to work with computers. Therefore it is necessary not only to adapt the curriculum but also to utilize ICT within the educational system in order to link intended learning outcomes, pedagogical methods and assessment of learning, a process called constructive alignment (Biggs, 1999).

Software intended to facilitate education are often put together in a package called a learning management system (LMS). Hence an LMS can be defined

as a ‘toolbox’ of programs intended to support learning, teaching and course administration. Other terms sometimes used include virtual learning environment (VLE) (Crook, 2008; Dutton et al., 2004), learning platform (LP), course management system (CMS), learning content management system (LCMS), managed learning environment (MLE) and learning support system (LSS) (Graf & List, 2005; Martín-Blas & Serrano-Fernández, 2009). Most modern LMSes (proprietary or freeware) have many features in common, such as shared documents, discussion boards, assessments, grade books, and chat rooms (Britain & Liber, 1999).

It has been argued that an LMS can facilitate teaching and learning in many ways. Tools for distribution, communication and course administration may save time and effort for lecturers and students without requiring any significant change in the educational process. These tools are widely used (Phillips, 2006) and highly appreciated by lecturers as an alternative to handing out paper copies, delivering multimedia files, recording students’ results, providing feedback to students and obtaining statistical data regarding the students or courses (Carvalho et al., 2011).

A particularly interesting feature, included in most LMSes, is the online asynchronous discussion (OAD). This term is used to describe a text-based asynchronous environment available online intended to support learner(s)-to-learner(s) interaction (Murphy, 2004; Murphy & Loveless, 2005). It has been argued that OAD can enhance learning by eliciting interaction and strengthening group identity (Britain & Liber, 1999; Irwin & Berge, 2006). Collaborative exchanges on course topics could have a substantial impact on the learning experience (Xie & Ke, 2011).

3.2.2 Theory and practice in engineering education

The use of real-life problems in engineering education generally means that the curriculum has to be adapted to the dynamic industrial and technological changes that are occurring in society and communication between educational institutions and industry must be increased (Fink, 2002). To include real-life problems, lecturers often must set up placements or links to industry. Engineering students are expected to conduct a practical degree project in a real setting and in that phase of their education, they need information-handling and problem-solving skills.

Problem-based learning (PBL) is gaining more acceptance in engineering education since it was first introduced in the 1960s in the medical school at McMaster University in Ontario, Canada (Barrows & Tamblyn, 1980), although some researchers emphasize that progress in this regard is slow (Hasna, 2008; Hunt et al., 2010).

Within engineering education, problem- and project-based learning models have been adopted, such as the Conceive, Design, Implement and Operate (CDIO) model developed by a consortium of technical universities including MIT and Chalmers. CDIO is most often project-based, and the intention of the project is to promote learning in a holistic way, combining theory, experience and practice. CDIO and other PBL-like types of curriculum are more common in engineering education today than in the past, although some authors still maintain that PBL is not utilized to its full potential (Hasna, 2008; Hunt et al., 2010; Mills & Treagust, 2003-04).

3.2.3 Open Educational Resources

The emergence of the internet and the accompanying convenient, low cost access to information is another significant factor that affects engineering education.

Educational resources that are provided for free when used for educational purposes are called open educational resources (OER). The most common definition of OER is as follows: 'open educational resources are digitized materials offered freely and openly for educators, students and self-learners to use and reuse for teaching, learning and research' (OECD, 2007, p. 30). The term 'Educational Resources' refers to full courses, course materials, modules, textbooks, streaming videos, tests, software, or other tools, materials, or techniques used to support access to knowledge (Atkins et al., 2007). The term 'open' in the context of OER usually means free online access and unrestricted distribution and re-use for educational purposes (Dinevski, 2010; Wiley, 2006).

Identifying problems associated with the use of educational software and investigating possible improvements in the use of OER can contribute to teaching and learning in engineering education and higher education in general and can also contribute to the use of similar technologies in non-academic sectors, such as business, industry, government, community organizations, schools and hospitals (UNESCO, 2012).

The possible improvement of the quality and accessibility of tertiary education is a strong argument in favour of a wider use of OER in both developed and developing countries. However, although the OER movement and similar initiatives have generated an impressive amount of free material, most teachers do not use OER as an everyday tool. A major obstacle for a wider use of OER is the low awareness about the available resources among educators (D'Antoni, 2009).

3.2.4 The use of LMS

Today most western universities are not only utilizing an LMS. They have also invested large amounts of capital in procuring and maintaining educational software (Dewanto et al., 2004; Dutton et al., 2004; Shemweta et al., 2014). Although an extensive amount of research and development has been conducted on the use of educational software in engineering education, the need to identify and develop methods, both technical and pedagogical, is, if anything, greater than before (Kozma, 2003, 2008; Law et al., 2005; Law et al., 2008; Smeds et al., 2010).

In the future, most educational institutions will provide a standard set of educational software as well as guidelines for their use. If there is no integrated LMS at a university, most of the time there will still be several computers programs that are available for teachers and students. If there is a list of programs and they provide similar features as the tools in a common LMS, then that list of programs works as a learning platform, and in that case, we can call it an institution-specific LMS. Actually, this situation is quite common. Systems for course management, reporting students´ performances and grades are usually not integrated in a LMS, due to security and access issues.

4. LiveUSB Mediated Education (LUME)

Based on general considerations and information obtained during the first and second case studies, the LUME method was developed as a way to overcome technical difficulties and the reluctance of lecturers to utilize ICT.

LUME was mostly developed in 2010, and experiences from using the method were first presented at a conference in Barcelona, Spain (Garrote Jurado, Pettersson, Seoane Martínez et al., 2010). At the conference, the course design received considerable interest but more as a viable solution to limited internet access than a pedagogical innovation. To further disseminate information about the method and promote its utilization, I participated in a conference in Havana, Cuba the same year (Garrote Jurado, Pettersson, Sigrén et al., 2010). After that conference, Tomas Pettersson and I decided the method needed a name, and we agreed on 'LiveUSB Mediated Education' or LUME. In 2011, the definition of LUME and the ideas behind it were first published in IJEDICT, an open-access online journal, in the section *Notes from the field*, and there the term was defined as '*a complete digital package including all course material and the software needed to access the material*' (Garrote Jurado & Pettersson, 2011a).

The use of portable software allows people to experiment with programs without installing them on a computer or accessing an external web server. It is difficult to prevent unauthorized copying of digital material, so the complete package must be free to copy and distribute. This also allows entire programs to be erased and replaced if needed (Garrote Jurado, Pettersson, Seoane Martínez et al., 2010).

The idea to distribute a package of course material that can be used on any computer was not new. Before the advent of USB flash drives with sufficient capacity available at reasonable prices, removable hard drives were used by lecturers to bring their material to lectures (Hailey & Hailey, 2002), and in 2009, Thomas Edison State College in the United States began to offer course packages on USB flash drives together with proprietary textbooks under the name 'flash track courses'. Those courses were intended for students who were unable to access the internet for longer periods of time, for example, US navy personnel (Mearian, 2009).

Using OER is an economically feasible way for educational institutions in developing countries to meet the challenge of integrating educational software

into tertiary education and make computer-assisted education available to an increasing number of students. There is plenty of material available online, but it is not easy to utilize it when there is a shortage of computers and internet access. In developing countries, it is very common for students and teachers not to have a computer of their own; instead they borrow or hire a computer for a limited time. LUME helps in this situation by allowing students and teachers to work on any computer at their convenience, offering a convenient tool for the distribution and utilization of OER. For both staff development and education in general, it means that the digital divide between developed and developing countries can be mitigated.

For students in the Western world, LUME can enhance their learning experience foremost by eliciting and facilitating a transition from teacher-centred, textbook-based educational practices to a student-centred education that uses collaborative methods. When students have experienced collaborative learning facilitated by an LMS, research has shown that they typically want to increase their use of such tools for interaction (Limniou & Smith, 2010). In a recent study, Heirdsfield et al. (2011) noted that students were more positive towards the use of interactive features than teachers.

4.1 The course Adaptation of Engineering Education to the use of Net-independent Software

The course *Adaptation of Engineering Education to the use of Net-independent Software* was developed in 2010 when the University of Borås took part in an international project intended to improve engineering education in Latin America (Campo Montalvo & Espinoza Montenegro, 2011). My part was to create and implement a course in which engineering educators in Cuba and Guatemala where introduced to pedagogical methods of using an LMS. Previously, I had given lectures, led seminars and conducted workshops about LMSes for lecturers at the University of Gadjah Mada in Yogyakarta, Indonesia as a part of the Asia Link project (Helgesson et al., 2006). My work in this project took me to Indonesia three times between 2004 and 2006. My experiences in Indonesia raised my awareness of the international perspective in engineering education and the problems with higher education in places under severe financial restrictions. In particular, those experiences made me realize the importance of preparing for a shortage of computers and internet access in Cuba.

The course *Adaptation of Engineering Education to the use of Net independent software* was to be given first in Cuba in March 2010 to lecturers at the Instituto Superior Politécnico José Antonio Echeverría, Facultad de Ingeniería Eléctrica, Havana and then at Centro Universitario de Occidente – Universidad de San Carlos. CUNOC-USAC, Quetzaltenango, Guatemala. Later,

after representatives from the Universidad Ricardo Palma (URP) made an appeal to the University of Borås, I gave the same course in Peru. On all three occasions, the course was given in two parts, an introduction with the participants gathered on campus for two weeks followed by approximately three months of distance education. The complete class corresponded to 15 ECTS points or ten weeks of full-time studies.

The course *Adaptation of Engineering Education to the use of Net independent software* had a two-fold purpose: to provide the participants with the technical skills they needed to use an LMS and an understanding of how the use of various LMS tools can benefit education. I realized that the limited number of computers and internet access made it inconvenient to use conventional course material and impossible to rely on internet access. When the course was given in Cuba, the participants had to take turns on the university's computers and most of the time there was no internet access. The solution was to emulate internet resources by downloading selected media files and portable software to USB memories. Using this approach, the participants could access the selected material the same way they would have if they had had internet access.

The next step was to select only OER and free portable software so that the complete course material could be stored on a USB flash drive and copied freely. Portable software means that programs are executed from the memory and do not need to be installed on the computer. Thus, each participant could use any computer, plugging in the USB flash drive, working with the material and then saving all their work and program settings when the session was completed. Once a USB flash drive is removed, no trace of the session is left on the computer's memory. Moodle (Modular Object-Oriented Dynamic Learning Environment), an open access LMS used by many institutions worldwide (moodle, 2015), was selected as the LMS for the course. It was important to have a non-commercial LMS so that each participant could have his or her own copy to use without restrictions.

The course materials were then copied to a 4 Gb USB flash drive, which was supplied to each participant. The following programs were saved together with more than 50 Spanish-language videos with practical guides that had been downloaded from YouTube (with permission from the creators): Moodle, Sumatra-PDF, VLC-mediaplayer, LynX, HotPotatoes 6, AbiWord, MoWeS II and Portable Open Office. Since all of the computers to be used during the course had some version of Windows installed, applications that work with Windows were selected and no operating system was supplied.

The course was based on PBL and the participants main task was to select a course they teach or plan to teach and adapt the material to the LMS Moodle so that the course would be flexible (i.e., could be utilized for distance courses or self-studies). The participants were instructed to plan the use of different

tools in Moodle, such as shared documents, bulletin board, forum, management of assignments, etc. Each participant was able to choose when to work. Between sessions, they could save their work and program settings on their USB flash drive.

During the courses, the participants were encouraged to share information and work together so that they could also experience the pedagogical efficacy of collaborative teaching and learning (Hsiu-Ping & Wei-Jane, 2005).

Since the participants in these courses would be expected to act as pioneers at their respective workplaces and promote the use of ICT in education, it was also highly desirable to use pedagogical methods that the participants would be able to apply to their work. It was also important to model and bring to their attention the abundant resources that are freely available on the internet. In particular, the participants were and still are free to copy and re-use the course package in their work. In fact, they may teach the entire course to others, something that has since been done in Cuba and Guatemala.

4.2 LUME, LMS and OER

USB is the most common means of digital storage today, but other digital removable and rewritable storage devices could be used. A live USB is a portable memory device with an operating system. Usually we do not need a true live USB to employ the LUME method, but it is always possible to provide a free OS, such as Linux. Furthermore, today in countries where the internet is available at low cost and where many students have laptops and mobile internet, we can distribute the material as a folder via the internet rather than stored on a portable memory device. At many institutions in developing countries internet is expensive or slow, but there may be a functional intranet (Ndou, 2004). Once a course package is stored within, the users can access the material. In this case the local intranet can be seen as a memory device, available to multiple users. The important distinction is that course material can be distributed as a complete package including the software needed to access it.

With LUME, it is very convenient to use an LMS to organize course material as it provides a substantial amount of conveniently organized educational software. By utilizing a free LMS, teachers can recycle the course material by copying the entire LMS and preserving all of the program settings and modifications. Even if the package of software is not fully integrated in an LMS, the package will serve as a course-specific LMS for a teacher and students. Because data can be easily copied, the risk of copyright infringements makes it necessary to use only free course material. Although it may be hard to find a suitable OER, and some teachers may be reluctant to allow their material to be disseminated as OER, the freedom to copy the material is essential.

4.3 LUME as a pedagogical approach

Leaving the technical details aside, LUME is a method based on the following principle: All students have access to course material and are free to work with their own copies at any time on any computer. That in itself does not guarantee that it will be used in a pedagogically sound way, but it offers substantial flexibility. Only if that flexibility is used to facilitate constructively aligned pedagogical methods can the students reap the full benefits of LUME.

The pedagogical value of interactive tools depends on the teacher's choice of methods and the students' activities. Some researchers point out that lecturers may need to spend time and effort to monitor and guide the use of tools for interaction (e.g., a discussion forum) in a course (Murphy, 2004; Salmon, 2000). With LUME, collaboration and interaction is facilitated by all participants using to the same software and material because it is distributed as a complete package. Collaboration and interaction makes it more likely that students will develop similar understandings of the subject and develop shared perspectives.

Today, many students have access to computers and social media. Thus, it is easy to underestimate the need for training in the proper use of interactive tools. Sometimes it is incorrectly assumed that students understand how to use tools for interaction, such as discussion forums, chat and E-mail. Clearly, many students use social media on a daily basis, but it is still a challenge to elicit collaboration in a group of students regardless of internet accessibility.

An important aspect of modern pedagogy is the adoption of a learner-centred perspective on the educational process and the attention given to the role of interaction as individuals construct their knowledge. LUME places great responsibility on the teacher as he or she has the opportunity to define course material as well as organize the work.

To meet that challenge when planning an electronically mediated course, a lecturer must select course material and prepare it for distribution using the internet or portable memory devices. It is also necessary to plan the use of software. The selected software may include tools for distribution, communication, interaction and course administration. However, lecturers do not need to create an original course package; existing material can often be recycled with minor modifications.

4.4 LUME in staff development

The design and planning of courses is an important task for teachers and educational institutions. With LUME, a teacher or group of teachers can select from the free material on the internet, organize the material, possibly adding

some of their own material, and then distribute it as a complete package. In this manner, an institution can build a library of course packages, readily available for teachers and students. When a certain course is offered, the material is checked and possibly modified, and in the same way, as software is updated, the course package can be modified to include the most recent version.

Planning the use of different tools in an LMS or other software with similar features may be perceived as an extra job by lecturers who have previously only assumed responsibility for the lectures and the examination process. The teacher-centred perspective of LMS is mainly concerned with how a tool can facilitate a lecturer's work within a set frame of teaching practices and institutional traditions.

A more comprehensive perspective on teaching and learning, takes students' interests, abilities, and learning styles into consideration. This student-centered approach places the teacher as a facilitator of learning (Lea et al., 2003; Rachman, 1987). The first perspective tends to focus on subject-specific competencies, whereas the latter includes generic competencies such as the students' development of information handling skills, problem-solving, social skills and a more general application of subject knowledge. Since a barrier to a wider utilization of computer-supported collaborative methods is the lecturers' fear of additional demands on their time, educational institutions may need to use some type of incentive for lecturers in addition to support and training. It is important that development courses in this area not only increase the teachers' technical skills but also introduce them to creative ways of getting the most out of technology from a teaching and learning perspective (Zhou & Xu, 2007).

4.5 The application of LUME

The definition of LUME given at the beginning of this chapter does not specify how the LUME method is intended to work. It may facilitate many different approaches to teaching and learning, but the benefits of LUME are demonstrated when its flexibility is used to facilitate constructively aligned pedagogical methods. In the course *Adaptation of Engineering Education to the use of Net independent software,* LUME was used together with PBL and the participants were encouraged to share information and collaborate. When I discuss LUME in chapter 8, (Case study III) and later, it is with the assumption that LUME is used to facilitate student-centred and collaborative methods.

5. Aim and research questions

As the title of this thesis suggests, the focus of this research is the use of educational software in engineering education. In particular, the thesis aims to demonstrate ways in which engineering education can be improved and made more accessible worldwide by the proper application of educational software. The research questions evolved as a result of the research process and my work experience. The first question is as follows:

- Can the use of an LMS improve engineering students' performances on their final exams projects?

A Case Study was conducted in response to this question. It was intended to gather information and improve the quality and completion rate of such final year projects. The findings were later presented at a conference (Garrote Jurado, 2005).

Subsequently, when the initial study indicated that collaborative learning can be elicited with the help of an LMS, my interest turned to the acceptance of LMS among lecturers. That interest gave rise to the second research question:

- What tools in an LMS are actually utilized by lecturers at the School of Engineering at the University of Borås?

Once the actual use of the LMS had been outlined and a pattern of usage could be seen, the next issue was to identify attitudes that helped or hindered a more elaborate utilization of LMS. This led to the third research question:

- What do lecturers think of the pedagogical possibilities of using an LMS in their practice?

The final question is different from the first three. Based on the information obtained in the first and second case studies, the LUME method was developed as an attempt to overcome technical difficulties and the reluctance of lecturers to utilize ICT in engineering education. When I gave a course about LMS using the LUME method, it became an opportunity to try out the method. The fourth question is as follows:

- Can the LUME method motivate and help lecturers to utilize ICT in a pedagogically sound way?

The first question was answered by looking at one example of collaborative learning in a group of engineering students facilitated by a LMS. In this case study, interviews and discussions with the students together with an assessment of the quality of their final project reports were used.

Question two was investigated on two occasions by conducting a quantitative survey. The results are presented in Article II. In the article, the two sets of data are presented.

Question three concerns the opinions of the lecturers on the use of LMSes, and a qualitative approach with guided interviews was used. The results from the interviews are presented in Articles I and III. In the latter, the data from both occasions are presented.

Put together, Articles I, II and III present the second case study and give a comprehensive picture of the use of an LMS within an institution. Changes in the use of the LMS and the attitudes of faculty members, perceived as a community of practice, are discussed in Articles II and III, respectively.

The last case study is an evaluation of the practical part of the action research undertaken. The assessment of the LUME method and its usefulness was performed by means of questionnaires, interviews and group discussions. The method and results are presented in Article IV.

So, of the four articles that form the basis of the present thesis, three refer to case study two and one concerns the third case study. The first case study was presented by a poster at a conference and not as an article.

6. Theoretical background

6.1 Learning and teaching theories

Since I hope this thesis will assist both lecturers and students in becoming more knowledgeable, some attention must be given to theories about how knowledge, skills and ethical attitudes are learned and taught. In particular, since the focus of the thesis is the pedagogical use of ICT in engineering education, theories that can influence this aspect are particularly important. Different learning theories that have influenced me (and their implications for teaching) are presented below.

As an engineering educator, I was surprised to encounter so many varied theories of learning when I began taking courses in pedagogy. Educational ideas and theories have had little impact on engineering education practice. Much of engineering education is well established, with course content and educational methods that have evolved slowly over more than a century (Grayson, 1993; UNESCO, 2010). Now, as a pedagogical developer, I must try to understand how the practical teaching and learning in this area is related to the various 'isms' that occur in the field.

The research that forms the foundation of this thesis is connected to a number of educational ideas and theories. These include experiential learning, problem-based learning (including CDIO) and approaches to learning, as well as social constructivism.

6.1.1 Pedagogy in the twentieth century

If one looks at the development of learning theories over the last hundred years or so, one can divide the theories into the following categories: behaviourism, cognitivism and constructivism. Behavioural psychologists such as Pavlov (1849-1936), Thorndike (1874-1949), Watson (1870-1958) and Skinner (1904-1990) developed theories that became known as Behaviourism. The behaviouristic position is that psychology should concern itself with the observable behaviour of people and animals, not with unobservable events that take place in their minds (Skinner, 1984).

In the post-World War II period, cognitive psychologists such as Bruner and Piaget reacted to criticisms of behaviourism and argued that there was

more to learning than stimulus and response. The result was a more inclusive theory, called Cognitivism, that acknowledged that mental states exist (Chaney, 2013).

Jean Piaget (1896-1980) and Lev Vygotsky (1896-1934), whose works were rediscovered outside of their own countries in the 1960s, are famous today for their theories of cognitive development (Piaget) and social development theory (Vygotsky). Together with Jerome Bruner (born 1915), they made major contributions to Constructivism as an epistemology and learning theory (Tobias & Duffy, 2009).

Two basic approaches to learning can be seen in the literature from the period: deep and surface learning and deep and surface learners (Entwistle & Ramsden, 1983; Marton et al., 1984). The differences is that deep learners engage in an active search for meaning when they learn, while surface learners are characterized by focusing on parts of the study material in order to memorize what they might be questioned about later (Marton & Säljö, 1976).

The notion of 'approach' is of course fundamental to their research contributions because learners in different settings can decide to take a surface or deep approach, depending on the circumstances. Some critique of the research about learning approaches is that it has concentrated on the individual learner's approach, which makes it less relevant for teachers, who must meet the needs of groups of students (Spoon & Schell, 1998). Finally it has been noted that after forty years of concentrated research, the most important question – why do so many students take a surface approach to their learning - 'appears to remain largely unanswered' (Haggis, 2009).

6.1.2 Constructivism and Social constructivism

According to Jerome Bruner's construction theory, learning is a process in which learners construct their knowledge from new information and their current and past knowledge (Bruner, 1986, 1990). Some specific assumptions about reality and knowledge are central to Constructivism as a theory of learning. A basic understanding is that reality is constructed through human activity. Hence, knowledge is a human product and is socially and culturally constructed (Ernest, 1998; Gredler, 1997; Prawat & Floden, 1994). Vygotsky emphasizes that people construct knowledge through social interaction in the context of a culture. Members of a society interact to create a theory of the world (Kukla, 2000). A person learns both what to think and how to think through social interaction. This perspective is known as social constructivism (Vygotsky, 1962). As I understand it, the difference between constructivism and social constructivism is a matter of perspective. These two theories share the assumption that individuals build new knowledge by processing infor-

mation, earlier experiences and previous knowledge. The difference is the relative attention to human interaction as a trigger to elicit the construction of knowledge.

In some sense, constructivism is a reaction to the positivistic position of the behaviourist and the effects behaviourism had on teaching and learning. One can see a definite shift from teacher-centred learning to student-centred learning and from programmed instruction to designed facilitation of learning. This is not to say that the teacher is more important in behaviourist pedagogical models than in teaching and learning based on constructivist theory. If we focus on constructivism, we need to emphasize the opposite; the teacher who aims to facilitate learning needs to understand the students so that he or she can design learning experiences that build on and extend the student's previous knowledge and experience (Spoon & Schell, 1998). Vygotsky's notion of Proximal Development (Vygotsky, 1978, p. 79-91) is important here because in this model, the teacher provides the scaffolding that allows the student to see beyond his or her own experiential limits.

6.1.3 Reflective thinking and experiential learning

Reflective thinking and experiential learning are concepts that owe much to the philosophy of John Dewey. He lived a long life (1859-1952) and wrote numerous books. I have focused on the earlier part of his career and on two key works, namely *How we think* (1910) and *Democracy and Education* (1916). Early on in *How we think*, Dewey stresses the fact that the origin of reflective thinking is 'some perplexity, confusion or doubt' and that 'given a difficulty, the next step is suggestion of some way out … the consideration of some solution for the problem' (Dewey, 1910, p. 12). Dewey differentiates between '*idle thought*' and '*reflective thinking*'. The stimulus for this sort of thinking is found 'when we wish to determine the significance of some act, performed or to be performed. Then we anticipate consequences. This implies that the situation as it stands is, either in fact or to us, incomplete and hence indeterminate' (Dewey, 1916, p. 177).

He points out, for example, that when we say '*A penny for your thoughts*', we do not expect to get a bargain. The thoughts you pay for, in that case, are usually random and unstructured, a 'flow of consciousness'. This is one type of thinking. The type of thinking that he is interested in analyzing is 'reflective' thought. By this, Dewey means the 'active, persistent and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it and the further conclusion to which it tends' (Dewey, 1910, p. 6). Dewey argues that although we are natural -born thinkers, reflective thinking takes practice and discipline. 'We sometimes talk', says Dewey 'as if "original research" were a peculiar prerogative of scientists or at least of

advanced students. But all thinking is research, and all research is native, original with him who carries it on…' (Dewey, 1916, p. 173-174).

In 1971, David A. Kolb presented a working paper that argued for the existence of different individual learning styles, and in doing so, he developed Kurt Lewin's action research cycle (see section 6.2.2) into a holistic learning model (Kolb et al., 2001, p. 227-ff). Kolb is credited with developing this theory but acknowledges that it has its intellectual origins in the experiential works of John Dewey, Kurt Lewin, Jean Piaget and others (Kolb, 1984). This model, shown below in figure 3 (Kolb's learning cycle), is described by Kolb as '…the process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping experience and transforming it' (Kolb, 1984, p. 41). Kolb argues that Dewey's philosophical pragmatism, Lewin's social psychology and Piaget's cognitive-developmental genetic epistemology form a unique perspective on learning and development (Kolb, 1984, p. 12).

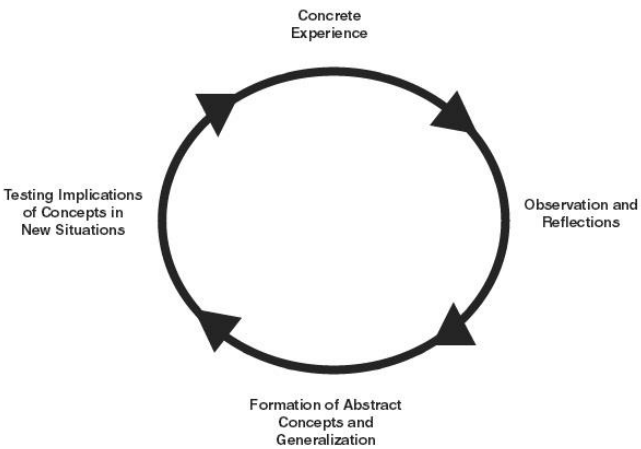

Figure 3: The experiential learning cycle (Kolb & Kolb, 2005)

The experiential learning theory and its application have been very important in adult education and have also gained ground, to a lesser extent, in engineering and higher education. In adult education, a number of researchers have developed similar theories. In *Using Experience for Learning*, David Boud and his colleagues use the term experience-based learning. They identify a set of assumptions about learning from experience. These include the following assumptions: (i) experience is the foundation of and the stimulus for learning, (ii) learners actively construct their own experience, (iii) learning is a holistic process, (iv) learning is socially and culturally constructed and (v) learning is influenced by the socio-emotional context in which it occurs (Boud et al., 1993, p.8-ff).

Many of the characteristics and assumptions of experiential learning theory and experience-based learning are applied in PBL. It can be argued that experiential learning and PBL are both grounded in constructivism and social constructivism, as described above. PBL is constructivist in its approach and encourages cooperation among learners. The need for cooperation and the practical application of knowledge helps develop both generic and subject-specific competencies (Krishnan & Ruhizan, 2009; Lei & Chengxiang, 2010; Richardson, 2009; Sahin, 2010).

The Lifestyle Project, which was started in 1993 in a physical geology program, is a good example of PBL that is experiential in nature. In an article by Kirk and Thomas (2003), the authors explain that the project focuses on not only individual and group construction of knowledge but also changed behaviour in terms of environmental action (Kirk & Thomas, 2003). In engineering education, the CDIO model is an example of experiential learning. CDIO, standing for Conceive, Design, Implement and Operate, is usually project-based with the intention to promote learning in a holistic way, combining theory, experience and practice.

6.2 Higher Education Research

Traditionally, the educational practice at most universities is dominated by lectures, tutorials or labs and reading followed by examination of students' knowledge of the course material (Phillips, 2005). Until the latter half of the twentieth century, as long as universities served a limited group of students, mostly from the upper classes of society, the methods were rarely questioned and most lecturers had no pedagogical education (Badley & Habeshaw, 1991).

As wealthier societies needed a more skilled workforce, the percentage of school graduates who went to the university increased dramatically in the second half of the 20th century and has continued to do so in the first decade of the 21st century. In Sweden alone the number of undergraduates increased from 14,000 students in the mid-1940s to 330,000 in 2007 (Bohlin, 2011, p. 77-78). Of school graduates born in 1979, ca 45% received some form of higher education (Högskoleverket, 2007b, p. 12) see also Högskoleverket (2010). The trend in other developed countries is similar to that found in Sweden (Bruneforth, 2009).

The demands on universities to increase the number of students who complete their education means that more students need special help (Högskoleverket, 2007a). To meet this need, universities must think in terms of the student rather than the teacher and create courses that are constructively aligned so that students can see clearly what they must do in order to acquire the knowledge and skills required to demonstrate mastery of a subject (Biggs, 1999; Ramsden, 1992).

In Sweden, a government strategy to broaden participation in tertiary education was for a time to provide funding for online courses offered via agencies such as the Net University (Christie & Garrote Jurado, 2007). Many researchers have argued that to maintain the quality of online education, courses must be pedagogically sound and make full use of the educational potential of ICT (Christie & Ferdos, 2004; Koschmann, 1996; Laurillard, 1999).

6.2.1 The Emergence of Engineering Education Research

In the so-called Western World, the idea of engineering education as a specific area of research has taken hold in the 21st century. In the report *Engineering: issues, challenges and opportunities for development*, the authors argue that research on engineering education is necessary 'to support the development of new theoretical concepts for understanding new learning paradigms and techniques' (UNESCO, 2010, p. 349). Although engineering education research seeks to become its own discipline, it can be seen as a subset of higher education research.

In the *Handbook of qualitative research* (Denzin & Lincoln, 1994), Guba and Lincoln argue that there are four competing paradigms in qualitative research, namely positivism, post-positivism, critical theory and constructivism. These paradigms differ in several aspects; the most relevant areas of difference for my research are as follows: the aim or purpose of inquiry, the nature of knowledge and the implications of each paradigm for the training of new inquirers (Guba & Lincoln, 1994, p. 105-117). One can rarely make a sharp distinction between these four, but when I look at my own research, it is clear that my view is predominantly constructivist. In my work, I have tried many times to improve teaching and learning by stimulating discussions and eliciting collaborative efforts.

Five research areas have been identified as specific for the new discipline of engineering education ("The National Engineering Education Research Colloquies," 2006):

- Engineering Epistemologies
- Engineering Learning Mechanisms
- Engineering Learning Systems
- Engineering Diversity and Inclusiveness
- Engineering Assessment

A key focus of research in engineering education is the recruitment and retention of a larger and more diverse group of engineering students (Jones, 2003). Other areas of interest are common to all research about higher education, such as the extension of teaching and learning processes to include the use of pedagogical online learning and Open Educational Resources (OER) or research into epistemologies, learning mechanisms and systems, equity and diversity and assessment of teaching and learning.

An objective of engineering education research is to improve engineering education through staff development. Such research was considered essential by the Engineering Education Research Colloquies (EERC); their report states that ‘research is needed to inform collegiate instruction and the instructional culture, institutional infrastructure, and the practices and epistemology of engineering educators’("The National Engineering Education Research Colloquies," 2006).

6.2.2 Communities of Practice

The concept of community of practice was first suggested by Lave and Wenger in Situated Learning: Legitimate Peripheral Participation, 1991 (Lave & Wenger, 1991). In a later publication, Wenger (1998) defines community of practice as ‘a kind of community created over time by the sustained pursuit of a shared enterprise’ (Wenger, 1998a, p. 45). He adds that ‘A community is formed by people who engage in a process of collective learning by interaction and collaboration within a shared domain of human endeavour’ (Wenger, 2011). In other words, communities of practice can be seen as groups of individuals who interact regularly and share a concern for something they do, for example, lecturers in a faculty who share a common goal to develop teaching and learning through discussion and collaboration (Wenger, 1998b). What is important in this concept is that if the community does not ‘interact and learn together, they do not form a community of practice’ (Wenger, 2011). My own research, involves groups within an organization, and the members of the groups are ‘willingly to act together to improve their situation’ and, arguably,

interact and learn together as they do so. Lave and Wenger's concept is useful, but the defining characteristics of it (the domain, community and practice) are broad in themselves, and because of this, the concept can be used rather broadly and may sometimes be ambiguous. For example, are members of a chess club a community of practice or should the term only be used for those members of the club who come together to interact and become better at their practice?

A community of practice may be more resistant to change than an individual member (Ford et al., 2008). In all groups there are some members with higher status, and we can see those members as the informal leaders in a community (Devereux, 1960). When a community of practice is changing, a person may take initiative and act as a pioneer, strengthening his or her position in the group (Howe & stubbs, 2003). This strengthening is what we call 'peer recognition' (Schmidt et al., 2009). In a work place community of practice, knowledge is created, shared and maintained via the natural processes of communication, negotiation and collaboration (Lintern et al., 2002).

If teachers in a workplace have a common goal and collaborate, they form a community of practice. Because teaching and learning have their own unique problems, teachers often develop an explicit teacher culture through discussion, collaboration and mutual learning. This in turn can lead to change and growth, promote communication and have a positive effect by rendering the intangible cultural atmosphere more explicit (Zeng & Zhao, 2009).

The concept of community of practice is often used in educational research, but if the common interest in a community of practice is aimed at learning, many researches prefer to use the term 'community of learners' (De Boer et al., 2009; Jiuming et al., 2009; Petersen, 2007; Suzuki & Funaoi, 2002; Wilson, 2007).

6.2.3 A modern learning theory

Constructivism says that knowledge is not transmitted directly but people construct their own understanding and knowledge of the world through experiencing things and reflecting on those experiences (Driver et al., 1994). In this thesis I adhere to a view of knowledge and learning where constructivism, social constructivism and experiential learning form a learning theory, with the learner as an active participant in the creation of knowledge. Knowledge is developed, shared and maintained by processes of action, communication and interaction.

7. Methodology

In this section I will describe the methodological stance of the research which draws on action research.

7.1 Action Research

In the 1980s and 1990s, there were a number of advocates for educational action research (also called participatory research). Within academia, scholars such as Argyris & Schön (1978), Stenhouse (1980), Carr & Kemmis (1986), McNiff (1988), Fletcher (1988) and Elliott (1991) argued for its acceptance as a mainstream research method. Today there is a whole family of action research practices or, as Reason and Bradbury call it, 'living inquiry or living theory' (Reason & Bradbury, 2008, p. 1). Reason and Bradbury refer to the 'dynamic practices' of action research and 'the collaborative manner in which the practices are carried out'. They also emphasize the goal of knitting together 'ideas and action in order to solve problems generate new solutions and consequently new knowledge'. They call their version of action research 'living inquiry'.

Action research 'is an outgrowth of the traditions of John Dewey and Kurt Lewin' according to Argyris et al. (1985). They assert that Dewey's theory of inquiry was 'a model both for scientific method and for social practice' and that both thinkers saw the need for 'the integration of science and practice'. Dewey and Lewin had met on a couple of occasions and agreed on the importance of applied research and the principles of 'progressive education' (Adelman, 1993, p. 12). The ideas of Dewey and Lewin were considered to be quite radical at the time, and 'action research' as a method remained largely untested until the late 1960s. At that time, government intervention made money available for 'social change projects', but throughout the 1960s, the use of action research waned, mainly due to the attitude of funders who were not altogether comfortable with its emphasis on social reform (Glanz, 2003, p. 15).

Dewey insisted that a suggested solution to a problem has to be tested by acting upon it. If the action brings about certain consequences or certain determinate changes in the world, the idea or theory is accepted as valid. Otherwise it is modified and another trial made. Thinking includes all of these steps:

the sense of a problem, observation of conditions, formation and rational elaboration of a suggested conclusion and active experimental testing (Dewey, 1916, p. 177).

Lewin was influenced by the Frankfurt School and critical theory. He was a significant figure in post-World War II psychology and is one of the founders of social psychology and a pioneer of organizational development, group dynamics and force field analysis (Lock & Nguyen, 2010, p.296). At the time of his death in 1947, he was Professor in charge of the Research Center for Group Dynamics at MIT. Lewin's motto was 'No action without research; no research without action', and he declared that 'Research that produces nothing but books will not suffice' (Adelman, 1993, p. 8).

According to Greenwood (2004), it was Lewin's vision to develop a socially useful psychological science that led to his engagement with 'action research', a term he elaborated on in an article that first appeared in 1946 in volume 2 of the *Journal of Social Issues*. The research that was required for social practice, wrote Lewin, 'is a type of action-research, a comparative research on the conditions and effects of various forms of social action, and research leading to social action'. He cited the research he had done on minority problems and argued that 'this and similar experiences have convinced me that we should consider action, research and training as a triangle that should be kept together for the sake of any of its corners' (Lewin, 1946, p. 42).

Lewin describes action research in his paper 'as a spiral of steps where each step is composed of a circle of planning, action and fact-finding' (Lewin, 1946, p. 38). The spiral starts with a problem or situation that needs improvement (Lewin, 1946, p. 37). This starting point leads to planning for change, where questions and facts are collected, defined and analysed. The analysis leads to a re-evaluation of the situation and tentative recommendations for changes that can lead to improvement. Changes are implemented, and this concludes one cycle of action research. If the changes are not completely satisfactory, a new cycle can begin and the research process enters another spiral of steps (Lewin, 1946, p. 38). In the new spiral, the same steps are repeated, namely planning and defining of a new intervention, action evaluation of the effects of the action and possible improvement. If new questions arise or new needs are identified, the research could enter a new phase.

Figure 4 shows a diagrammatic representation of Lewin's spiral of steps with the starting point where an issue or problem is identified, the action to improve matters and the analysis and evaluation of the intervention making up one cycle of 'action research'. If new issues or questions arise, this may lead to a new cycle in the spiral process.

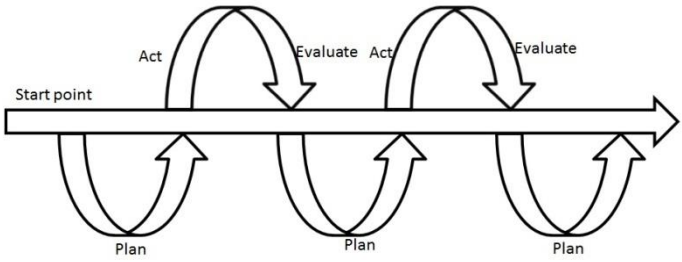

Figure 4: The spiral of steps in action research described by Lewin

Action research is collaborative by nature since actors within the situation are not only 'objects' of research but also the ones who will need to enact new procedures that the research shows are important to perform if the situation is to be improved. This was an important issue for Lewin, who studied organizational and attitude change. A high degree of collaboration is what more recent researchers call 'core action research' (Coghlan & Brannick, 2010; Zuber-Skerrit & Fletcher, 2007). However, there can be varying degrees of collaboration. Action research in many school situations, for example, has a high degree of collaboration (McNiff, 1995; McNiff & Whitehead, 2005; McNiff & Whitehead, 2009; Whitehead & McNiff, 2006). In studies of higher education, the level of collaboration can vary.

7.1.1 Case studies

Case studies are often used in action research (Blichfeldt & Andersen, 2006). Yin (2009) defines the research process of a case study as 'an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context' (Yin, 2009, p. 18). In a somewhat similar vein, Merriam (1988) emphasizes the in-depth nature of a case study, saying that 'A qualitative case study is an intensive, holistic description and analysis of a single instance, phenomenon, or social unit' (Merriam, 1998, p. 21). There are many ways to study a particular case. One can approach it 'qualitatively, or analytically, or hermeneutically, or by mixed methods' (Flyvbjerg, 2011). Flyvbjerg also points out that an important aspect of a case is 'the demarcation of the unit's boundaries'.

7.2 Method

The research presented in this thesis follows the action research methodology first advanced by Kurt Lewin. It is an action research project, divided into three case studies, each section representing a step in the spiral of action research (see fig. 4). The research design is a mixed methods design. To achieve a deeper understanding of the way the LMSes were utilized and problematize

issues for further development, a combination of quantitative and qualitative methods were applied. The case studies include investigations undertaken together with engineering students, engineering educators at a small regional university in Sweden and lecturers in a number of South American universities.

I used the categories of people and place to delimit the boundary of my three case studies (MacNealy, 1997). In the sections below, each group is presented as a separate case study, and the validity and reliability of the studies and ethical considerations concerning them are discussed. The Latin American educators who took part in the third case study form a single case study with the participants divided into three subsets, one for each country. The subsets were similar in terms of backgrounds and objectives.

In action research there can be varying degrees of interaction. In my case studies, the involvement was limited because the phenomena I investigated and the problems I addressed are premised on a lack of lecturer time. Most of the people who participated in my research are engineering educators, not educational developers. They have their own research, administration and subject-specific teaching to attend to. They were willing to participate in the projects that I started but did not share responsibility for the research.

7.2.1 The three Case Studies

The first case study investigated the use of an LMS by a group of eight engineering students who were working on their final degree project reports. My research question was as follows: Can the use of an LMS improve engineering students' performances during their final exam projects? The investigation was conducted using interviews and discussions and an assessment of the students' final reports. The results were presented at an international conference (Garrote Jurado, 2005).

The second case study was conducted over a period of five years in order to investigate acceptance of an LMS by the lecturers. The use of an LMS and the lecturers' attitudes about it were investigated at the School of Engineering at the University of Borås. The study consisted of four investigations, two predominantly quantitative and two based on semi-structured interviews. The results are presented in Articles I, II and III. In Article II, the quantitative data were combined with qualitative data received from a focus group formed by five lecturers from the School of Engineering who regularly used the LMS. Some participants left their positions at the university during the time window between Articles I and III. At the beginning, 22 lecturers at the School of Engineering participated; five years later, seventeen of them were interviewed again using a similar interview form. The same procedures were followed on both occasions.

The third case study is an evaluation of the practical part of the action research. It was conducted during the implementation of the course *Adaptation of Engineering Education to the use of Net independent software* at three Latin American universities, and the participants at each university were considered to be a subset of the same case. The course utilized the LUME method to provide both the necessary technical skills and motivation to utilize ICT in a pedagogically sound way. The assessment of the method and its usefulness was performed by means of questionnaires, interviews and group discussions.

7.2.2 Quantitative and qualitative data collection methods

In the first case study, data were collected by interviews, discussions and the assessment of the students´ work. The purpose of the discussions was to gather data, as well as to reinforce the students' sense of belonging to a community of learners (Wilson, 2007). At the time, the focus was on the practical aspects of LMS usage and the students´ work on their projects.

To collect the qualitative data in the second case study (Holme et al., 1991), I used a combination of interviews based on an interview schedule, questionnaires used in conjunction with the interviews, field notes, memos and focus groups. The interview schedule in articles I and III was inspired by the list of questions that Dutton et al. put forward in the article The Social Shaping of a Virtual Learning Environment (Dutton et al., 2004). A key question Dutton asks is 'Which main social, cultural, psychological, economic, technical and other factors facilitate or constrain the uses to which the VLE is put?' The question is extremely broad but provides a starting point for the second case study. To limit the focus somewhat, more attention was paid to the cultural and psychological aspects. The questionnaires used in the second and the third case studies consisted of yes/no, multiple-choice and open-ended questions.

In articles I and III, a similar five-grade Likert scale was used in interviews and questionnaires to investigate the results. The respondents chose from a list of answers or values on a scale from 1 to 5 and ticked the value that best matched their point of view. In both investigations, a test interview was performed with an observer present, after which the questions were finalized. During the interviews, the respondents had the opportunity to review their responses, which resulted in some changes and additional comments.

The quantitative data in the second case study (article II) was collected by the researcher logging into the LMS with teacher or main administrator rights. I had these rights as the coordinator and technical support person for the LMS. Every course was examined, and it was noted what tools had been used in the LMS. The observations were recorded in a spreadsheet to enable the processing of the data. Before the investigation began, the approval of the dean of the School of Engineering was obtained.

The analysis of the responses was inspired by Lewin's work with force field analysis, in which helping and restraining forces or factors are considered (Lewin, 1943). The value of factors such as workload, perceived ease of use, peer recognition and previous experiences may vary among people. To some extent, teachers can decide if or how they will utilize educational software and the decision is based on the strength of different factors.

In case III (article IV) data was collected with questionnaires, discussions and field observation. Responses from the questionnaires were analysed in the same way as in case II, using a five-grade Likert scale. The questionnaires with opinions about the course were filled in anonymously.

7.3 Methodological and ethical considerations

Both the validity and reliability (Cohen et al., 2011, p. 179-216) of the investigations were considered for each article. Validity means that the studies measures factors that are relevant in the context (Bjereld et al., 2002, p. 108). Reliability means that the measurement is repeatable and consistent regardless of the number of data collectors (Bjereld et al., 2002, p. 111). A high level of reliability is reached when systematic observations are performed using the same data collection mechanism (Denscombe, 2000, p. 165-174). In the second case study article II give quantitative data concerning the LMS usage. To avoid random variation in the results, an observation scheme was used. Before the observations were executed, the scheme of observations was tested by two people independently examining 10 courses according to set instructions. The obtained results were in full agreement.

In all three case studies the conclusions rely on qualitative data. The research cannot be fully repeated and it is not given a priori to what extent the results apply in another setting (Patton, 2002). The results presented in the articles have been subjected to an informal evaluation by many participants to guarantee a high level of respondent validation (Cohen et al., 2011, p. 202).

For all of the studies including the work that I conducted before I became a PhD student, I discussed the procedures for data collection and analysis with my supervisor. Additional discussions with colleagues and other researchers helped me understand the principles of reliability and validity. Furthermore, the research included in this thesis has been published in peer-refereed international journals or presented at international conferences, lending a more formal note of quality assurance. An important aspect of the peer review process is the feedback from reviewers, and I have benefited from many useful suggestions.

During the research, the ethical aspects put forward in *Research Methods in Education* (Cohen et al., 2011, p. 75-ff) were observed by informing the

participants that I was gathering data and intended to publish the results and obtaining any ethical clearances that were required.

All of the case study participants were involved in engineering education. In my first case study, students were included, and therefore there were some risks to be considered. As Pring says, '*…thus the educational researcher faces the same kind of moral demands as does the teacher as he or she applies professional judgment in the 'educational practice'* (Pring, 2010, p. 142). Discussions and interviews can affect the participants in many ways and the teacher/researcher must not allow scientific curiosity to compromise the teacher-student relation (Levinas, 1979, p. 177 ff). There is a risk that cooperation and relations within a group could be adversely affected if one delves too deeply into the group dynamics and interviews could disclose sensitive personal information and opinions. Therefore, a high level of confidentiality was maintained, I was the only person who handled the research material. The students were aware that I was planning a publication and had no objections. The risk of revealing sensitive information was reduced since the results were only published as a summary of the group's performance.

During the second case study, articles I-III. I worked with colleagues, teachers at the University of Borås. The research focused only on the participants in their professional capacity, and the purpose of the research was to arrive at conclusions that could be beneficial to the participants. There were no risks that would follow from the publication of the results. The actual interview only took approximately half an hour to finish, and the participants willingly participated in such a task that was not time consuming but potentially helpful to their practice.

In the third case study, article IV, all of the participants gave their consent; any potentially sensitive information was treated confidentially and answers to the course evaluations, were provided anonymously.

Another consideration was the possible consequences for the organization, which in this case are the universities. At universities, research about teaching methods may have effects at different levels. Research results can provide arguments for or against methods, programs, technology, and organizational models. Therefore, there may be people in the organization who object to some research or would have if they had understood the possible impact. During my work in Latin America, I raised awareness about OER and advocated for the use of free programs and OER without considering the interest of those who were interested in continuing to use proprietary software. In doing so, I decided that public interest outweighed commercial interests (Pring, 2010, p. 147).

8. Summary of the case studies

8.1 Case Study I

This study began when I was assigned to supervise eight engineering students who were working on their final degree project reports. The students at the School of Engineering were required to complete a project report during the last year of their education to graduate. Teachers who were assigned to supervise students got paid for 7.5 hours teaching, which corresponds to 22.5 hours of working time, per student. The students worked on their projects full-time for about ten weeks or half-time for twenty weeks. A typical project involved solving a technical problem and presenting the work in a report.

8.1.1 Background

I had been told by my colleagues that there were some recurring problems in the education process that resulted in too many students failing to complete their education within the allotted time. Many lecturers were discontent with the standard of the students' final projects; the complaints were mostly directed at the written reports rather than the practical work on the projects. In addition, many students did not finish their reports on time, and others never completed their reports and left the school without receiving a diploma.

My observations as well as discussions regarding teaching and learning with my colleagues confirmed that the students tended to work independently and focus on one course at the time. This meant that long-term generic competences, such as problem solving, information handling and collaboration with other students, were less developed than their subject-specific knowledge. Most colleagues with whom I discussed this viewed it as a major reason why many students failed to deliver their final reports by the due date and why many reports were of poor quality.

8.1.2 The project

My own experience as student as well as the theories of learning I was introduced to when I began taking courses in pedagogy suggested that more interaction and collaboration was the natural way forward. After a discussion with my students, I decided to make use of the available LMS to facilitate increased

interaction and cooperation within the group. For the students, I set up a discussion room, calendar, common area with a weekly report on progress, working papers, debates, and final reports. The students were strongly encouraged to provide feedback on each other's projects and working papers.

8.1.3 The investigation

This case study constitutes the first cycle of the action research project presented in this thesis. The study was conducted before I began my doctoral work and was not intended to be an academic project at the time but rather a practical test of the potential feasibility of an LMS. However, my approach fit into the concept of action research in which a problem is identified, an action is taken to improve the situation and the intervention is evaluated, constituting one cycle of action research. As a support person for the LMS, my intention was to test the claims of researchers that an LMS could improve student performance and enhance the learning experience (Björck, 2004; Britain & Liber, 2004; Chodorow, 1996; Gisselberg, 2002). The investigation was conducted by interviews, discussions and the assessment of the students' final reports.

8.1.4 Outcome

Seven of the eight students finished their reports on time and passed their exams. The eighth student stayed in touch with the other students and participated in the discussions. He did not finish his report at this time because he was offered a paid job at the firm where he was doing his project and decided to take a break from his studies. All of the students appreciated the interaction and cooperation very much and responded well to the possibility of receiving feedback from each other as well as from the instructor. Discussions with the students in the group and colleagues at the School of Engineering together with the assessment of the students' final reports clearly demonstrated that collaborative efforts facilitated by an LMS can improve the quality of project reports and elicit a far better time management by the students. As for the teacher, the time allotted for instruction and supervision, 22.5 hours of working time per student, was sufficient. The time used to manage the LMS was well compensated by reducing the need for face to face meetings and individual instruction. Both the students work process and the quality of the final reports benefited from interaction with group members and teacher in the LMS. The results were presented at IMPACT 2005, the 7th Annual WebCT User Conference San Francisco, USA.

8.1.5 Conclusions

Collaborative efforts facilitated by an LMS can improve the quality of reports and the students' time management. For a computer literate teacher the time

needed to manage the LMS is well compensated by reducing the time needed for face to face meetings and individual instruction.

8.2 Case Study II

This case study constitutes the second cycle of the action research project. I suspected that the LMS was underused at the School of Engineering at UB. To verify my initial impressions, I felt I needed hard evidence. Hence, in 2004 I decided to verify the pattern of LMS usage.

The case is delimited as follows: the usage of LMS by lecturers at the School of Engineering, University of Borås between the years 2004 and 2010. It was conducted as a longitudinal study with four investigations, two predominantly quantitative, based on observations of electronically archived material, and two qualitative surveys, conducted by interviews.

Despite the pedagogical possibilities offered by an LMS, it is often used simply as a repository for electronic documents (Bongalos et al., 2006; Collis & van der Wende, 2002; Dutton et al., 2004). Many researchers have asserted that access to an LMS together with staff training and support will not suffice to change a lecturer's practice (Blin & Munro, 2008; Lonn & Teasley, 2009; Selwyn, 2007).

8.2.1 The quantitative investigation

Article II charts the use of an LMS at the School of Engineering, University of Borås in the calendar year 2004 and the academic year 2009-10. Data was collected on two occasions, in 2005 and then in 2011. Data from the first investigation was published in a book chapter (Garrote Jurado, 2006). This study outlines the use of an LMS at the School of Engineering in 2004, when I was administrator for WebCT, a proprietary LMS. As the administrator, I could access 'log-files' and other archived material, including statistical data about the extent to which the lecturers utilize the LMS.

The second investigation was performed in 2011. For both investigations, the LMS (WebCT or PingPong) were examined and a similar observational scheme was used. Each course was investigated, and the tools in the LMS that were used were noted in a spreadsheet.

In Article II, the data from both investigations were compared and a classification of the features in the LMS was introduced. The following categories were used:

A. *Tools for distribution*: these include the features that allow lecturers to upload documents and make files available to the students. The process is basically one-way, that is, teacher-to-learner distribution of information.

B. *Tools for communication*: the most common example of this type of tool is the E-mail function or message board.

C. *Tools for interaction*: these tools require reaction and/or feedback. Discussion boards and wikis are typical examples.

D. *Tools for course administration*: these tools are primarily used to monitor and document the educational process rather than facilitate teaching or learning.

The above classification system was based on the actual application of tools within the surveyed courses. For example; if E-mail was used to work on group assignments, then it was classified as a tool for interaction in that particular course. On the other hand, some tools clearly intended for collaborative work may have been used only to disseminate information.

In many courses examined in these investigations, several tools were made available according to the log-files generated by the system but were not actually used. This means that although log-files show all of those tools, we can only determine if a tool has really been used within a certain course by looking at the archived material. Thus, while it is tempting to rely on log-files for surveys of this kind, to do so without actually verifying tool usage could give a false indication of much higher usage.

The tools for interaction are useful for encouraging student activity and collaboration, thereby enhancing the learning experience. In the literature, there are many examples of high expectations linked to an LMS as a tool to enhance the learning experience by promoting student-centred methods and the creation of effective learning environments (Blin & Munro, 2008; Bush & Mott, 2009; Findik & Ozkan, 2010; Ladyshewsky & Gardner, 2008; Ubell, 2000; Wilson & Stacey, 2004). Other researchers have asserted that both scholarly and social interaction may enhance learning by helping students to form communities of learners (Hopperton, 1998; Irwin & Berge, 2006; Murphy, 2004).

There is also political pressure on the education system. Sweden as well as other countries aims to increase the use of ICT to enhance performance and facilitate flexibility in education (Dearing, 1997; Regeringen, 1996; Wan Ng & Gunstone, 2003).

Numerous educational institutions worldwide have made substantial efforts in terms of time and money to buy and maintain LMSes and provide the technical and pedagogical support needed to run them (Brill & Galloway, 2007; Browne et al., 2006; Czerniewicz & Brown, 2009; Klobas & McGill, 2010; Marshall, 2004; Paulsen, 2003; Weaver et al., 2008). The University of Borås is no exception, and most lecturers have had access to computers and internet connection since 1995 and support and the opportunity to utilize an LMS since 1999. Until 2007, there were two different LMSes used at UB, Luvit and WebCT. At that time, there was not a general policy for the use of LMSes. When a procurement process was completed in 2007, an LMS called Ping-Pong was introduced. In 2008, it was decided to only use and provide support for this particular LMS.

8.2.2 Comment to the findings

The results from the School of Engineering at UB are clearly consistent with the results of a number of earlier studies that demonstrated that lecturers prefer to use LMSes predominantly to distribute documents to students (Bongalos et al., 2006; Collis & van der Wende, 2002; Dutton et al., 2004; Phillips, 2006). In spite of considerable efforts by the department to provide education and support, the lecturers at the School of Engineering were using the LMS in the same limited way in 2010 as they did in 2004. The findings confirmed that access to an LMS, staff training and support will not suffice to change a lecturer's practice (Blin & Munro, 2008; Lonn & Teasley, 2009; Selwyn, 2007).

8.2.3 The qualitative investigation

The qualitative part of the investigation was intended to provide a better understanding of why LMS use was so limited and what could be done to elicit a wider utilization of the interactive tools. The lecturers' perceptions about LMS use were investigated by guided interviews in 2006 and 2011. Article I is based on interviews with 22 lecturers conducted in 2006.

In 2011, 17 lecturers who had been interviewed in 2006 and had worked at the School of Engineering with the new LMS (Ping Pong) were approached, and they all agreed to be interviewed. In Article III, data from both surveys were compared to answer the following three questions: What expectations do lecturers have regarding the future impact of LMS? Were there any particular problems when a new LMS was introduced in 2008? Has there been any change in the lecturers' perceptions over time?

8.2.4 Findings from the interviews

The purpose of the interviews was to understand why tools that facilitate dissemination of information were used routinely by most lecturers but the tools intended to promote collaboration and interaction were seldom utilized.

The interviews confirmed that the lecturers found the LMS to be useful in their work, but they did not think it has a substantial impact on the students. This finding was not surprising because if the LMS is used merely to distribute documents, then it is likely to facilitate traditional, teaching-centred pedagogical methods, and the students will work in the same way as they did when documents were distributed as paper copies.

One explanation as to why collaboration and interaction are not given more attention is that the lecturers and students focus on the subject-specific content of the courses. Many of the expected positive effects of promoting collaborative learning are long-term and interdisciplinary.

During the interviews, it was evident that many lecturers realized the potential long-term benefits of collaborative learning. However, lecturers and to an even greater extent students are under severe pressure to produce results within a set frame of time and subject-specific knowledge. The result is that generic competences and other long-term effects of more collaborative, learner-centred methods are rarely a priority in education.

8.2.5 Conclusions

Case Study 2 strongly supports the view expressed by many theorists (Blin & Munro, 2008; Lonn & Teasley, 2009; Selwyn, 2007), that access to an LMS as well as support and training are necessary but not sufficient for the optimal utilization of an LMS in the educational process. Most lecturers chose to use tools in an LMS that facilitate their old teaching practice rather than trying to improve their teaching methods with the help of new features. The lecturers' choices of tools suggested a strong resistance to changing their teaching practices. A feasible explanation for the slow acceptance of new pedagogical methods is that institutions develop traditions, defining both content of courses and pedagogical procedures (Hunt et al., 2010). Traditionally lecturers focus on the subject-specific content of the courses rather than generic skills and the assessment of many courses is designed so that students must focus on memorizing facts (Biggs, 2003; Biggs & Tang, 2011, p. 227-229).

How teachers perceive the usefulness of tools for interaction depends on their view on the role of interaction in the educational process. According to the social constructivist perspective learners construct functional knowledge by processing information in a social context. If that is true, features in a LMS

that elicit collaboration are likely to have a beneficial impact on the learning experience. Hence, the perceived usefulness of tools for interaction depends on to what extent the teacher adheres to a social constructivist perspective. By facilitating interaction, an LMS can also support the creation of communities of learners.

The results confirmed that the future utilization of tools for interaction and the subsequent transformation of educational practices must be treated as a coherent process of professional development, and lecturers should be strongly encouraged to look at the aims and purposes of education beyond the scope of single, subject-specific courses. To overcome the lecturers' fears of increasing demands on their time and attention, incentives are probably necessary. It should be noted that peer recognition, professional development and interaction within a community of practice are probably better than money at stimulating creativity and collaborative efforts (Boudreau et al., 2014).

8.3 Case Study III

The third case study is also the third cycle of the action research spiral of steps, with a circle of planning, action and fact-finding (Lewin, 1946). Based on the observations made during the second case study, it was determined that support and training are necessary but not sufficient for the optimal utilization of LMS. In particular; future utilization of the tools for interaction depends mostly on the lecturers' motivation rather than technical systems or training.

With this in mind, the course *Adaptation of Engineering Education to the use of Net independent software* was designed to give the participants the technical skills they needed to use an LMS and equally important, an understanding of how various tools can benefit education by facilitating a wide range of pedagogical procedures.

The purpose of the study was to investigate if the LUME method can facilitate the integration of the handling skills of educational software with the motivation to utilize ICT in a pedagogically sound manner.

8.3.1 Background

The benefits of educational software depend on the ease of access, the way in which it is applied pedagogically and the computer literacy of teachers and students. In developed countries, computer literacy and ample access to computers and the internet are taken for granted. However, there is still a striking difference in the degree to which features that facilitate traditional, teaching-centred methods are used compared with tools intended to facilitate interaction and collaboration in engineering education in these countries.

As shown in the second case study, access to computers, educational software, support and training are not sufficient to elicit the utilization of tools for interaction. It seems that there are substantial barriers that prevent a movement in educational practice towards methods that could be facilitated by interactive tools (Christie & Garrote Jurado, 2009). Such barriers could be institutional traditions or lecturers' lack of motivation.

In developing countries, access to computers and the internet cannot be assumed and the use of LMS is not widespread; however, the situation is likely to change. Access to computers and the internet in most developing countries is increasing and is expected to continue doing so (Dutta & Mia, 2009; Murphy, 2004). The ratio of the cost of computer equipment compared with the cost of books is decreasing rapidly, and even in poor countries, computer-aided education can be cost-efficient. Hence, the proper use of ICT to maintain the quality of and increase access to education could be a feasible way for universities in developing countries to provide education for a growing number of students.

Much of the potential of utilizing an LMS, in particular the tools for interaction is closely connected with collaborative pedagogical methods. From a constructivist viewpoint, interaction, discussions and collaboration are important for learners to construct knowledge (Holton, 2010, p. 40-51). Such interaction also promotes the formation of a community of learners. Easy access to a wide variety of information sources can facilitate PBL because students become accustomed to using and analysing different sources of information to solve a given problem. Weighing and discussing the best solutions based on the best available information is a good way to underpin collaborative learning and build communities of learners.

A major advantage of electronic documents over paper is the ease with which they can be copied and transferred. Only if teachers are willing to cooperate and share course material can they reap the full benefits of ICT in education. The implementation process for an LMS and its subsequent utilization at an educational institution elicits collaboration amongst the lecturers and enhances the function of the faculty as a work-place community of practice. The processes for supporting and using an LMS at educational institutions can further extend such collaboration so that it involves administrators and technicians as well as students and teachers.

An important aspect of the LUME method is the convenience with which OER can be utilized. In the course *Adaptation of Engineering Education to the use of Net independent software* it was desirable to raise the participants' awareness of the abundance of free resources on the internet because this knowledge can contribute to making computer-aided education more accessible worldwide.

8.3.2 The investigation

The study was conducted with participants in the course *Adaptation of Engineering Education to the use of Net independent software*. There were three groups of lecturers participating, one each in Cuba, Guatemala and Peru. The course was intended to give the lecturers the necessary skills to handle an LMS and act as support persons for the use of an LMS in their respective workplaces. They were also to be prepared to teach courses to other teachers. Thus, in addition to technical skills in handling the LMS, the participants needed a clear vision about its pedagogical application.

At the start of each course, the participants met and worked full-time for the first two weeks of the course. The first questionnaire was completed at the beginning of the course in order to survey the participants' prior experiences working with an LMS. At the end of the first two weeks, two more questionnaires were used to gather the participants' opinions about the use of LMSes and OER. A separate questionnaire with opinions regarding the implementation of the course was completed anonymously.

Additional information was gathered by observations and discussions. I made field notes and with the participants' informed consent, videotaped the participants during the course.

8.3.3 Findings

The LUME method was perceived by the participants as a step forward in their professional development. The results indicated that the participants were well prepared and better motivated to utilize ICT to promote student interaction and collaboration than the lecturers we surveyed at the University of Borås in Sweden during Case Study II.

From the discussions and later communications with several participants, it can be concluded that the collaborative learning strategy prompted the formation of a community of learners. The participants realized that the learning experience could be enhanced by the appropriate use of educational software.

Some changes were made in the questionnaires based on the earlier results. To find out how the participants in Guatemala and Peru perceived the method, the following statement was added: 'The use of a USB memory to emulate the resources of the internet makes it much more feasible to use open educational resources (OER).' In Cuba, the internet is limited and unreliable; hence, it was necessary to use some type of memory device to utilize media files. The need to take turns on different computers would have made it highly inconvenient to work without USB flash drives.

For the Guatemalan and Peruvian groups, it was more a matter of convenience and flexibility. In both Guatemala and Peru, internet access was generally sufficient to access much of the OER, for example, media files. The positive response to the statement reflects two different concerns. The obvious one is the risk of unreliable internet connections and technical limitations. The other one is that from a pedagogical point of view; LUME gives the teacher more control over the selection of information than is the case when students search the Internet. This is important because the teacher must be prepared to provide feedback to students and act as a moderator in discussions (Murphy, 2004).

9. Answers to the research questions

This thesis has aimed to demonstrate ways in which engineering education can be improved and made more accessible worldwide by the proper application of educational software. In Chapter 5: The following four research questions were put forward:

[1] Can the use of an LMS improve the performance of engineering students during their final exams projects?

[2] What tools in the LMS are actually utilized by lecturers at the School of Engineering at the University of Borås?

[3] What do lecturers think of the pedagogical possibilities of using an LMS in their practice?

[4] Can the LUME method help and motivate lecturers to utilize ICT in a pedagogically sound way?

The answer to question number one is that the LMS, in particular the online asynchronous discussion forum, contributed to the students learning experience and prompted the development of a community of learners. The students performed very well on their project reports and appreciated the collaborative efforts. For the lecturer, the time and effort required to manage the LMS, moderate the discussion forum, etc. turned out to be well compensated for by the decreasing demand for individual help from the students.

Question number two was investigated on two occasions, and the answer was consistent. Lecturers predominantly used the LMS to distribute documents to students. The tools that facilitate teacher-centred practices, such as the distribution of learning material, were used routinely, whereas lecturers refrained from using features intended to enhance the learning experience by facilitating collaboration and the creation of communities of learners.

Question number three was an attempt to specifically identify the reason why the features intended to facilitate collaborative learning and the creation of communities of learners are not utilized more often. Again, the result was consistent. Despite a cautiously optimistic attitude about the potential for an LMS to improve education and provide for interaction and collaboration, the lecturers were not prepared to face the risk of increased demands on their time or attention.

Question number four was answered in the third case study. A strong claim is made for the potential of the LUME method to improve education. In Cuba, it was possible to emulate selected internet resources and work without internet access. In all three subsets of the case, it was clear that using selected documents from the internet rather than searching for information on-line facilitated collaboration and group interaction because all of the participants had the same, manageable information in a USB flash drive. This is an important feature of the LUME method. The use of a collaborative learning strategy prompted the participants to form a community of learners. This experience immediately demonstrated the possibility of enhancing the learning experience by using educational software. The most significant result was the positive attitudes expressed by the participants in the investigated courses. The results from the courses indicate that the participants were highly motivated to utilize ICT to promote student interaction and collaboration. Only the future can tell if that motivation will have a significant impact on educational practice.

10. Discussion

The literature and the findings reported in this thesis confirm that a widespread utilization of computer-enhanced, collaborative learning in engineering education demands an initial effort by teachers and institutions (Yefim et al., 2013). Many researchers have concluded that access to computers, the internet, support and training is not sufficient for optimal utilization of ICT in the educational process (Blin & Munro, 2008). How to prepare and motivate lecturers to utilize educational technology in a pedagogically sound way is an issue for universities all over the world to consider (Blin & Munro, 2008; Lonn & Teasley, 2009; Selwyn, 2007).

A question that arises is, of course, what it means to use educational software in a pedagogically sound way. To answer that question, the concept of constructive alignment (Biggs, 1999) can be used. Biggs emphasizes the importance of linking intended learning outcomes, pedagogical methods and assessment of learning if one is to continuously improve education (ibid.). If the use of educational software is in line with the intended learning outcomes and improvement of the learner's experience, then the use is pedagogically sound.

There is a base of well-established scientific and mathematical knowledge that is common to many engineering programs throughout the world. The knowledge is transferred from books and teachers to new generations of students. As a result, engineering institutions develop a tradition, defining both content of courses and pedagogical procedures. Those traditions are a viable explanation for the slow uptake of new pedagogical methods and innovative educational technology in engineering education in developed countries (Hunt et al., 2010). In general, one cannot expect institutions in well-established academic fields, which have a large share of persistent knowledge, to be prone to making changes in their pedagogical practices. In the near future, faculties with less traditional baggage, for example computer science or business management faculties, may be able to function as pioneers and testers for new educational methods; however, this question is outside the scope of this thesis.

Engineering education in developing countries is largely copied from more developed parts of the world (Jones, 2003). The same basic knowledge is taught, using similar methods. When educational technology becomes available, it is widely used but mostly to replace older, less efficient technology and

textbooks (Dutton et al., 2004; Phillips, 2006). Therefore, educational software is not likely to have much impact on the quality of education or on students' learning experiences until the educational practice is adapted to available technology. As is shown in articles I, II and III, neither the patterns of ICT use or the lecturers' attitudes change significantly over time or depend on the particular brand of LMS the institution uses.

By following the path set by universities in rich countries, the developing countries are running the risk of underestimating the importance of the lecturers' motivation when new technology is introduced (Al-Busaidi & Al-Shihi, 2010; Blin & Munro, 2008; Mahdizadeh et al., 2008). This mistake is likely to lead to educational software being used to facilitate existing practice rather than to stimulate the transition of pedagogical procedures (see article II). If, on the other hand, appropriate action is taken in staff development and education, then educational software can be used to facilitate the development of collaborative learning methods and elicit the transformation of student groups into communities of learners (Suzuki & Funaoi, 2002). That would allow educational institutions in developing nations that are starting to utilize ICT to leapfrog the process in many developed nations and immediately pursue more elaborate computer-supported educational practices (Harris & Rausch, 2013).

10.1 The future of educational software

The relevance of this thesis is closely connected to the future of educational software. To optimize students' performance, courses should be carefully planned and the use of educational software should be adapted to the student group (Harris & Rausch, 2013). As a result, sometimes teachers will make extensive use of computers, internet resources and educational software; at other times, the teacher may not need to use them to the same extent. It should be noted that while lecturers should choose appropriate tools for specific courses and target groups, it is also important that students develop their own computer literacy and information-handling skills. In addition to familiarizing themselves with software that can facilitate their studies, students can benefit by preparing for life-long learning and future professional and personal development. Developing competence and confidence in the pedagogical use of ICT can have positive spin-off effects in a wide range of activities (UNESCO, 2011, p. 16-17).

Throughout this thesis, I have used the term LMS to depict a fully integrated set of educational software intended to facilitate teaching, learning and course management (Piña, 2013). The research presented in this thesis concerns three different brands of LMS, two proprietary (WebCT and Ping-Pong) and one free, open source (Moodle). All three have similar features, and computer-literate lecturers should be able to switch from one system to another

without difficulty. If a university or an institution does not have an integrated LMS, it probably still provides a package of programs that are available to teachers and students. If such a package offers similar features as a common LMS, I would argue that the software package forms an institution-specific LMS.

Whether we use the term LMS in the future, most educational institutions will need a standard set of educational software as well as guidelines for their use. The continued and extended use of educational software at universities requires technical and pedagogical support including hands-on help with course development. It is necessary to discuss and reflect upon the connection between pedagogical approaches and different educational software (Harris & Rausch, 2013). In particular, teachers who use an educational software program for the first time must be aware of the potential advantages of using the tools since it takes an initial effort to learn both the pedagogical and technical details involved (see article III). Many institutions in developed countries utilize some proprietary LMS, and in general, institutions that utilize proprietary LMS not only pay for the software but also pay for instruction and support for their staff.

As shown in article IV, when freeware such as Moodle is used, it is usually possible to find free advice regarding its use on the internet (Liao-Troth & Griffith, 2002). In addition to the instructional material, there are many discussion forums on the internet that can provide support for both novice and experienced users. They can be helpful, but the unwillingness of many lectures to set aside time for such activities is a concern. Because of this reticence in both educational systems and industry, it is sometimes more cost-effective and certainly less time-consuming to pay for outside service and expertise. This is one explanation why there is a commercial market for educational software packages despite the fact that programs with similar features are available as freeware.

Another explanation as to why institutions use commercial software when there are open source alternatives is administrators' fear of being held responsible for mistakes. Anyone who makes a decision to utilize open source programs instead of purchasing a commercial product risks being blamed for any dissatisfaction with the software. A procurement process gives the decision a stamp of objectivity and makes it difficult to place blame on the purchaser. Obviously, once a procurement procedure is initiated, the non-commercial alternatives are ruled out (Kagiri et al., 2013; Wheeler, 2014).

To date, there is no indication that LMSes are going out of fashion (Sclater, 2008). For example, by 2008, more than 90 percent of academic institutions in the USA had implemented an LMS platform (Hill et al., 2009). The market for LMSes is estimated to grow to nearly $2 billion during 2013 (McIntosh, 2013). Figure 5 shows the most commonly used LMS by country; the map is based on data from 5,600 higher educational institutions and represents the most recent data (from August 2013). In most countries, the open source LMS Moodle is most commonly used. It should be noted that institutions sometimes buy education and support for open source LMSes.

Many researchers have argued that LMSes will soon be obsolete (Cohen,

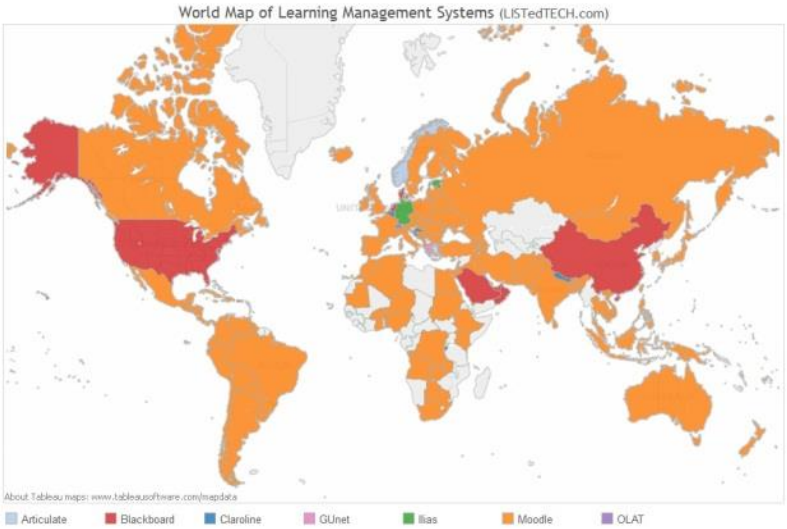

Figure 5: World Map of Learning Management Systems (http://listedtech.com/)

2010; Pontefract, 2009; Weller, 2007). It is easy to follow their line of thought. If we look at the features in a modern LMS and compare it with the resources we find on the internet nowadays, it is obvious that tools similar to those we may find in an LMS are available as freeware. Thus, some conclude that there is no need to continue using and paying for a powerful system, especially if staff use a limited set of the available tools.

Other researchers are not convinced of the potential benefits of an LMS because they focus on the individual learner. For example, Dalsgaard argues that 'it is necessary to move e-learning beyond LMS and engage students in an active use of the web as a resource for their self-governed, problem-based and collaborative activities' (Dalsgaard, 2006). A problem with this individual learners approach is that if each student utilizes a different selection of soft-

ware and sources of information, it is difficult to engage in collaborative learning. Perhaps less obvious is the fact that the teacher's ability to guide the students may suffer.

In traditional education, from primary to higher levels, students find information in textbooks and are guided by teachers, but they also interact with other students. Discussions and collaboration are then facilitated by a common understanding of the subject in question. Interaction and collaborative work is the main focus of constructivist theories of learning and from a constructivist perspective, there are risks with replacing conventional textbooks with free internet access. If we use a textbook or rely on a lecturer's knowledge, the students will have access to the same information but if we use the internet, each student could pick their own sources for information. The risk is that discussions will turn into arguments regarding the merits of the various sources of information, rather than the creative co-construction of shared perspectives the constructivist teacher aims for. This is a difference from real-life situations where most people want quick answers to questions, or solutions to specific problems.

During their studies, students will encounter a selection of programs, and together with other selected resources, that package will form the student's personal internet gateway. When learners select a collection of educational software and adapt it for personal use, the term personal learning environment (PLE) is sometimes used (Chen & Han, 2007; Johnson & Liber, 2008; Soumplis et al., 2011). I find this term less useful for a number of reasons. The most important reason is that internet users form their personal gateway to the internet with links, bookmarks, etc., and usually there is no specific area for educational activities. The other problem with the concept of PLE is that two PLEs will never be similar. Even if two computer users have exactly the same programs, links and bookmarks on their computers, their pattern of use can be very different. Previous experience, computer literacy, random events and personal taste will soon lead to different changes in the personal internet gateway. The lack of a standardized user interface and contents may lead to unreasonable demands on the teacher to provide individual assistance.

10.2 Live USB-Mediated Education (LUME)

Bringing together educational software, free information and modern pedagogical methods is an obvious aim for most educational institutions. It is equally important in both staff development and education to look at all three aspects and how they are connected. Below I argue that LUME integrates all three points, and the intentions of LUME are presented graphically (fig. 6). In the figure the broader term "Information and Communication Technology" is used to include computers and other technical devices.

The first time the LUME method was used was in the course *Adaptation of Engineering Education to the use of net independent software* as reported in article IV. The course was designed to compensate for the shortage of computers and limited internet access in Cuba and to implement the use of multimedia course material in the context of PBL.

As shown in article IV, the method had additional advantages: the participants received first-hand experience in computer-supported collaborative learning. The method elicited a substantial amount of group activity and facilitated the transformation of the group into a community of learners, and the use of the LUME method introduced the participants to OER.

In the articles included in this thesis, it is argued that the future utilization of ICT and the transformation of educational practices should be treated as one coherent process of professional development. This is necessary in order to motivate lecturers to utilize new technology in a pedagogically sound manner.

When LUME was used in a staff development context, the outcomes confirmed that a combination of technical training and discussions about pedagogical methods is a viable way to prepare university teachers for a change in their pedagogical practice. Of course, there may still be a need to stimulate the use of educational software and reward people who act as leaders or pioneers in the workplace.

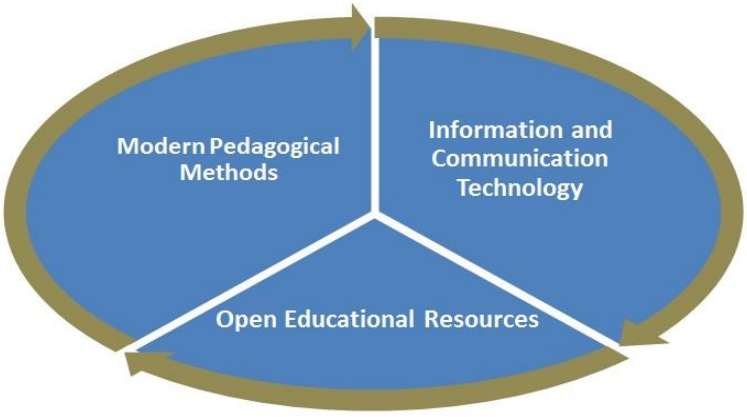

Figure 6: The aim of the LUME method (Garrote Jurado & Pettersson, 2011b)

10.2.1 Information and communication technology

Technical development and decreasing prices of both hardware and software may change the way in which LUME is utilized. In many countries, especially

in developing nations, there will be a shortage of computers and limited internet access in the foreseeable future (Dutta & Mia, 2009). But, if there are a sufficient number of computers available, it is easy to connect them into a functional intranet. Then the LUME method can be applied as it is described in Article IV and the local intranet (possibly just a couple of connected computers standing in a room) can be seen as one memory device, available to multiple users, once the material is stored within. In developed countries, all of the students in a class may have a laptop with mobile internet in the near future. Then there would be no need for a portable memory device, but it would still be convenient to distribute course material and software as a complete package and utilize similar procedures for teaching and learning.

10.2.2 Open educational resources

LUME is convenient as a tool to utilize and share OER on a large scale. This offers the possibility of significantly improving the availability of education in countries that have growing numbers of tertiary students and severe financial restrictions (Caswell et al., 2008). The internet offers abundant instructional materials that are free for educational use as well as free software, including complete LMSes, such as Moodle (D'Antoni, 2008). When material is free to copy and redistribute, with LUME the complete package including the educational software can be copied and redistributed, an important aspect of the LUME method (see article IV). To use proprietary software or course material could cause a lot of problems with unauthorized copying.

10.2.3 Modern pedagogical methods

The term ‘modern pedagogical methods’ in figure 6 needs to be elaborated. One’s view of knowledge determines the choice of educational procedures. The traditional view that knowledge exists and can be transferred unaltered from books to students has been replaced by the view that knowledge is created in a process with the learner as an active participant (Harris & Rausch, 2013). Learners form their knowledge by processing new information and combining it with previous knowledge. This process can take place in the mind of a single person, but it is usually enhanced by interaction with others or the outside world.

In chapter 6.1.1, the development of learning theories over the last hundred years is outlined. Together, constructivism (Driver et al., 1994), social constructivism (Ernest, 1998) and experiential learning (Kolb, 1984) form a modern learning theory, with the learner as an active participant in the creation of knowledge. Among theoreticians, this view gained acceptance in the later part of the twentieth century, and many well-known pioneers recommended a shift

from teacher-centred to student-centred pedagogical methods (Ausubel, 1963; Badley & Habeshaw, 1991; Ramsden, 1992; Vygotsky, 1978).

Based on this view of knowledge and learning, we can identify some common denominators of modern pedagogical methods. The modern teacher should facilitate learning by a design and implementation of courses that takes the student's previous knowledge and experience into consideration (Beaudoin, 2013). The learning, or the creation of knowledge, is facilitated by a combination of theory, experience and practice with collaborative efforts to promote interaction. Certainly, all courses cannot meet all of these demands, but they serve as objectives during the planning process.

With full internet access, we must ask ourselves if LUME or similar methods still offers any advantages. Some theoreticians see the access to information as a limiting factor for learning and want students to use the internet as a resource for self-governed learning in the future (Dalsgaard & Mathiasen, 2008). Obviously LUME is subject to the restrictions applied by pre-defined internet resources and other information the students may utilize, similar to the use of traditional textbooks.

It has been strongly argued that education needs clear intended outcomes (Allegre et al., 1998), but it also is a problem in mass education that students' performances are commonly tested by their ability to repeat or apply pre-defined, subject-specific pieces of information. Even if both educators and learners are aware of the strong arguments in favour of a constructivist learning approach and the importance of long-term generic skills, they are required to focus on short-term performance.

At the heart of social constructivism is the idea of collaborative learning and construction of shared perspectives (Harel et al., 1991; Kukla, 2000). As much as one may sympathize with the idea of free information for students, it is difficult to see how students would be able to fruitfully collaborate and discuss matters of their course without a substantial amount of common established knowledge. Furthermore, a teacher's ability to lead and guide a student group will suffer if each student has different sources of information. Hence, we can see that education based on self-governed students, each with their specific personal learning environment (PLE), would leave most students without a teacher's guidance and with unclear aims about what they can and ought to achieve in their chosen form of education.

To summarize, in organized education, students are entitled to guidance from teachers to facilitate their learning. Interaction with other students can enhance the learning experience, and that aspect is enhanced by shared knowledge and a common understanding of the subject at hand (Chang, 2003). Even if we abandon conventional textbooks and all students have free

internet access, for most courses, it will still be convenient to have a pre-defined collection of course material common for all students. Whenever a course is created, lecturers should select course material carefully and decide upon pedagogical procedures, including the utilization of ICT. LUME may then offer a viable method to handle material and facilitate collaborative learning even in places where there is limited access to the internet.

10.3 Issues for further investigation

Although the studies that make up this thesis are situated within the context of engineering education, most of the arguments, evidence and conclusions are relevant to higher education in general.

Evaluating all aspects of engineering education is an important means of quality control and of allocating expensive resources. The aims and purposes of technology and scientific education reflect the demands from society and industry and continually change as those demands evolve over time.

A basic question in engineering education research is what the best way is to teach someone the things an engineer needs to know. That question cannot be unambiguously answered unless we can agree on what it is an engineer should know. Most likely, the answer is slightly different for different students. On the other hand, an answer that applies to most students in engineering will likely apply to a wide range of university students. Thus it would be detrimental to the overall purpose of pedagogical research to create or maintain too great a demarcation between engineering education and higher education in general.

During the work on this thesis, I encountered a number of issues that should be investigated in order to better understand the actual and potential role of ICT in education. In many ways, the use of educational software has changed the way students approach their studies, and it often challenges traditional educational procedures. ICT provides many tools for collaborative learning and social interaction, within or outside organized courses and programs. Its impact on collaboration and interaction among students and teachers needs to be further investigated.

In addition to providing tools for collaboration and interaction, ICT can facilitate individualized learning by supporting students search for information and increasing the ability to plan studies according to personal learning style and interests (O'Donnell et al., 2013). On the internet we can often find the same information as text or media files, in different languages and adapted to different levels of previous experience.

One of the primary purposes of action research on educational technology is to bring the technology and technical expertise together with the needs of

teachers and learners by developing feasible pedagogical methods. As was first pointed out in Article II, one can distinguish between four types of educational software, each one with a different impact on educational procedures. Whether the software is integrated in an LMS or not, future research must consider how different types of tools impact the educational process and distinguish between the applications of different tools.

The tools intended for interaction are of particular interest, and the dynamic development of social media and changes in the way students use ICT give rise to many questions. If we assume that social interaction can benefit the learning experience, then one may conclude that access to social media and a wider use of mobile phones would be beneficial for education. But many students use such tools foremost to maintain contact with friends outside their study group, and as a result, the social and academic interaction within student groups may actually decrease over time as the use of social media increases.

In traditional education, before students had access to electronic media, courses were given on campus and students had to move close to the university. Because they temporarily gave up contact with their families and friends from their earlier school days and instead found themselves in a new group of people with similar interests, the students were likely to interact socially outside lecture time. As a result of social interaction and the educational demands, it was natural for engineering students to spontaneously form a community of learners (Brown & Campione, 2002; Rogoff, 1994; Wilson, 2007). Today it is desirable to find methods to elicit similar interactions and collaborations to maintain the level and quality of the learners' educational experiences. More research will help us reap the potential benefits of ICT in education while maintaining the positive aspects of traditional learning environments. Another challenge for the future is the dissemination of information within educational institutions. People involved in the design and implementation of education need to pay close attention to research on the impact of ICT on group processes and collaborative learning as well as the impact on students' general personal and intellectual development.

11. Swedish summary

Pedagogisk mjukvara inom Ingenjörsutbildning

Ett återkommande tema i litteraturen om utbildning är att samtidigt som ny teknik skapar nya möjligheter för lärande, kräver de också betydande förändringar i pedagogik för att komma till sin rätt (Murphy, 2004; Scott, 1999; Sife, 2007). Därför är det viktigt för utbildningsinstitutioner att förbereda lärare för framtida förändringar och utmaningar i undervisningen (t.ex., flexibelt lärande, distansutbildning, etc.) (Menchaca & Bekele, 2008; Schmidt et al., 2009). Nya arbetsmetoder som bygger på ny teknik och pedagogiska idéer samt kunskap om hur elever lär sig är en nyckel till att utveckla och locka människor till högre utbildning (Selwyn, 2007; Stuckey, 2007).

Att analysera olika aspekter av teknisk och vetenskaplig utbildning är ett viktigt medel för att fördela de resurser samhället satsar på området (Uys et al., 2004). Teknisk och vetenskaplig utbildning återspeglar krav från samhället och näringslivet som ständigt förändras och utvecklas över tid. Även om de studier som ingår i denna avhandling genomförts inom ramen för ingenjörsutbildning, är de flesta argument och slutsatser relevanta för högre utbildning i allmänhet (Gredler, 1997).

Denna avhandling baseras på tre fallstudier som kombinerar kvalitativa och kvantitativa metoder. Tillsammans utgör dessa tre fallstudier ett aktionsforskningsprojekt (McNiff & Whitehead, 2005), inspirerat av John Dewey och Kurt Lewin (Dewey, 1910, 1916; Lewin, 1946). Fokus för undersökningarna är den pedagogiska tillämpningen av Informations- och kommunikationsteknik (IKT) inom ingenjörsutbildning (Elliott, 1991).

I linje med Lewins modell utvecklades forskningsfrågorna efterhand som ett resultat av forskningsprocessen och andra erfarenheter. Den första frågan är följande: Kan användandet av en lärplattform (Learning Management System; LMS) förbättra kvalitén på studenternas examensprojekt och rapporter? En fallstudie genomfördes för att svara på denna fråga med hjälp av intervjuer och diskussioner med eleverna samt en bedömning av kvaliteten på deras examensarbeten.

Resultatet, att ett LMS kan stimulera till kollaborativt lärande, gav upphov till nästa fråga: Hur används LMS inom ingenjörsutbildningen? Mer specifikt: Vilka verktyg i det LMS man hade tillgång till utnyttjades av lärare vid Institutionen Ingenjörshögskolan vid Högskolan i Borås?

När den faktiska användningen av verktyg i skolans LMS hade kartlagts och ett mönster av användning kunde urskiljas genom att verktygen delades in i fyra grupper efter sitt användningsområde (artikel II), var nästa uppgift att identifiera attityder som hjälpte eller hindrade ett ökat nyttjande av LMS. Detta ledde till den tredje forskningsfrågan: Hur ser lärarna på de pedagogiska möjligheterna att använda ett LMS i sin praktik?

Eftersom fråga två och tre gällde användningen av LMS vid samma institution, Ingenjörshögskolan vid Högskolan i Borås, behandlas det som en fallstudie, men materialet publicerades i flera omgångar. Av de fyra artiklar som ingår i denna avhandling är artikel I en kvalitativ undersökning av lärarnas attityder till användningen av LMS år 2006, artikel II är en kvantitativ studie som visar vilka verktyg som användes i undervisningen dels 2004 och dels läsåret 2009-2010. Artikel III är en longitudinal studie av förändringar i attityder hos lärare som intervjuades både 2006 och 2011.

Fallstudie 2 stöder uppfattningen hos många teoretiker, att tillgång till ett LMS samt support och utbildning är nödvändiga, men inte tillräckliga, för att ett LMS skall utnyttjas optimalt i undervisningen. De flesta lärare väljer att bara använda de verktyg i ett LMS som underlättar befintliga undervisningsmetoder, snarare än att försöka utveckla och förbättra undervisningen med hjälp av pedagogisk mjukvara. Valet av verktyg kan tolkas som ett starkt motstånd mot att förändra undervisningsmetoderna (Ford et al., 2008), vilket i sin tur förklaras av att lärare och studenter fokuserar på det ämnesspecifika innehåll i kurserna som är lättast att examinera.

Hur lärarna upplever nyttan av verktyg för samverkan beror på deras syn på rollen av interaktion i utbildningsprocessen. Enligt social konstruktivistisk teoribildning bygger studenterna funktionella kunskaper genom att bearbeta information i ett socialt sammanhang. Om det är sant, borde funktioner i ett LMS som uppmuntrar till samarbete och interaktion ha en positiv inverkan på lärandet (Mahdizadeh, 2007). Alltså kommer lärarnas uppfattning om nyttan av verktyg för samverkan att bero på om de åtminstone till del anammar ett sådant synsätt.

Baserat på den information som erhållits i de första fallstudierna utvecklades metoden LiveUSB Mediated Education (LUME) (Garrote Jurado & Pettersson, 2011a). Metoden innebär att kursmaterial och program sparas på ett USB-minne som sedan kan kopieras så att varje deltagare får sitt eget exemplar av materialet. Därmed kan man arbeta på vilken dator som helst när man har tillfälle och spara sitt arbete på minnet så att inget ligger kvar på en

speciell dator. För att utnyttja många av möjligheterna med IKT krävs att materialet får kopieras fritt, sådant material kallas fria lärresurser, på engelska Open Educational Resources (OER) (D'Antoni, 2008; Dinevski, 2008).

LUME användes för att ge kursen *Adaptation of Engineering Education to the use of Net-independent software* till ingenjörsutbildare i Latinamerika som bara hade sporadisk tillgång till internet och ibland måste dela datorer. Deltagarna som alla var verksamma inom ingenjörsutbildning bestod av tre grupper, en vardera i Kuba, Guatemala och Peru. Kursen syftar till att ge lärarna de kunskaper som krävs för att hantera ett LMS och fungera som stödpersoner för att använda ett LMS i sina respektive arbetsplatser. De skulle också vara beredda att ge kurser till andra lärare. Således, förutom tekniska färdigheter inom hantering av LMS, behövde deltagarna en tydlig vision om den pedagogiska tillämpningen av IKT (Nojima, 2000) och användningen av OER.

När kursen genomfördes samlades kursmaterial och mjukvara på ett USB-minne. Materialet omfattade Moodle, en open source lärplattform (moodle, 2015), mediespelare, ordbehandlare och andra program som kunde köras direkt från minnet och alltså inte behöver installeras på datorn. Dessutom fanns 53 videos (på spanska) med instruktioner om användningen av Moodle. Allt material var OER och kunde kopieras fritt. 'LiveUSB' innebär egentligen att datorn startar med ett operativsystem (OS) som ligger på USB-minnet i stället för datorns vanliga OS som ligger på hårddisken, men i den här kursen användes datorernas vanliga OS.

Frågan var alltså om LUME-metoden dels kunde möta de tekniska problemen och samtidigt motivera deltagarna att tillämpa IKT på ett pedagogiskt sätt i sin undervisning samt fungera som pionjärer och stöd för den framtida IKT-användningen på sina arbetsplatser.

I början av varje kurs träffades deltagarna och arbetade heltid under två veckor. En första enkät genomfördes i början av kursen för att kartlägga deltagarnas tidigare erfarenheter av LMS. I slutet av andra veckan användes frågeformulär för att samla in deltagarnas åsikter om användningen av LMS och OER. En separat enkät med synpunkter på genomförandet av kursen besvarades anonymt.

Resultaten av fallstudie III (artikel IV) visar att deltagarna uppfattade LUME metoden som ett steg framåt i deras professionella utveckling. Deltagarna blev väl förberedda och motiverade för att utnyttja ett brett urval av verktyg i ett LMS, de blev uppmärksammade på möjligheterna att utnyttja OER och moderna pedagogiska metoder som betonar studenternas roll som aktiva skapare av kunskap. Från enkätsvar och diskussioner under kursens gång kan man se att betoningen av kollaborativt lärande bidrog till en positiv upplevelse av kursen och stimulerade deltagarna till att forma en studerandegrupp ('Community of Learners'). Deltagarna höll med om att användning av

IKT och OER kan förbättra deras undervisning och göra högre utbildning tillgänglig för fler människor. Man instämde även i att LUME-metoden erbjuder ett kraftfullt verktyg för att sprida elevaktiva arbetssätt och utnyttja OER.

11.1 Avhandlingens disposition

En allmän bakgrund och syftet med forskningen presenteras i kapitel 2. Kapitel 3 handlar om ingenjörsutbildningar i allmänhet, med en kort historik och beskrivning av struktur och aktuella trender. Det framhålls att ingenjörsutbildningar är mycket lika över hela världen, ett resultat av både planering och utbildningstraditioner. Det visas att antalet teknologer är konstant eller ökar sakta i de flesta utvecklade länder, men ökar snabbt i vissa andra delar av världen.

Utvecklingen av LiveUSB-medierad Education (LUME) presenteras i kapitel 4. LUME föreslås som ett sätt att möta utmaningen att integrera informations- och kommunikationsteknik (IKT) med pedagogisk utveckling inom utbildning.

I kapitel 5 presenteras forskningsfrågorna och deras relation till var och en av de tre fallstudierna. Här kan utvecklingen av min forskning, med nya frågor som uppstår som resultat av mina erfarenheter följas.

Kapitel 6 ger en allmän beskrivning av teorier om lärande som framhäver betydelsen av studenternas aktiviteter, interaktioner och samverkan. Kapitlet ger också bakgrunden till forskning om ingenjörsutbildning i allmänhet och det teoretiska sammanhang som denna avhandling bygger på.

Kapitel 7 Ger en översikt över hur data samlats in och analyserats. Mycket uppmärksamhet ägnas åt begreppet aktionsforskning, som en process av faktainsamling, planering och handling, först beskriven av Lewin.

Kapitel 8 presenterar de tre fallstudierna utförligt med resultat och slutsatser. Utvecklingen av LUME metoden som ett svar på slutsatserna i de två första fallstudierna beskrivs.

Kapitel 9 redovisar en sammanfattning av resultaten, och ger svar på de fyra forskningsfrågor som presenterades tidigare.

Kapitel 10 inleds med en diskussion om de resultat som redovisas i avhandlingen. Framtiden för IKT och LMS i utbildningen diskuteras. Diskussionen leder till slutsatsen att för överskådlig framtid kommer LMS att vara en del av den pedagogiska praktiken, kanske inte i form av kompletta paket som kan köpas och säljas, utan som en samling av program som står till en viss lärares förfogande.

Avhandlingen inkluderar nedanstående fyra artiklar, som återfinns i fulltext i appendix, längs bak i avhandlingen:

Garrote Jurado, R., & Pettersson, T. (2007). Lecturers' Attitudes about the Use of Learning Management Systems in Engineering Education: A Swedish Case Study. Australasian Journal of Educational Technology (AJET), 23(3), 327-349.

Garrote Jurado, R., & Pettersson, T. (2011). The use of Learning Management Systems: A Longitudinal Case Study. e-learning and education (eleed), 8(1).

Garrote Jurado, R., (2012). Barriers to a wider Implementation of LMS in Higher Education: a Swedish case study, 2006-2011. e-learning and education (eleed), Vol. 9(1).

Garrote, R., Pettersson, T., & Christie, M. (2011). LiveUSB Mediated Education: A method to facilitate computer supported education. Australasian Journal of Educational Technology (AJET), 27(4), 610-632.

12. Spanish Abstract

Esta tesis tiene como objetivo mejorar la enseñanza de las ingenierías, así como aumentar el acceso a la educación a nivel mundial, mediante el fomento de la enseñanza y el aprendizaje asistidos por ordenador. Utiliza la epistemología de John Dewey (1859-1952) y se basa metódicamente en el modelo de investigación, la investigación-acción, término que fue propuesto por primera vez por Kurt Lewin (1890-1947). Los estudios se llevaron a cabo utilizando una combinación de métodos cualitativos y cuantitativos.

En el primero de los tres estudios, participaron estudiantes de ingeniería que trabajaban en su proyecto de final de carrera. A fin de conseguir una mayor interacción, se utilizó una plataforma de aprendizaje (Sistema de Gestión para el Aprendizaje, SGA, con sus siglas y nombre en inglés LMS, Learning Management System). Se recomendó encarecidamente a los estudiantes que discutieran los informes finales de cada uno y otros aspectos de sus trabajos.

El segundo estudio se centró en los obstáculos para un mayor uso de las tecnologías de la información y comunicación (TIC) en la enseñanza de las ingenierías y las razones de la lenta adopción de nuevos métodos de enseñanza. Las investigaciones se llevaron a cabo en la Escuela de Ingeniería de la Universidad de Borås, Suecia.

El tercer estudio se realizó con tres subgrupos de participantes. Consistió en un curso dirigido a proporcionar a los profesores participantes competencia técnica en la gestión de un SGA y motivarlos a utilizar las Tecnologías de la Información (TI con sus siglas en ingles IT) de una manera educativa. El curso fue impartido en Cuba, Guatemala y Perú.

El primer estudio de campo mostró que el aprendizaje colaborativo asistido por ordenador puede mejorar el rendimiento y la experiencia de aprendizaje de los estudiantes. El segundo estudio de campo mostró que las herramientas de un SGA que facilitan los métodos de enseñanza tradicionales se utilizan de forma rutinaria, mientras que las funciones diseñadas para facilitar la colaboración y estimular la creación de grupos activos de estudio rara vez son utilizadas.

El tercer estudio el uso de un paquete completo, con los materiales del curso y el software en el mismo dispositivo USB, denominado Educación mediada

por LiveUSB (en inglés, LiveUSB-Mediated Education, LUME), mostró que LUME puede ser utilizado para facilitar los métodos pedagógicos de enseñanza constructivista, y así ayudar a superar las barreras para un mayor uso de las TIC en la enseñanza.

13. Acknowledgements

I want to acknowledge the following four people who significantly affected my life: Bogdan Patoka, Magnus Lundin, Siv Eliasson and Kurt Hansson. Thanks to all of you!

I am very grateful to my supervisors Prof. Michael Christie and Prof. Max Scheja and PhD Program Administrator Christina Edelbring for their support and encouragement.

Much of the work was performed in collaboration with Tomas Pettersson. I am grateful for his cooperation, which I consider essential to the existence of this thesis.

I would like to thank my employer, the University of Borås and former rector Prof. Lena Nordholm,

I also want to give heart-felt thanks to my friends and colleagues, especially, Staffan Lööf, Thomas Södergren, Markus Södergren, Mattias Bräck, Fernando Seoane, Martin Borg, Svante Kristensson and Per Nilsson. Please accept my most sincere thanks for helping me and being my friends.

Most importantly, I must thank my family, my wife Magdalena and my children, Emma, Emil, Nadja and Linda, my son in law Andreas and my daughter in law Lisa Andersson. None of this work would have come to fruition without you. Two new family members were born during the time this research took place. Stina Elisabeth Fredman Garrote and Elliot Felix Garrote Andersson, I hope you will grow up happily and became great researchers.

And last un recuerdo a la memoria de mis padres Ramona Jurado Ayuso, Francisco Garrote Alcalá y a la memoria de mi gran amigo Paul Berglund, por desgracia no pudisteis ver este trabajo finalizado. También un agradecimiento a mis hermanos Rafa, Manuela y José, por su apoyo. Quiero agradecerles especialmente a mi tío Juan Jurado Ayuso y a su pareja Carmela García Peral, por su hospitalidad durante mis estancias en su hogar de Sierra Morena. Tampoco me puedo olvidar de mencionar a mi primo José Carlos Jurado Jurado, sus Jamones Serranos, han sido decisivos para finalizar este trabajo.

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15. Appendix articles I-IV