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LEARNING IN FOCUS

RETHINKING THE ROLE OF TECHNOLOGY IN MEDICAL EDUCATION

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Ai miei genitori - To my parents

Abstract

Educational computer applications have flooded into all fields of education, especially during the past few decades. Medicine is one such domain where technology has overwhelmingly entered the educational sphere, pushed by policy-makers and leaders who thought better to embrace it before even considering it. Study I shows that this is in fact still the case. The choice of a learning platform was solely economic, and the results of the study revealed that students expressed readiness to and positive attitudes towards information technology in education and exposed a possible benefit from its use in the long run. However, they also suggested negative opinions about the learning management system used in their coursework, suggesting a need for change of the technology. This study provides evidence that in order for computer-based systems to be effective they must be designed and implemented with care, otherwise they may risk to lower students interest and activation.

Study II explored whether students' approaches to learning related to their perception of the same learning platform already mentioned. Scales of the ASSIST questionnaire loaded in a two-principal components solution, surface and deep-strategic. We found statistically significant correlations between approaches to learning and students' attitudes toward ICT. We concluded that early identification of approaches to learning and attitudes toward ICT may prove important in order to provide assistance to and aid the transition of students with diverse individual characteristics and to the design of new learning environments.

In Study III we observed the pilot implementation of 3D Embryo, an interactive multi-dimensional animation. Students were overwhelmingly positive about the application. However, there was no statistical difference between the control and experimental groups on a performance test. A positive trend was found between deep processing and general test score. Also statistical significance was found between deep processing and three-dimensional perception. The essential result was that of deep learning being more decisive than the interactive application itself in the learning task. Even though interactive multimedia

may not be superior as a learning tool, they offer the opportunity to extend the possibilities of the traditional learning environment. The evidence that students who adopted deep processing performed better generally and especially in the spatial task is a key finding that calls for future studies on medical anatomy expertise and transfer.

Study IV proposed a both theoretical and practical framework that attempted to provide information and scaffolding mainly to teachers, course designers and administrators who currently face the initiative of implementing innovation, in all its forms, in the education system. But it could be also informative for policy-makers and educational officers. It aims at helping all these different actors with issues of analysis of, leading and sustaining innovation in medical education; it provides with the kind of information to be considered at each step of the innovation process in order to make decisions and reach set objectives; it suggests how to process the data generated from the analysis; and how to feed the results back into the process of innovation. In addition, it provides these actors with practical information on how to analyse innovation through the approach of Activity Theory and implement it through Participation Action Research.

This last study ties together the other studies and grounds them to several theoretical frameworks. It indicates that educational technology is not the answer to our educational problems, but a multi-function tool at our disposal with teacher and student at the centre. Educational technology can most definitely lend us a hand in the effort of renovating medical education. Therefore, issues of implementation become central for the success of educational technology, but they must be based on sound scientific approach, educational theories, procedures and techniques.

List of original papers

This thesis is based on the following papers, referred to in the text by their Roman numerals:

I. Italo Masiello, Robert Ramberg and Kirsti Lonka (In Press). Attitudes to the application of a Web-based learning system in a microbiology course. Computers & Education.

II. Italo Masiello, Robert Ramberg and Kirsti Lonka (Accepted). Learning in a web-based system in medical education. Medical Teacher.

III. Italo Masiello, Kirsti Lonka, David Örtoft, Hanna Reuterborg and Matti Nikkola. Deep learning and a virtual application: A small empirical investigation. Submitted.

IV. Italo Masiello and Kirsti Lonka. How to sustain innovation in medical education. Manuscript.

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I. Introduction

> And it ought to be remembered that there is nothing more difficult to take in hand, more perilous to conduct, or more uncertain in its success, than to take the lead in the introduction of a new order of things. Because the innovator has for enemies all those who have done well under the old conditions, and lukewarm defenders in those who may do well under the new. This coolness arises partly from fear of the opponents, who have the laws on their side, and partly from the incredulity of men, who do not readily believe in new things until they have had a long experience of them.
>
> Nicolò Machiavelli
>
> Chapter VI, The Prince
>
> Translated by W. K. Marriott

The above quote by Nicolò Machiavelli sets the stage for this doctoral thesis. Before delving into depth, I believe it is important to begin with some contextual information to better elucidate the various steps of this work. Most of the results or ideas generated from the empirical research my colleagues and I have conducted cannot be called arbitrary or definitive truths but are simply educated interpretations of small 'realities', in line with a postmodern view. Postmodernism is neither a movement nor a set of theories: rather it tries to provide a critique of forms of thought and organization and questions the very notion of objective and universal explanation (Mourad, 1997). Postmodernism symbolizes plurality and difference, a critical questioning of the benefits of technology and a disbelief of progress as always inevitable (Hlynka, 2004). Lovlie, quoted in Usher & Edwards (1996, p. 7), affirms: "…an index term for a position that is 'different' from traditional ones." Thus, the results of this thesis are explorative in nature.

The theme of this thesis addresses anyone who works with, will soon work with, or is generally interested in educational technology, and today this comprises a very broad audience. With this work, my intention is to assist the review of current teaching and learning practices to encompass innovation. I do not hide the fact that one of my main intentions is to start a discussion within the medical institution at which I work in order to help the acceptance of innovative practices of this tough-to-enter, creature of habits medical domain; as Berwick (2003, p. 1970) put it: “In health care, invention is hard, but dissemination is even harder.” And it is for these reasons that I have chosen to write this thesis using an informal style.

In this work I attempt to see the field of educational technology in a postmodern perspective. Although postmodernism is a way of theorising and practising art, architecture, literature, psychology and education, my intention is simply to use it only in reference to educational technology and only then. Postmodernism is complex and multiform and also very controversial, so I do not wish to get myself astray from the main subject: innovative practices in higher education.

The reason behind postmodern research on educational technology is straightforward: there is nothing that changes and becomes obsolete as fast as state-of-the-art technology. Likewise, predicting the future of technology or the use of it is merely unrealistic due to complex social, behavioural and economic contexts in which new technologies are embedded. The results I present in this thesis are, as I already mentioned, relative to the exploratory ‘realities’ of my research at a particular timepoint, and they are not absolute and certain, for after six months a new technology or a new use for it arrives that will remodel the empiricism of research. This however does not make me resistant to carry out research, but on the contrary, eager to understand those small ‘realities’.

Outline of the thesis

There are two main focuses of this thesis: technology and education. The aim of the introduction in Chapter II is to enable all readers to follow current research on technology and general education, and to present a perspective to my line of reasoning about these subjects. A section on current learning theories follows to provide an appreciation of these theories. After that, there is a section on collaborative approaches to research, followed by a description of approaches to learning, learning styles and self-regulation to better follow current research in education. Then technology and education are examined in the context of medicine. Finally, the chapter considers student learning in new and 'powerful' learning environments.

In Chapter III, I state the overall aims of this thesis, followed by Chapter IV that outlines the material and methods used to carry out my research. This latter chapter contains a portrayal of the participants in and the context of the studies. There is also a description of the educational applications, the research instruments, the forms of assessment, and the statistical analyses carried out in the studies.

Chapter V divides into themes the results and discussions generated from the studies. The choice of using themes instead of going carefully through each study was supported by the idea that it would be easier to follow the argumentation around the results and discussions in this fashion given that some arguments overlap between the studies. Thus, each theme presented has both technology and education as a focal point. This chapter contains also advice to institutions and single teachers on how to implement innovation in education in order to succeed.

In Chapter VI, there are concluding remarks about the need to collaborate at all levels of the education system to create learning environments that can support innovation.

In Chapter VII I acknowledge all the persons that in some way or another have contributed to this work. After that, in Chapter VIII, there is a summary of this thesis in Swedish. In Chapter IX I take a small space of this thesis to express a personal thought about the generation of this work and the environment around it. And finally Chapter X contains the references used to write the scientific content of this thesis.

II. Background

The institute that provides higher education, the university, is in phase of transformation and restructuring. Behind this change there is a multifactor underlying principle: first, globalisation and internationalisation; second, funding and economics; and finally, technology development (Altbach, 1998; Manicas, 1998). University boundaries are disappearing promoted by communication technologies that made scientific information readily available on a global scale. Training of qualified workers is becoming globalised by online learning systems. In addition, the falling of geographical borders registered in recent years, such as the inclusion of Eastern European countries in the EU, contributes to the exchange of students and scholars, and common use of the English language leads the process. Institutions collaborate with national and international industries and open branches overseas, very much like enterprises. The escalating university budget is typically caused by the adoption of new and expensive technologies, higher enrolments, higher administrative salaries and charging for the use of campus facilities. To aggravate that, state governments keep cutting university funding. Nonetheless, technology is transforming the current way of teaching and learning and the roles of the teacher, the student, research, and the university.

When teaching and learning in higher education in general and medical education in particular are performed in the most traditional way, a teacher—usually a researcher with a teacher's hat—provides students with information about a particular subject; the student listens to him or her, studies and then completes an exam that tests for the most part factual knowledge. On closer inspection, we could reach the conclusion that nothing is wrong with this linear process, as surely it is common practice in many learning institutions worldwide. Specific to traditional medical education, the teacher transmits his or her biomedical knowledge to the student during the preclinical phase, and only after two or three years is the student prepared to train and practice in the clinical, real-life environment. In fact, from the very early times, medical education has followed this disjointed apprenticeship model (Bullimore, 1998), and "the result of this training experience was an individual whom others perceived to have special powers to heal the sick" (Folse, 2000, p. 161).

If this has 'worked reasonably well' to the present, then why change? Because as information and our scientific knowledge increase, new operating methods such as laparoscopy are developed, new diagnostic tools such as CT, MRI and PCR are improved, medical care becomes gradually more complex, and medical errors become a substantial societal problem. Will a newly appointed physician adapt to these new developments? As Thomas Huxley, quoted in Bullimore (1998, p. 18), wrote more than a century ago: "The burden we place on the medical students is far too heavy and it takes some doing to keep from breaking the intellectual back. A system of medical education that is actually calculated to obstruct the acquisition of sound knowledge and to heavily favour the crammer and the grinder is a disgrace."

Recent research has shown that traditional methods of teaching medicine may not lead to optimal learning results, even though conservative teaching methods have managed to produce good physicians (Lonka, 2001). Researchers have emphasised that methods and approaches to education should always find confirmation from the latest research (Harden et al., 1999; Lonka & Lindblom-Ylänne, 1996). There is now evidence that a better integrated curriculum of practical experience with real patients, tutorial groups and self-study may help the development of expertise in medicine (van de Wiel, 1997), and technology may help the process.

The technological aspect

Why look at technology in education? An encompassing answer is that 'technology is us' (Marshall McLuhan's media determinism (Bicket, 2001)). It may sound difficult to accept; nonetheless as Hlynka (2000) eloquently stated: "Technology is how and where we live, and how we make our environment user-friendly. Technology extends our senses in unbelievable ways. We swim faster than the fish; we move faster than animals; we fly higher than birds. Technology is our culture, our science, our religion, our hopes and our dreams… quite simply, technology is us." We must agree that technology is part of some of us, or our extension, more than we would like to admit. And as a result of this, some theoretical approaches such as among others Activity Theory and Distributed Cognition have developed new appreciations for the connotation of human and cognition and have redefined them in relation to information communication technology (ICT). We will learn more about this in section *Current learning theories and collaborative approaches*.

We have shifted our *modus operandi* and have come to depend extensively on technology or information communication technology, at times simply to the point of losing our patience or suffering withdrawal symptoms if we cannot 'log on' (Yahoo! & OMD, 2004), and at times, more dramatically, to the extent of bringing down friendly aircraft as happened in the recent Iraqi war (CBSNews.com, 2004). To give an anecdotal example, during a boat conference, I had to arrange some laptop computers with wireless connection for the conference participants, but it took me longer than I thought it would. Some of the participants were very anxious to get online and kept asking me how long it would take. Knowing that I could not give a definite answer, I always replied with an openly interpretable: "As soon as I possibly can." Some of them kept insistently asking me about their need to check their email, as if the emails they were going to receive or send were of utter importance and could not wait a minute longer. Of course, I did not doubt that, but knowing academics as well as being one, I was also confident that there was very little that could not wait a few hours which could have being instead spent 'cruising' the boat and enjoying the stunning panorama. Yet, for some of them being able to check their email was a priority to the point of being an addiction, and making them unable to relax until that was accomplished. I am also positive that many of us can picture ourselves in the above vignette.

Thus, we do recognize the importance that ICT plays in some of our work, and we have unconsciously shifted our means of sharing information. The ubiquity of email has allowed it to be established as a standard way of communication (de Pablos Heredero, Albarran Lozano, & Montero Navarro, 2000). E-mail and now also mobile telephone SMS have gained that niche in an almost seamless or not-so-difficult way. Most probably this shift took place out of necessity after we realized the speed and informality of the means, or because simpler technologies require little adjustment to existing practices. However, even though we recognize the need to change our way of teaching and learning to suit technical advances, we have difficulty in considering it a necessity. Maintaining the status quo in medical education could be regarded as irresponsible. Technology is pushed into the formal curriculum, without a deeper understanding of teamwork, social interaction, critical evaluation and reflection. This can eventually jeopardize the strength of technical advances and the reputation of the medical profession (Armstrong, 2001).

The educational aspect

As we have learned from the *Background* section, technology seems to be playing a key role in the transformation phase of higher education, and its impact is far reaching, yet its effects remain at times contradictory (Gumport & Chun, 1999). Technological optimism of the 1960s led to an over-implication of technology in education with the intention that educational technology would become the solution to educational issues such as knowledge acquisition, metacognitive skills development and learner self-empowerment (Harden, 2000; Osberg, 1994). However, radical postmodernists critically question the benefits of technology and are sceptical of its progress (Hlynka, 2004; Wilson, 1997). Research has not yet shown consistent advantages of the use of ICT in medical and general education (Devitt & Palmer, 1999; Greenhalgh, 2001; Watson, 2001). Thus, the solution to solve human problems with technical solutions and without accounting for the human subject and its subjectivity may be the wrong approach (Osberg, 1994). Above and beyond, “learning is an integral and inseparable aspect of social practice” (Lave & Wenger, 1991). Technology provides pressure and opportunity for transformation, but success is not guaranteed, and the following excerpt is exemplary of this idea:

> In a few hundred years, when the history of our time will be written from a long-term perspective, it is likely that the most important event historians will see is not technology, not the Internet, not e-commerce. It is an unprecedented change in the human condition. For the first time - literally - substantial and rapidly growing numbers of people have choices. For the first time, they will have to manage themselves. And society is totally unprepared for it.
>
> *—Peter F. Drucker (1999),*
> *Learning and Management Conference, closing plenary session*

To understand how ICT could be implemented to foster learning in education, we first need to acquire knowledge of what is involved in the processes of studying, learning, and teaching in higher education. However, distance education and computer-aided instruction do provide the means of reorganizing the learning environment and for changing the relationship between the learner, the learning content and the social organization of learning, respectively (Richardson, 2000). Hence, the relation between technology and education becomes compelling and interesting.

How strong then is the bond between technology and education? Does the one require the other? If we consider transmission as the main concept of learning, then a linear model of pedagogy such as Information Processing most probably does not need heavy support from technology. This model may provide the least technological of the approaches. A source of information (the teacher), the senses of a receptive individual (the student), processing and storage capacity (the student's processing knowledge base), and finally retrieval and cognitive activity (the student's output); this model is clean and clear cut and the use of technology is not required. In fact this cognitive science model, besides being the most prevalent paradigm in use in schools today (Osberg, 1994), is what education has entailed for centuries, successful or not. Furthermore, this model for which learning occurs only in the learner's mind still guides today the design of multimedia tools (see the Special Issue of Learning and Instruction Vol 13, Issue 2, 2003).

However, technology enables the implementation of new educational approaches. Pahl (2003) briefly describes some of the characteristics of several attributes of education associated with different teaching and learning environments. In multiservice systems, various services supporting various learning activities are integrated into one system. In multimedia systems, many different media can be used to deliver and interact with learning objects. In collaborative systems, where students work in groups on a common task, the co-operation and communication is supported by synchronous and asynchronous tools and shared workspace (email, forum, chat, whiteboard and file-sharing) for joint work. In autonomous systems, important functions of the educator, such as dialogue and feedback, are replaced by the system. In adaptive systems, the system adjusts to a student's particular characteristics and needs. In interactive systems, a student can interact with the system in order to actively learn by doing. Thus different technological tools offer the possibility to utilise different educational attributes.

What then is a strategic place for information communication technology in education? Or better, what is an ideal combination between technology and education? Recent findings have suggested that a blended approach to education in which the combination of face-to-face and e-learning elements are combined can provide real benefits (Davis & Harden, 2001), particularly in medicine (Greenhalgh, 2001)

One of the most evident shifts afforded by ICT in education is that of students becoming more independent learners, moving away from the teaching paradigm (Okamoto, Cristea, & Kayama, 2001; Pahl, 2003). The educational support facilitated by the Web now obscures the notion of teachers as dispensers of unequivocal objective truth. According to Gordon and collaborators (2000), we are witnessing the perception that experts—teachers—are becoming less vital than high-quality information sources that are available at any time. Hence educators, besides holding the designation of content experts, are now also invested with new roles of facilitator and designer of the learning environment, the *learning experts*. Research demonstrates indeed that tutors are a decisive factor for learning in a simulated environment (Ahlberg et al., 2005).

In the last few years research on learning has focused on the active and constructive processes of the learners, replacing the passive and reproductive ones. Students are seen as intentional individuals, personally or collaboratively responsible for their own learning (Lonka, Joram, & Bryson, 1996; Pelgrum, 2001). This role marries well with the use of some of the technologies utilized for learning, which, as already stated, require active participation. In integrating ICT into education, the changing roles of both the teacher and the learner thus have to be taken into account (McNeil, Robin, & Miller, 2000; McPhee & Nohr, 2000). This requires a new kind of teacher-learner relationship and forces the teacher to broaden his or her repertoire of skills (Smeaton & Keogh, 1999).

Current learning theories

Generally there are different types of learning, both simple and complex such as committing information to memory, acquisition of complex skills or understanding of something abstract, that require different learning strategies. Additionally, the position taken by traditional versus new, situated perspectives regarding the nature of human cognition has given rise to diverse views of learning, such as transmission of information directed to the individual as opposed to situated learning, which occurs as a function of the activity, context and culture in which it develops, is situated and socially based (Karlgren & Ramberg, 1996). There are many learning theories that attempt to explain each type of learning, and a theory that explains one phenomenon does not necessarily explain the other. Because a comprehensive learning theory does not yet exist, it is then reasonable to consider that each learning theory is perhaps useful in a different context. It is not the purpose of this thesis to describe the various theories of learning and their stance; this task would require many books by itself, although if anyone is interested I would suggest a short book by Phillips and Soltis (1998) who take this into consideration from a teacher perspective. In this section just of a few "modern" theories that suit current learning through technology will be described.

Constructive learning is regarded as a meta-theory, that is, it encompasses a number of cognitive and other theories of learning based on works by Dewey (2004), Piaget (1995), Bruner (1996), and Vygotsky (1978). Constructive learning is an active process in which learners construct new ideas, concepts or hypothesis based upon their current and/or past knowledge on the basis of interaction with the environment. The assumption is that knowledge is physically, symbolically, socially and theoretically constructed by the learner.

Collaborative learning broadly encourages active learner participation in the learning process and refers to an instruction method in which learners work together in groups toward a common goal (Dillenbourg, 1999). The learners are responsible for one another's learning as well as their own. Thus, the success of one learner helps other learners to be successful. According to Vygotsky (1978), learners are capable of performing at higher intellectual levels when asked to work in collaborative situations than when asked to work individually. Group diversity in terms of knowledge and experience contributes positively to the learning process, and what the singles “can do together today, they can do alone tomorrow” (Vygotsky, 1962).

Situated learning, as we have already learned, occurs as a function of the activity, context and culture in which it develops, i.e., it is situated. Social interaction is a critical component of situated learning, where learners become involved in a ‘community of practice', which embodies certain beliefs and behaviours to be acquired. As the beginner moves from the periphery of this community to its centre, he becomes more active and engaged within the culture and hence assumes the role of expert (Lave & Wenger, 1991). Thus they gradually become independent experts who can also collaborate.

Distributed cognition is not a learning theory but an approach to human cognition that has consequences for theories of learning and education. It proposes that cognition is distributed among individuals, that knowledge is socially constructed through collaborative efforts in order to achieve shared objectives in cultural surroundings, and that information is processed among individuals and the tools and artefacts that are provided by culture (Salomon, 1993). It is not possible to explain humans by reference to what is in their minds alone. We must also take into account the cognitive roles of the social and material world (Hutchins, 2004).

Many aspects of these theories and the approach overlap, and what they have in common is the socio-cultural, active and collaborative aspects of knowledge construction, the learner as point of departure and the distribution of knowledge to humans, the environment and artefacts. Learning can only occur if the learner is active by taking learning into his or her own hands, therefore leaving to the teacher the task of suggesting and monitoring the learning activity. The activity is then learner-centred and learning and understanding are constructed collaboratively. Finally, knowledge is not only what lies in the mind of one learner, but distributed among learners and the system for today’s information is far too vast and rapidly increasing to be borne by the single learner.

Collaborative approaches to innovation in education

As we have just learned, collaboration has recently emerged not only as an approach to teaching and learning, but also as a new and potential way to succeed with the implementation of innovative educational applications. With this in mind, I am going to describe three approaches to innovation that build on collaborative and social aspects and which also might help with the analysis and comprehension of the educational research process.

Action Research is an approach to research for social practice. The idea is to carefully examine, in a series of cycles, actions of participants in social situations in order to improve their practice (Smith, 2001). Therefore, Action Research is a process of joint learning and understanding of the relationship between theory and practice between the researcher and the researched, although they are not both necessarily involved on the inside of the process. Dialogue becomes an important tool when dealing with actors in different situations and with their own individual feelings, experiences, thoughts, etc. (Ottosson, 2003). In Participatory Action Research the idea is instead to make teachers and researchers become partners in a shared process, with the researcher becoming active participant. In the early 1970s, Action Research gained a significant foothold as a form of practice oriented to the improvement of educational practice. The objective was to bring the practicing teacher into the research process as being the most effective person to identify problems and find solutions (Riding, Fowell, & Levy, 1995). As 'reflective practitioners' (Schön, 1983), teachers following the Participatory Action Research can become more interested in educational aspects and more motivated to integrate their research into their own practice.

In the 1920-30s, the Russians Lev Vygotsky, Leont'ev and Luria first introduced Activity theory to develop a 'new psychology', which at the time was dominated by psychoanalysis and behaviourism. Just as his predecessors, Engeström (1987) presented in the 1980s Activity Theory as a model of artefact-mediated and object-oriented action (for a thorough review of Activity Theory please refer to the following source: http://carbon.cudenver.edu/~mryder/itc_data/activity.html. The relationship between the human agent and the object is mediated through cultural means, tools and signs. The emphasis on the division of labour is a fundamental historical process behind the evolution of mental functions. Investigators are becoming aware that conceptual change is not only an individual, epistemic process in nature but takes place through transforming social practices (Säljö, 1995). Mediated by tools, work is also performed in conditions of collective activity, where tensions and conflicts are inevitable but seen as the manifestation of systemic contradictions within and between activity systems that participate in the innovation process. These contradictions are, however, regarded by Activity Theory as moving forces of change and development in the innovation process (Hasu & Engeström, 2000). Activity Theory offers neither ready-made techniques and procedures for research, nor a practical methodology. What it does offer as a framework is the possibility to evaluate and improve the complexity of innovation through a better understanding of the relationships between all participants—multidisciplinary innovation—and objectives, mediated through tools.

Design Research, also known as Design Experiments, was recently introduced by Ann Brown (1992) to develop a new set of methodologies for carrying out studies of educational interventions. Design Research addresses the following issues: focus on theoretical questions about learning in context, study learning in the real world, go beyond the narrow measure of learning, and obtain research findings from formative evaluation. The challenges of Design Research are: complications arising from the complexity of real-world situations and their resistance to experimental control, the large amount of data generated from quantitative and qualitative analysis, and comparing across design (Collins, Joseph, & Bielaczyc, 2004). Design Research involves putting the first version of a design into practical use. It is then revised based on the results until all the contradictions and bugs are worked out. This approach also takes into account two sides of the intervention, i.e., contribution to learning theories and practical feasibility. Therefore, researchers and teachers collaborate in the same design process (Bereiter, 2002). Design Research should then constitute a means of addressing the complex educational system which involves multiple elements of different types such as tasks or problems to solve, encouragement of discourses, norms of participation, tools and related material means, and levels such as classroom, school district or larger educational system, out-of-school learning contexts, workplace, and others (Cobb et al., 2003).

After a short analysis, we can safely assume that Participatory Action Research, Design Research, and Activity Theory have the following commonalities: several methodologies can be applied in order to collect data—triangulation of quantitative and qualitative methods; participatory, collaborative effort between researchers and practitioners within a community of practice who should also closely collaborate with all others involved in a project of innovation such as designers, managers, technical people, students, etc.; the data generated from such research should be analyzed and reinvested in the project of innovation; obstacles and shortcomings can then be solved iteratively; and finally all actors should be ready to critically review their work and be prepared to change their practice in accordance to new goals that arise and evolve in the course of cycles of innovation.

Approaches to learning, learning styles and self-regulation

During the last 30 years, research on learning has also been focusing on how students approach academic tasks. From qualitative and quantitative research, three main approaches have been identified (Biggs, 1987; Entwistle & Ramsden, 1983; Marton & Säljö, 1976). Some students are meaning-oriented and attempt to obtain a holistic picture of what they are to learn, trying to relate to previous knowledge and reformulating new knowledge (deep approach); others simply try to learn everything by memorising and then to reproduce during exams the material they learned (surface approach); and a third group studies to optimize success in assessment through effective use of time (strategic approach). The deep approach is associated with academic success in undergraduate education (Biggs, 1987; Entwistle & Ramsden, 1983; Marton & Säljö, 1976), including medical education (McManus et al., 1998; Newble & Entwistle, 1986), and it may extend past medical school, contributing to the developmental of physicians who display essential approaches to self-directed learning and studying in medical practice (Mattick, Dennis, & Bligh, 2004).

Medical schools with traditional curricula tend to promote surface approach (Lonka & Lindblom-Ylänne, 1996). However, the development of students' approaches to learning appears to be different in problem-based medical schools, where deep approach develops earlier (Norman & Schmidt, 2000). As we have come to learn, it is important that medical school curricula utilize teaching and assessment methods that promote adoption of the deep approach; the latter can be monitored by inventories. However, verifying that the deep approach has been adopted is not sufficient to ensure high-quality learning. Constructive alignment (Biggs, 1999) describes teaching methods, curriculum, assessment procedures, the climate teachers create in their interactions with the students, and institutional rules and procedures as a balanced system in which all components support each other and where each works towards the common end, deep learning. Imbalance in the system will lead to a breakdown, in this case poor teaching and surface learning.

In current higher education this imbalance is common (Biggs, 1999). Scientific knowledge in the education system at present is recognized through a structured examination, which is not the problem per se. However, this form of assessment often is not constructively aligned with the intended goals of a course. A consequence of this imbalance is the backwash effect of assessment on learning, which is closely related to the students' perceptions of the demands of the assessment rather than to what the teacher intends to assess (Biggs, 1999). If an assessment is perceived to require only passive acquisition and reproduction of details, students will then adopt a surface approach, and employ a low-level cognitive strategy such as rote learning and concentrate on facts and details while preparing for the assessment; this is the most recurring type of effect, a negative effect. When assessment instead is perceived to require high-level cognitive processing to demonstrate a thorough understanding, integration and application of the context knowledge, then the students are more likely to engage a deep approach in order to accomplish the task, a positive effect.

In their article, Newble and Entwistle (1986) summarized the literature on learning styles by separating them based upon two sets of ideas: 1) the North American approach based on cognitive theories (for which intelligence is comprised of a set of mental representations of information and a set of processes that operate the mental representation) and psychometric theories (intelligence as a combination of abilities that can be measured by mental testing such as analogies and series completion), and 2) the European approach, with significant contributions from Australia and America, based on educational research carried out in the everyday learning environment. The former approach—

also known as the Information Processing tradition (Lonka, Olkinuora, & Mäkinen, 2004)—focuses on identifying basic learning processes or individual characteristics, and learning styles are viewed as personal traits or information-processing strategies; while the latter—also known as the Students' Approaches to Learning tradition (SAL) (Lonka, Olkinuora, & Mäkinen, 2004)—attempts to explain the differences observed in how students approach a learning task and how this affects learning.

There are differences between the approaches and learning styles. Approaches can be influenced by the teaching and learning environment as we have previously seen. Thus, they change according to context and time. Approaches are not a trait of students, but a result of a dynamic interplay between the teaching and learning environment, the assessment methods and the curriculum. Moreover, they take into account students' motivations and individual preferences, whereas learning styles do not take into account students' intention or motivation and are insensitive to context.

The concept of self-regulation in student learning was investigated by Vermunt and van Rijswijk (1988). They defined self-regulated learning as the student performing educational activities him- or herself by taking over educational tasks from teachers. A self-regulated student is one who wants to find out things, draw his or her own conclusions, structure parts of a course into a significant whole, relate new information to previous knowledge, determine the learning objective and content, generate questions, reformulate knowledge, think about teaching and learning, and employ all these activities to design their learning processes. Self-regulated learning is also part of the SAL tradition (Lonka, Olkinuora, & Mäkinen, 2004).

When the teacher, however, takes over the responsibility of these activities often, especially in traditional education, and the learning environment—curriculum, teaching and assessment—conflicts with deeper learning processes, the student finds him- or herself lacking the capabilities to regulate these processes. Yet, 'powerful' learning environments can improve the levels of self-regulated learning (Vermetten, Vermunt, & Lodewijks, 2002). Features such as realistic contexts, collaborative learning, possibilities for applying knowledge, definition of thinking strategies, opportunities for activity, assessment that appeal to real understanding and the ability to apply knowledge in diverging situations are all a part of powerful learning environments.

These concepts are central to the understanding of the teaching and learning processes in medical education, and their implications are numerous: modification of assessment formats, introduction of courses on teaching and learning skills, curriculum planning, course design, teaching methods and student selection.

The medical aspect

We have looked at the implications of technology in education, and also why education needs rethinking. Then the next logical question is why medicine? Even though postmodernism, as defined earlier, may sound radical, it helps in framing educational technology within 'modern' medical education. The societal implication of educational technology within medicine is one of tremendous significance that will leverage the teaching of medicine in the coming years and the future of the health care system. Recent studies presented a cold picture of the error rate in medicine and its resulting devastating effects to human life by stating that the failure rate in medicine is estimated at one per cent in many industrialized countries (Rosenthal, Mulcahy, & Lloyd-Bostock, 1999), and that in the United States alone 98,000 individuals per year lose their lives due to medical error (Kohn, Corrigan, & Donaldson, 2000). These incidents draw attention to serious failures in standards of care, where mistakes are made and then perhaps even covered up by incompetent doctors. This result is in part due to an evasion of responsibility among those delegated with educating the students throughout their training (Challis, Flett, & Batstone, 1999).

Technology is now taking the lead and entering the medical domain to counter this very unfortunate phenomenon, empowered with the idea that by simply teaching and learning with technology this problem may be solved. Just as training with technology is now a requirement in the aviation industry, one day it will also be required in medicine. Not only that, technology is poised to once again be the human problem-solver. However, as we already learned, problems with human subjectivity are not so easily resolved by the introduction of technology. This is a very complex political and societal problem for which we first need to improve working conditions, create surplus capacity and monitor practice (Coats, 2001). Thus, technology will undoubtedly assist, but not solve all our problems.

One domain that has seen the involvement and success of sophisticated technology for learning of skills is that of development of surgical expertise. Research has shown transfer of surgical skills from a virtual trainer to the operating room (Seymour et al., 2002). The very nature of complex surgical skills calls for a technical environment that allows simulation of complex and atypical cases. Often learning is embedded in the mindless repetition of the action itself rather than reflection in action. It sometimes is a lengthy process to train a skilful medical professional because certain critical incidents take place so infrequently.

This problem may be solved by creating simulations that are deliberately designed to model emergencies and critical failures during operations in various ways so as to provide ample opportunities for professional learning (Hoffman, 1998). Applications based on computer simulations have already yielded good results in respect to learning to cope with infrequent or unanticipated hazards (Lajoie & Lesgold, 1989). These kinds of error simulations may help both students and professionals to develop skills for dealing with various atypical or exceptional cases. Medical students can no longer be trained by using humans and animals only, and the endless possibilities offered by simulation can diminish human and animal suffering. Simulation-based medical education can also be a valid tool to reduce ethical issues concerning safety of patients and animals. An ethical imperative: if they can be replaced, do so! (Ziv et al., 2003).

According to Feltovich and his colleagues (1997), *cognitive flexibility* would be facilitated by practicing problem solving in varied and partially unexpected situations through a wide and rich variety of complex cases. Thus, it is already necessary to start facilitating cognitive flexibility in general and professional education. Moreover, it appears to be important to create collective practices that facilitate cognitive flexibility, such as practices of encouraging individual agents and their communities to reflect on and transform their current practices.

The stigmatisation of technology as being nothing more than a tool at our disposal for which its effects are still unclear may be a bit unfair. The research methods and experimental designs we utilise in order to understand how technology or ICT can be used to foster learning may perhaps be implicated in this. Consequently, our shortsightedness makes a new and consistent problem possible, i.e., the adoption of technology fails to be sustained (Zhao & Frank, 2003).

ICT mediates our activity, it restructures our thinking and changes our interactions. However, the steady improvement of technology and software causes the emphasis to be placed on the technology itself and underrates the efficacy of its educational aspects (McGowan & Berner, 2002). Moreover, adequate training time is necessary to benefit from complex display and computer technologies (Goldman, 1999; Rouet, 2001). For these reasons and the fact that it is difficult to control for confoundings in real life experiments, qualitative studies that go beyond students' reactions to technology may prove more informative (Lonka, 1997). Sustaining innovation then becomes a complex objective with many variables.

Student learning in new learning environments

Today's medical workplace is demanding in terms of its workforce who should think critically and strategically in order to solve problems. These professionals must learn in rapidly changing environments and build knowledge taken from numerous sources and different perspectives. Knowledge becomes thus socially and physically shared and mediated by complex artefacts. Professionals must understand and diagnose patients in diverse contexts and collaborate both locally and around the globe. These attributes contrast sharply with the content-assessment methods and low-level skills that traditional medical education support. The new workplace requirements for learning are incompatible with instruction that assumes the teacher is the information giver and the student a passive recipient. The new requirements are at odds with testing programs that assess skills that are useful only within the education environment.

An optimal learning environment is one in which the curriculum, teaching, learning and assessments methods are constructively aligned; where students become responsible for their own learning, develop their own learning strategies and develop new understanding by collaborating with peers; where learning tasks are authentic and difficult enough to be interesting; where the learning context allows knowledge building in groups, so that many perspectives are pooled together and impartial learning conditions are created; where the teacher stimulates and monitors discussion and project work, helps students construct their own meaning and considers self as learner and co-worker; and finally, where students have the opportunity to explore new ideas and possibly develop new ones useful to themselves and others. Educational technology is assuming an increasing role in this respect (Jones et al., 1995).

These constructive and collaborative learning environments where successful and deep learning is promoted have been adopted in medical education during the last 30 years, e.g., problem based curricula, integrated and multidisciplinary curricula, student-based learning, and interprofessional education. As Harden and Hart (2002) have stated, even though these changes in medical education are significant, they are not enough to respond to the system and health care delivery, advances in medicine, increasing public expectations of physicians, increasing demands on teacher and the increasing number of students. Given the possibilities technology offers in terms of constructive and collaborative teaching and learning, its role in medical education will keep mounting steadily, yet it is too early to predict its extent.

In the end, it becomes necessary to research how students approach learning and studying and how they perceive the learning environment. It is also essential to research their attitudes to educational technology, the evaluation of educational technology for validity and usability, the educational added value of technology, and possibly teaching and assessment methods. Taken together, they should give a researcher and educator the keys to understand, manage and regulate the learning environment in its entirety and complexity and perhaps even enhance it.

III. Aims of the thesis

The specific aims of the present thesis were to:

1. Investigate students' approaches to learning and studying in relation to
    a. Students' attitudes to ICT within the context of
        i. Technology usability and its
        ii. Educational value;
2. Understand the function of deep learning in virtual environments; and
3. Finally, a goal was to combine all of the above into a complete picture to facilitate the understanding of new learning environments and their potential to enhance teaching and learning.
4. My own personal goal was also to bring awareness of the research field of educational technology in the context of medicine within Karolinska Institutet itself.

IV. Material and Methods

Study IV is theoretical; therefore no material and methods were used except for literature search and comparative work.

Participants

The participants of the studies were first-year medical students enrolled in preclinical courses. All students were volunteers and signed a consent form that described the research goals and their rights as a research subject, according to Swedish Medical Research Council regulations and approved under protocol number KI Dnr 02-169.

Because ours were field studies, we had no control over factors such as gender, age and computer experience. This imposed restriction also made two studies (I and II) strictly observational in their design and no group randomization was possible. As an alternative, the other study utilized a matched-pair design (Study III), where groups were assigned to either a control or experimental group on the basis of previous knowledge of the subject, entrance basis to the medical program and gender.

The context of the studies

Karolinska Institutet is a traditional medical university (Savage et al., 2002). As such, biomedical knowledge is transmitted by the teacher to the student during the preclinical phase, and only after 2-3 years is the student ready to train and practice in the clinical, real-life environment. Like many other institutions around the world, Karolinska has been introducing educational technology elements in many undergraduate courses in order to build competency on their implementation and adaptation into the curriculum and to bring awareness of ICT to faculties. In Studies I and II we looked at the implementation of Ping Pong (PP) in a preclinical course. While examining the learning tool from a range of different perspectives, we focused on general, theoretical ideas and on practical applications, especially in relation to innovations in medical education. In Study I we evaluated the validity of PP as an e-learning tool; this was the first research carried out on this computer tool. Our aims were to understand whether PP followed any educational principles, whether it was useful in supporting the teaching of a course, and more generally we wanted to understand the readiness of the students and faculty involved in the course for the use of innovative forms of learning environments. In Study II, we wanted to understand whether students' approaches to learning were related to their use of and their perception of PP.

Within the medical program at the institution, students apply broad biomedical science knowledge in order to solve medical problems. The program is divided into three main blocks, each of which has different focus: theoretical, applied, and specialisation. In Study III, the idea was to help first-year medical students to learn embryology by introducing supportive educational material, 3D Embryo, during the last period of the course. The subject of embryology entails quick structural and temporal changes that occur within the first few weeks of development, and traditional educational tools fail to present the rapid dynamics of the process. For this reason, two students produced an animated, three-dimensional and interactive model of early embryonic development, the most critical weeks. Our working hypothesis was that the use of 3D Embryo would enhance students' motivation, comprehension of the content and the learning of such a complex natural phenomenon. However, we also expected that students who applied deep learning would perform better in tasks calling for three-dimensional perception, and this expectation was rooted in the notion that deep learning could speed up the process of becoming an expert. Furthermore, we wanted to evaluate the educational value of 3D Embryo.

The computer applications

The computer applications employed for the studies were two different products, Ping Pong and 3D Embryo, which required two different forms of learning characteristics. Ping Pong (Studies I and II) is a learning and content management system developed for web-based training. As such, the system allows for automation of administration of the teaching and learning processes. PP is also loaded with technological features (for more details about PP see section '2.2. The computer tool' in Study I). During the course and study, PP was utilised daily by students and teachers and served as repository of course information, topics, discussions, PowerPoint presentations, animations, pictures and self-study questions. The system allows active and collaborative learning, student-centred approach and the distribution of knowledge among system, teachers and students.

3D Embryo (Study III) is an interactive multi-dimensional animation of embryonic development during weeks three and four. Within these two weeks, at overlapping times, several layers of tissue will eventually develop into differentiated organs and parts of the familiar fetus (for more details about 3D Embryo see section '3D Embryo model' in Study III). During the course the students in the experimental group had only two hours to become acquainted with the application and to possibly construct a unified three-dimensional model in the mind, with assistance also of pictures in the textbooks and the lecture. This system allows active and interactive learning.

Questionnaire

In the studies, I utilised several scales from different questionnaires to test students' learning styles, approaches to learning, and attitudes to information technology (IT). In Study I, the *IT Learning Questionnaire* was constructed of statements taken from Dewhurst, Macleod and Norris (2000), Slotte, Wangel, and Lonka (2001) and others constructed by the research group, and it tested students' learning styles and attitudes to IT. In Study II, scales from the ASSIST questionnaire (Tait, Entwistle, & McCune, 1998), i.e., seeking meaning, lack of understanding, transmitting information and time management, probed students' study patterns. In Study III, items were taken from the inventory of learning styles (Vermunt, 1994), i.e., *deep* and *stepwise processing*, *self regulation* and *lack of regulation*, time management scale from the ASSIST inventory (Tait, Entwistle, & McCune, 1998) and the *IT Learning Questionnaire* (Masiello, Ramberg, & Lonka, In Press). All questionnaires were constructed on a five-point Likert scale, ranging from 5 (highly agree) to 1 (highly disagree) in keeping with their original formats.

The reason behind the use of existing questionnaires was simple: the items had been extensively tested and were therefore expected to be reliable in other university student populations as well. In addition, the choice of utilising items from various scales, a combined approach, reflected our needs to investigate diverse aspects of learning with technology that could not be captured by a single inventory and that could be linked to diverse characteristics of new forms of learning environments.

Assessment

In Studies I and II we did not have access to grades or assessment data, whereas in Study III we had the opportunity to assess the effects of 3D Embryo as an interactive learning application. The test administered was constructed to probe various levels of understanding of the subject of embryology: the ability to recall factual information (what), contextualize and conceptualize information (why), the use of spatial abilities (spatial dimension) and relate events to time (temporal dimension). The test was constructed for research purposes only.

We also collected general students' written comments at the end of each course.

Statistical Analyses

We measured changes in students' attitudes (Study I), i.e., before versus after use of Ping Pong, by the Mann-Whitney U non-parametric test for independent samples. In Studies I and II we calculated principal components analysis to evaluate students' IT orientations and approaches to learning, which gave way respectively to three- and two-principal components Varimax solutions. Further, we validated the reliability of each scale by calculating Cronbach's Alphas. The relationships between the approaches to learning and the IT orientations were then calculated in Study II by correlation coefficients.

In Study III, box plots measured first the homogeneity of the control and experimental groups on several factors, i.e., gender, entrance to medical program and test scores. Then a t-test also measured the statistical significance of the test scores between the two groups. Main-effect ANOVA was used to test the effect between control and experimental groups on the *deep processing* scale. In addition, one-way ANOVAs were used to test significance between the groups and the visualization questions and the deep processing scale and the visualization questions.

V. Results and Discussions

Questionnaire data

The *IT Learning Questionnaire* (Study I) yielded three principal components, which are shown in Table 1. The first principal component (PC1) is called *Blended Orientation* and is characterized by high loadings on possibilities of using IT in medical education with the addition of support from teachers and peers. This component is in agreement with a blended approach to education in which the combination of face-to-face and e-learning elements can bring real benefits (Davis & Harden, 2001), particularly in medicine (Greenhalgh, 2001). The second principal component (PC2), *Independent Orientation*, shows high loadings on independent learning styles, which are supported by technology. Negative loadings on statements concerning traditional learning are also quite strong, reflecting a positive attitude towards IT. According to Gordon et al. (2000), the independence factor reflects the perception that experts, i.e., teachers, become less vital than high-quality information sources that are available at any time. Characteristic of the third principal component (PC3) are high loadings on confidence on the use of technology, and a negative loading on the inability to use it. This component was named *IT Orientation*, in accordance with the assumption that most medical students today are already reasonably competent users of IT at their time of enrolment (Gordon et al., 2000).

Table 1. Principal component loadings (a 3-component Varimax solution) of scales from Dewhurst, Macleod, & Norris (2000) (D), Slotte, Wangel, & Lonka (2001) (S), and Masiello, Ramberg, & Lonka (In Press) (M). Pre-Ping Pong items only.

Variables	Principal components			Reliability Alpha
	PC1	PC2	PC3	
IT-Oriented				**(.73)***
2. I am familiar with the different online media, i.e., browsers, email, chat rooms, etc. (M)			.84	
3. I have experience with information technology (M)			.81	
4. I use web-based services, i.e., KI courses web material, Yahoo! and more, at home (S)		.36	.54	
6. I feel confident about using information technology (M)			.76	
8. I am worried that I will not be able to use the technology (D)			-.45	
12. Communication between teachers and students works fine via the internet (S)			.34	
Independent				**(.75)***
5. Web-based services can support my learning (M)		.64		
7. It would be useful to read clinical cases via the internet (S)		.60		
9. WBLE's allow me to work at my own pace whereas traditional lectures do not (D)		.74		
10. I prefer to learn from a book than a WBLE (D)		-.78		
11. WBLE's can be used more flexibly than textbooks and lectures (D)		.62		
13. A WBLE allows me to choose where and when I study (D)		.58		
14. A lecture is a better way to learn a topic than a WBLE (D)	.40	-.60		
Blended				**(.88)**
15. Getting study material via the internet could improve learning (S)	.64			
16. When using WBLE I would prefer to work with a friend so that we can discuss (D)	.70			
17. As methods of teaching, traditional lectures and WBLE can be equally effective (D)	.49			
18. Computer-supported learning would fit in medical education (S)	.70	.44		
19. I would like to use WBLE's to supplement rather than replace lectures (D)	.73			
20. Information technology training is an important part of medical education (S)	.73	.39		
21. If I am having troubles with PP, I will ask for help to the teacher the next day in class (M)	.63			
22. When using a WBLE I would prefer to work on my own (D)	----	----	----	
23. I expect the teachers to answer promptly when I contact them through a WBLE (M)	.64			
24. If I am having troubles with PP, I will look for help by using all possible tools of a WBLE (M)	.74			
25. The teacher should motivate and encourage me (M)	.77			
Eigen values	6.03	3.46	2.39	
Percentage of variance	21	16	12	

Notes: * Negatively loading items omitted. Decimal places and loadings less than 0.30 are omitted.

The four scales of the ASSIST (Tait, Entwistle, & McCune, 1998) questionnaire (Study II) loaded into two components, shown in Table 2, that reflected those by the original authors. The first principal component (PC1) is characterized by high loadings on the sub-scales Lack of Understanding and Transmitting Information, reflecting the original *surface approach* factor, and the second one (PC2) shows high loadings on the sub-scales Seeking Meaning and Time Management, reflecting the original construct *deep-strategic approach*. The research instrument confirmed the conventional distinction between deep and surface approach, and the coupling of deep and strategic approach. The reliability of the scales in both Studies I and II resulted satisfactory (Cronbach's Alphas > 0.6), demonstrating that the scales were consistent and reliable in this context and with this sample population.

Table 2. Principal component loadings (a 2-component Varimax solution), Cronbach's Alpha and means values of scales from approaches to studying of the ASSIST inventory (Tait, Entwistle, & McCune, 1998).

Variable	Principal component		Reliability Alpha	Means
	PC1	PC2		
Approaches to Studying				
Deep-Strategic approach			**(.65)**	
Seeking meaning (SM)		.62		3.79
Time management (TM)		.84		3.25
Surface approach			**(.62)**	
Lack of understanding (LU)	.86			2.67
Transmitting information (TI)	.77			3.42
Eigen values	1.48	1.08		
Percentage of variance	36	27		

Maximum mean score per scale is 5

In Study III, we simply analysed the questionnaire items of the four scales of the inventory of learning styles, i.e., *deep* and *stepwise processing*, *self regulation* and *lack of regulation* (Vermunt, 1994), the *time management* scale from Tait et al. (1998), the *IT Learning Questionnaire* scale from Masiello et al. (In Press) without further factorization. The results of the analysis will be described in the next sections.

Educational technology

From the analysis of the students' general comments (Study I), we observed that the participating students valued the importance of IT in education and their desire for more of it in order to be better prepared for the future of lifelong learning. Interestingly, they stated that they did not want just any IT tool: they wanted applications that were tested and usable for their purposes, and they wanted to begin gradually when using applications that complemented their traditional learning mode, classroom and textbook learning. The evidence provided by the *IT Orientation* component in Study I for which students expressed adequate IT competency is a reassuring aspect since they should concentrate on content and not on the technology. Technology should be 'transparent'.

One aspect to take into account is the appropriate use of technology for learning. Redundancy between traditional lectures, material and online applications is an indication of maladaptive use. This was the case demonstrated from the results of general observations in Study I, since this relocates the learning offline, failing to exploit the potential of computer-based learning (Evans et al., 2004). Moreover, the same material is then simply represented digitally without consideration of the different media that require a different interaction approach. Educational technology provides a "rich environment for active learning"; nevertheless it is used for didactic purposes (Greenhalgh, 2001). Perhaps for the foregoing reasons the students that used Ping Pong in the study became sceptical about the active learning features provided by the tool. This was reflected in the result data from the pre versus post use of PP of the *Independent Orientation* factor, as shown in Table 3. We believe this result is the direct consequence of teachers' maladaptive application of PP and failure of the developers of the application in general to perform usability testing. Thus learning management systems should not be used merely as “traditional campus-based learning in electronic form” (Dringus, 2000), because their capabilities to reorganise the learning environment is sizeable.

An interesting result and one that supports the ideas above was that of a negative correlation ($R = -0.27$, $p < 0.05$) between the *Lack of Understanding* and *IT Orientation* components (Study II): the surface approach was associated with lower confidence in using technology. One interpretation is that students who expressed confusion about learning would also be confused about using technology for learning. These students would probably prefer and benefit from having at their disposal a ‘cookbook approach’ that would guide them specifically on how to go about learning or use technology for learning.

Online learning environments should free learners from inconvenient time schedules and trips to campus, and together with educational technology in general should provide ample opportunities for lifelong learning. However, these methods require a new kind of interaction. Learning calls for an active role, a role in which students and instructors are not familiar. Teachers become moderators and guide students towards the right online tasks, but do not provide them with an outline of steps to follow. Consequently students perform those tasks aided both by their own willingness to learn by doing and discovering and by peers. In such tasks, collaboration and self-regulation, as in real life, are of great significance. The enormous amount of knowledge is now distributed to individuals and systems and is not borne in its entirety by the individual. Not only does knowledge becomes distributed, but also our preliminary findings (not included in this thesis) from a national project indicate that students who only want certain knowledge, e.g., a ‘cookbook approach’, may be at risk for stress and exhaustion.

Table 3. *IT Learning Questionnaire*. Students' responses (%(n)) to learning styles, motivation, and attitudes toward IT in the pre- and post-Ping Pong questionnaires.

WBLE = Web-based learning environments. (In parenthesis the formulation of the post-Ping Pong questionnaire)

Statement	**Pre-Ping Pong**			**Post-Ping Pong**		
	Agree	**Neutral**	**Disagree**	**Agree**	**Neutral**	**Disagree**
2. I am (more) familiar with the different online media, i.e., browsers, (discussion forums), email, chat rooms, etc.	84 (47)	13 (7)	4 (2)	28 (14)	26 (13)	46 (23)***
3. (Now I feel) I have (more) experience with information technology	78 (43)	18 (10)	4 (2)	30 (15)	30 (15)	40 (20)***
4. I use Web-based services, i.e., KI courses Web material, Yahoo! and more, at home/(I used Ping Pong at home)	64 (36)	7 (4)	29 (16)	52 (26)	8 (4)	40 (20)
5. Web-based services can support my learning/(Ping Pong provided support for learning)	68 (38)	23 (13)	9 (5)	40 (20)	32 (16)	28 (14)*
6. I feel (felt) confident about using information technology	71 (40)	18 (10)	11 (6)	86 (43)	12 (6)	2 (1)*
7. It would be (was) useful to read clinical cases via the internet	71 (40)	20 (11)	9 (5)	20 (10)	48 (24)	32 (16)***
8. I am worried that I will not be able to use the technology/(I was not able to use the technology)	19 (10)	22 (12)	59 (32)	12 (6)	8 (4)	80 (40)*
9. WBLE's (Ping Pong) allow (allowed) me to work at my own pace whereas traditional lectures do (did) not	27 (15)	38 (21)	36 (20)	12 (6)	24 (12)	64 (32)**
10. I prefer to learn from a book than a WBLE (Ping Pong)	69 (38)	29 (16)	2 (1)	84 (42)	12 (6)	4 (2)*
11. WBLE's can be used (I used Ping Pong) more flexibly than textbooks and lectures	49 (27)	33 (18)	18 (10)	16 (8)	22 (11)	62 (31)***
12. Communication between teachers and students works (worked) well via the internet	38 (21)	51 (28)	11 (6)	42 (21)	46 (23)	12 (6)
13. A WBLE allows (Ping Pong allowed) me to choose where and when I study (studied)	40 (21)	11 (6)	49 (26)	22 (11)	12 (6)	66 (33)
14. A lecture is (was) a better way to learn a topic than a WBLE (Ping Pong)	62 (33)	30 (16)	8 (4)	76 (38)	16 (8)	8 (4)
15. Acquiring study material via the internet could improve (improved the) learning	69 (37)	22 (12)	9 (5)	50 (25)	18 (9)	32 (16)
16. When using WBLE (Ping Pong) I would prefer (preferred) to work with a friend so that we can (could) discuss	48 (26)	33 (18)	19 (10)	2 (1)	38 (19)	60 (30)***
17. As methods of teaching, traditional lectures and WBLE (Ping Pong) can be equally effective	22 (12)	46 (25)	31 (17)	18 (9)	14 (7)	68 (34)**
18. Computer-supported learning would fit (fits) in medical education	65 (35)	28 (15)	7 (4)	52 (26)	38 (19)	10 (5)
19. I would like to use WBLE's (Ping Pong) to supplement rather than replace lectures	89 (48)	4 (2)	7 (4)	88 (44)	4 (2)	8 (4)
20. Information technology training is an important part of medical education	57 (31)	24 (13)	19 (10)	70 (35)	16 (8)	14 (7)
21. If I am having (When I had) troubles with Ping Pong, I will ask (asked) the teacher for help the next day in class	51 (27)	23 (12)	26 (14)	6 (3)	50 (25)	44 (22)***
22. When using a WBLE I would prefer to work on my own/(When I used Ping Pong I preferred to work on my own)	33 (18)	46 (25)	20 (11)	60 (30)	34 (17)	6 (3)**
23. I expect (expected) the teachers to answer promptly when I contact (contacted) them through a WBLE (Ping Pong)	65 (35)	26 (14)	9 (5)	42 (21)	48 (24)	10 (5)*
24. If I am having (When I had) troubles with Ping Pong, I will look (looked) for help by using all possible tools of a	55 (29)	30 (16)	15 (8)	30 (15)	48 (24)	22 (11)
25. The teacher should motivate (motivated) and encourage (encouraged) me	87 (45)	12 (6)	2 (1)	34 (17)	36 (18)	30 (15)***

Students comments

Suggestions for improvement of Ping Pong: Keep it as a course Web page, that is, it should provide only information, instructions, links, and nothing more. Good for complementing a traditional course, but it should never replace it.

Impression of Ping Pong: Very bad, 6%; Bad, 6%; OK, 48%; Good, 26%; Very good, 10%; Don't know, 2%

Notes: * $p < 0.05$, ** $p < 0.005$, *** $p < 0.0001$.

It is the instructor, though, who must be very clear about the role of technology in his or her teaching process. Any negligence on their part can confuse students about the role and purpose of technology and its use for learning. Students' comments in Study I illustrate exactly this aspect. However, the blame cannot and must not be attributed to the instructor alone, since he or she at times may simply be following the regulative conventions of the organization.

The creation process of educational applications has been driven mostly, and perhaps involuntarily, by shock factors. Without doubt, computer applications with their high degree of dimensionality, innovation and interactivity commonly stir a sensation of awe in the audience. When describing such applications, one of the first results is the appreciation and enjoyment of them, 'WOW…cool!' This enthusiasm was also true for the students who used 3D Embryo (Study III), whose comments about the application were overwhelmingly positive, although the advantages often described by the endorser of these kind of applications may be more imagined than real (Garg et al., 2002).

Indeed, we encountered this latter phenomenon in our study (Study III), where the students, assisted by the application that should have enhanced their learning, nevertheless failed to receive higher test marks ($t(90=0.649$, $p=0.517$). The interactivity and third dimension did not help test performance. However, our short test that measured factual and conceptual information, spatial ability and relation of events to time, even though apparently valid, may not have captured those processes. So, did the application help in any other way? We will find out in section *Approaches to learning*.

In Study IV we put forward a series of suggestions for succeeding with the implementation of innovative educational applications. One suggestion was to adopt a Participative Action Research approach to encourage teachers and researchers become partners in a shared process, with the goal to jointly carry out faculty/staff development, the development of the project and research. After regular data collection and analysis of the dynamic and complex processes of innovation, critical incidents that could retard or conclude any project would emerge; examining these would illuminate the reasons behind the project outcomes and steps for its progress.

Another suggestion in Study IV was to use Activity Theory as a framework to possibly evaluate and improve the complexity of innovation through a better understanding of the relationships between all participants—multidisciplinary innovation—and objectives, mediated through tools. In this way, a systemic analysis of the system and critical incidents and contradiction can assist the success of any project of innovation, including innovation in medical education.

Teaching and learning

The pace of technology development and the desire to incorporate such technologies into the curriculum jeopardise our will to understand how to use them most effectively (Ellaway, 2004) and the ability for teachers to use them at all (Ward et al., 2001). Teaching staff need adequate training both in the use of information technologies and in the educational use of them for teaching and learning (Cravener, 1999; Ward et al., 2001). This problem became evident in our first study (Study I) where many instructors had difficulties entering their teaching material into Ping Pong, and used the educational tool mostly as a redundant tool for presenting their teaching material. Thus, the teachers, because they are the ultimate "keystone species" that can assure the exploitation of technology in education, need training in how to make the best use of technology and in the teaching and learning styles that best suit any particular application (Zhao & Frank, 2003). For example, teachers need first to understand that a student-centred teaching style would be most beneficial to students because of the higher level of students' self-involvement and their active role. To achieve this in their courses, teachers would need to take staff-development courses where they would also learn that they can use different functions of online learning systems to promote engaged learning and create tasks which focus on students' active learning. They would learn that they could use forum sections to facilitate and guide discussions on authentic and challenging tasks, giving way to collaborative learning. They could present authentic problems that would need to be solved in small groups, using the chat function, and for which a solution is available at given online resources, giving way to collaborative problem-solving and higher order learning. These are just two examples of the many possibilities of educational technology.

Following Hinostroza and Mellar's (2001) suggestion of involving the teachers in the development process of educational applications, we too believe that this is the correct course of action. In addition, we suggest that teachers play an active role in the decision on which specific tool to use for their teaching, and not allow institutions or 'techies' decide for them, as the data indeed demonstrated in Study I. It needs to be emphasised that a participatory process of innovation would be more fruitful. It is the teacher who has to make certain that the features of a powerful learning environment exist in their educational application and practice.

Returning to the participatory design (Study IV), the aim was to reintroduce the active individual into the internal structure of the training environment, from whom the passive individuals can learn and be motivated. This is an essential condition for transforming the normative ideology of technical rationalisation for which technology is the solution to any teaching and learning problems into an active ideology for which the environment and its technological tools are now instruments at the disposal of human activity.This active individual may well become a "champion" of this transformation and can have an impact on the group where the change will occur (Lorenzi & Riley, 2003), and for whom the development and negotiation of the feeling of innovation become personal and essential.

Approaches to learning

As mentioned earlier, research has suggested that 'powerful' learning environments can improve the levels of self-regulated learning, deep level and critical thinking (Vermetten, Vermunt, & Lodewijks, 2002). Research has also shown that it is typical of successful students in the traditional medical curriculum to prefer independent learning and be less interested in collaboration (Lindblom-Ylänne & Lonka, 1999). A positive correlation result ($R=0.33$, $p<0.05$) between the *Seeking Meaning* scale and the *Independent Orientation* scale demonstrates that this was true in our study (Study II), and again in a traditional context such as the current curriculum at Karolinska. Participating students who displayed a deep approach to learning expressed a preference for a web-based learning environment that supports independent learning.

This phenomenon is both positive and negative. On the one hand, we see students who are ready to take learning into their own hands and to take advantage of new learning environments. On the other hand, the medical profession, more often than not, requires collaboration between practitioners with different specialities to perform high-quality medical prognoses. Beyond that, recent research demonstrated that also collaboration at an interprofessional level, e.g., training between medical, nursing, occupational therapy and physiotherapy students, provides learners with an opportunity to develop their own professional roles and their functions as team members (Ponzer et al., 2004). Thus, lifelong-learning collaborative skills are perhaps a benefit, and should be used in training from the very beginning of the medical career. Conversely, we just may need to explain more clearly how to use new learning environments proficiently and in a way that leads to collaboration.

In a traditional learning environment, textbooks and atlases are used to teach embryology development. However, the phenomenon is spatially and temporally complex, and the transfer from 2D images to a comprehensive and 3D entirety is complicated. This procedure stresses the learner's 3D imaginative capabilities, and it takes long experience to succeed (Ganser et al., 2004). The idea behind 3D Embryo (Study III) was to assist this process. The model partially succeeded in this task, that is, only students who adopted a deep approach to learning, regardless of the use of a three-dimensional aiding application, obtained more often correct answers on the test as a whole ($F(4,83) = 2.383$, $p = 0.057$) and the visualisation questions in particular ($F(1,82) = 9.921$, $p = 0.002$). The visualisation questions followed the principles of spatial ability tests, which measure the ability to visualise a three-dimensional object from a two-dimensional model, and to visualise how this object would look if rotated in space (Barrett, 2004a, 2004b). It was not surprising that deep approach to learning, being a result of a long period of development, would overcome a short intervention with 3D Embryo.

In Study III, we made another interesting analysis about the better performance on spatial abilities from the students who made use of deep processes. One might be brought to believe that these students either have innate high spatial abilities or that the characteristics attributed to deep processing helped or motivated them to perform better. We hypothesised that the nature of expertise in anatomy may be three-dimensional in nature, that is, the deep learner has a better three-dimensional understanding of anatomy. Nevertheless, this remains tentative since this small test cannot fully measure such complexity, and accordingly we are already preparing to test our hypothesis in a larger scale study, where we will measure spatial abilities first and then use a 3D application in the classroom to evaluate understanding of neuroanatomy.

The approaches to learning seem to play an important part in our Studies II and III. Because of the characteristics of the deep approach previously mentioned, it can predict how learners will learn and succeed in their studies (Entwistle & Ramsden, 1983; Lindblom-Ylänne & Lonka, 1999; Vermunt & van Rijswijk, 1988). Students who adopt a deep approach are able to regulate their own learning (Vermunt & Vermetten, 2004) and are more likely to adapt to new and different learning environments. A dynamic interplay exists between the learner and the learning environment that directs our attention to how approaches to learning develop (Vermunt & Verloop, 1999). We should take into account learners' approaches to learning when implementing educational technology, and avoiding focusing only on technology. However, we should try to treat the approaches to learning not as the property of individuals, but rather as a set of functional relations distributed across person and context (Barab & Plucker, 2002).

Research methods

The methods used in our studies are certainly not without shortcomings. It may be argued that the questionnaires used to determine learning styles and approaches were only subscales, and therefore could not capture the full extent of what they are meant to evaluate. The number of students participating was not large, and more studies would need to be performed. Also motivation and compensation effects and length of interventions may be considered as issues. Nevertheless, our approach was explorative in nature, and the outcomes were not meant to be explicatory of all phenomena, although it was sufficient to confirm a malady that afflicts education—the rush by institutions to apply educational technology without an authentic goal and theory. This approach only undermines the value of educational technology, which on its own already faces an ascending struggle to maintain its public appeal. In fact, because of its fast pace of development, educational technology renders itself quickly obsolete, which destabilizes its attraction.

I am currently carrying out more such small studies and even larger ones on a European scale, with different educational tools and students. These are not reported here because of time contraints, but it is intended that they will be reported in the future. However, some of the preliminary findings from our pilot studies in Sweden have shown a relationship between interest, engagement and optimism. These are negatively correlated with a combination of experienced stress, exhaustion, task avoidance and pessimism – a combination we call "dysfunctional pattern of beliefs". According to the analysis, they indicate that dysfunctional patterns are related to epistemological beliefs about certainty of knowledge: students who only want certain knowledge may be at risk for stress and exhaustion. This is a confirmation of our result in Study II for which students who expressed confusion about learning conveyed also confusion about using technology for learning: negative correlation between the scales of *Lack of Understanding* and *IT Orientation* ($R = -0.27$, $p < 0.05$).

In real-life educational settings it is difficult to maintain control over numerous variables. Motivation, compensation and time variables are almost impossible to control, as well as cultural and social ones. These variables are part of each individual and each plays different roles in everyone. For this reason, explorative studies seemed more appropriate and informative for our studies than experiments imitating the methodologies of natural sciences (Lonka, 1997). These types of studies allow us to first test the ground and acquire a basic understanding of technology, learners, teachers and the learning environment as a whole. In addition, qualitative over quantitative studies would also be instructive. The latter would allow us to discover what lies behind the correlations presented in the studies of this thesis. It is for this reason that some of my future studies will involve qualitative measurements. I do think that using different tools to acquire a deeper understanding of a matter is quite profitable, even though arguable.

Despite the methods used for research, we believe that it is necessary first to define the new learning environment by finding common objectives, the modes of action, and finally the tools that allow their implementation (Study IV). This approach integrates beyond the principles and the methodology of Action Research, and it centres on the elaboration of common objectives that should be negotiated and agreed upon by all actors involved. This may lead to questions about what is at stake from day to day in the actualization of new practices. For example, such an approach should clarify to the actors the significance of improvement which is the aim of innovation: what they gain, and also what they lose with innovation. For example, by implementing an on-line learning system, it can become easier for teachers to administer their courses and student data, but thereby losing leisure time because they must answer emails from concerned students before an exam. The definition of a new learning environment also requires the identification of risks both before and during the project.

The new learning environment must be defined in terms of human and technology commitment. Each actor's functions and roles, relationships and connections with the other actors, resources, schedules (personal and professional), weaknesses and strengths, epistemological ideas, educational approaches and skills have to find correspondent associations to and needs in the course web page, the graphical illustrations and presentations, the on-line system with its functions (forum, chat, help, email, and more), video conferencing, simulations, and all their educational benefits. In addition, a flexible and leading role in both human and technology management must guide the way and cooperate in the process. This is a complex job that can be accomplished only by sharing information and knowledge between administrator, researcher, educator, and technology. The former are three actors with different functions and roles, and collaboration is essential in order to create 'powerful' learning environments.

Each of the three approaches to research on innovation in education, Action Research, Design Research, and Activity Theory, has the potential to assist and enhance the understanding of learning environments in order to improve them. Their close commonalities are favorable features in the analysis of the research process: several methodologies can be applied in order to collect data—triangulation of quantitative and qualitative methods; participatory, collaborative effort between researchers and practitioners within a community of practice; these actors should also closely collaborate with all the others involved in a project of innovation such as, designers, managers, technical people, students, etc.; the data generated from such research should be analyzed and reinvested in the project of innovation; obstacles and shortcomings can then be solved iteratively; and finally all actors should be prepared to critically review their work and be ready to change their practice in accordance with new goals that arise and evolve in the course of cycles of innovation. With this in mind, i.e., a set of research methodologies and means of analysis, we now turn to more practical actions for the support of innovation.

Framework for sustaining innovation on a system level

In Study IV we suggest the following modes of action in order to guide and sustain innovation in medical education on a wide system level. They are reconstructed from work by Garant (2000), Peraya, Jaccaz, Masiello, Armitage, and Yip (2004), and Lorenzi and Riley (2003):

1. Begin with an educational vision: look at the problematic at hand or at the current *status quo* and ask why changes, if any, are necessary. What is the general epistemological standpoint of the members of the institution? Is the members' vision to become active participants of a medical school that can transform the traditional curriculum into a learner-centred one? In that case the institution as a whole must prepare and be able to manage changes, to create staff development options, articulate and share the vision in order to change the educational culture and reorganise itself.
2. Proactive attitude rather than reactive: the development and appropriation by all the actors of the relevant elements of innovation, sense of ownership. For example, the participatory design of the Action Research approach should be able to make the feeling of innovation personal for each actor and therefore essential. Moreover, the feeling of change should start early in the process, not in the middle of a crisis.
3. Flexible and evolutionary management: opposing a political management of innovation, dynamic development of the project and its priorities depends on the role of the person(s) in charge who must be able to evolve from a first positioning of stimulating, to the next of "let them do their work", to thereafter be able to manage conflicts and finally lead the process. Successful innovation leaders might have the ability to plan and organize well, although they must also have the mental flexibility to deal with changes in plans in the area and level of focus and also with interruptions.

4. Support for action as well as provision of related resources: in relation to change, the project leader usually distributes resources such as schedules, redistribution of management, organisation of teaching and technology and so forth. In managing change, his or her role would be of moral and technical support rather than just of a leader of innovation. This is a key to the professional development of teachers. Therefore, a good project leader must typically combine technical experience, managerial knowledge, and an educational vision.

5. Taking into account the representation of teachers: if we really want to change attitudes and practices, we must look into the idea that the teacher is well represented and clearly informed about changes about to occur. Staff development becomes then a key phase. This should allow for his or her reassurance about the project and nourishment of his or her implication in it. A well-defined organizational strategy may then be essential: "Effectively managing resistance to change and helping convert that resistance into commitment and enthusiasm is a planned process" (Lorenzi & Riley, 2003, p. 202). A shared educational vision obtained through discussions becomes necessary.

6. Better articulation between individuals and organisational practices: the facilitation of interaction between the individual (administrator, researcher, teacher, or member of society) and the institution or organization. This interaction often does not take place spontaneously and needs the integration of a third party, a change agent who professionally can introduce a significant transformation of practices. For example, one effective strategy is to seek assistance from a "champion" who is from the same group where innovation will occur. This is essential in order to change the current educational culture.

7. Reorganization of work in terms of time and place of dialogue: in research it is essential to analyse, evaluate and explore new solutions. Whether the introduction of innovation has been voluntary or imposed, a flexible mode of coordination of the reform realized in mutual terms cannot be carried out without space for reflection and without being recognized as quality time. Communication is one reason for failures in implementing information systems in health care: ineffective outgoing communication, ineffective listening, and failure to effectively prepare the staff for the new systems.

Framework for sustaining innovation on an individual level

The foregoing modes of action are directed to institutional intervention, but very often changes are implemented on a smaller scale. Therefore, we would like to propose a few strategic recommendations for any teacher wanting to introduce innovative practice in education:

1. Think about your own ideas of knowledge and learning. Reflect on those and the vision of the institution. Are they compatible? Is there any friction? If the previous were true then it would be easier to introduce changes. Otherwise, if the latter were true, you would then need to mediate and negotiate you actions.
2. Network and communicate with colleagues who think in the same way you do or who have interesting and challenging ideas. It is also important to collaborate with educational consultants and researchers in order to create 'cognitive partnerships'.
3. Small steps: start with a very simple web page where you can post course information or other material that you want to always be available to your students, and provide links to public informational material. Students will most probably tell you whether that information is welcomed and/or needs changes. If they do not make spontaneous suggestions, then ask them.
4. If you want to advance one small step further, introduce small learning objects (LOs), e.g., animations, video or audio clips, and descriptive text to explain some of the more complex subjects. Bring them into the lecture and let the students use them. More often than not, you do not have to create LOs from scratch, and a search on the Internet may pay off:

   http://www.uwm.edu/Dept/CIE/AOP/LO_collections.html.

   Many LOs are available either for free or after a simple request to the author. Don't be afraid to ask, many developers will be very happy to share their work. Again, feedback from students and colleagues could help you with issues of implementation, integration and sustainability. If your institution provides help, then take advantage of it. As Davis and Harden (2001, p. 442) have written: " [LO] has the potential of making possible the fast and economic production of high-quality education programmes individualized to the needs of the teacher developing the course”.

5. Obtain also formative and summative evaluations. Just as learning assessments assist in understanding how learning is proceeding and to grade students performance, you need to understand the ability of the LO to support educational processes or to simply improve motivation of students. Perform evaluations over time and find a suitable experimental design. Ask the students—they are the best help.

6. Active student participation in the learning process has the potential to provide learners with the opportunity to construct new ideas, concepts or hypotheses based upon their current and/or past knowledge on the basis of interaction with peers and the environment, and as a result, you decide to introduce an e-learning application. There are many free-to-use applications that are easy to install and maintain, e.g., Moodle (http://www.moodle.org) as an example. If the technical part is too complex, then seek help from the IT department of the institution, they may already have something for you to use. This step requires a little more time from your side. You must research on what, how, when to and why use specific functionalities of the e-learning applications. Most importantly it requires a role change that may be simply excessive for you, especially if you are alone. You need to shift to student-centred learning; you will become more of a moderator than the traditional teacher; you will need to spend more time online (students want answers at desperate hours of the day and night, especially before exams, but you can avoid this if you provide clear instructions on how and when you can be reached); you need to know more about technology if students need help with that; you are required to do a job that is different from the one to which you are accustomed and for which you have to do more work; are you certain you are ready for it? Again, if you can get support, use it. Remember, the notion that information technology can save you time is only a myth, at least when you are first attempting to implement it.

7. If you are that teacher and take these tips into consideration you could eventually become a change agent and a catalyst for innovative practice: a “champion”. Because content specificity is important for

each teacher, others working in the same domain, or next door, would probably approach you and ask for help.

These simple steps are not reflective of all possible scenarios, and in fact are targeted to teachers working in a traditional learning environment. However, if a teacher works alone this will not be too far from “reality”. We must be critical of what we do and be ready to change our approaches and role if necessary. We need to remember that technology improves as fast as we can get it. But we should not become discouraged and adopt it one small step at a time, for radical innovation has no chance in education (Bereiter, 2002). In this way we should be able to pick the fruit of our hard work.

VI. Conclusions

There has been a flood of educational computer applications into all fields of education, and undoubtedly this has happened during the last few decades. Medicine is one such domain where educational technology has overwhelmingly entered the educational sphere pushed by policy makers and leaders (General Medical Council, 1993; World Federation for Medical Education, 2003) who thought better to embrace it before even considering it. Somehow this type of technology inspires an intangible trust and is believed to bring a ‘great fortune’ to those who use it, and it is therefore welcomed, even though its capabilities remain impossible to foresee.

Medical education per se is already under fire. The General Medical Council (1993) and the World Federation for Medical Education (2003) argue powerfully for revision to the medical curricula and for changes in teaching practices (Harden et al., 1999). However, reality tells us that there is a lack of integrated use of educational technology within the curriculum (Earle, 2002). As a result, this is one area where research like we conduct can prove useful in locating the best approach to fit the technology to the curriculum. A scientific approach, educational theories and well-designed procedures and techniques are needed to create successful and effective new learning environments (Cloete, 2001). Additionally, this goal is not achievable as a one-man task. A collaborative approach among administrators, faculties, researchers and students must be established for the development of such learning environments. In Figure 1, we depicted graphically four forms of expertise, i.e., education, technology, management and content, that unite to collaborate in the creation of a new learning environment, and each is equally important for its success.

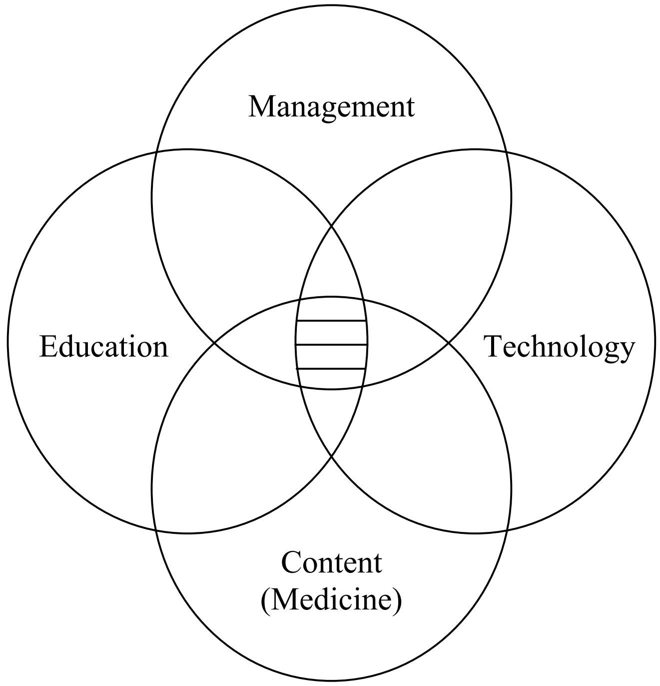

Figure 1: Forms of expertise

The transition to a learner-centred approach afforded by educational technology may be difficult for some students, and the identification of students' approaches to learning may prove to be essential in providing assistance to students with diverse individual experiential background (Cromwell, 2000) and the design of web-based learning environments (Martens, Valcke, & Portier, 1997). However, the success of new learning environments ultimately depends on teachers and how they are able to efficiently use these tools for the transition. Therefore, teachers need to be informed not only about the students' different approaches to learning and about technology, but also on teaching and learning theories that promote a student-centred approach and a sense of community among online faculty and students (Lieblein, 2000). Researchers, consultants and teachers should partnership in this endeavour.

However, we must also be cautious not to over-interpret questionnaire data; by no means should these be regarded as objective measures of some fundamental psychological reality, but simply to be used to pose new and more relevant research questions, such as redefining the idea of deep approach to better fit modern collaborative learning environments (Lonka, Olkinuora, & Mäkinen, 2004). The transformation of medical education calls for a new mindset, and staff development may become critical in transforming teachers' idea of learning (Lonka & Bolander, 2002). This means that before we simply change the medium for learning we must first review the methods used for learning (Campbell & Johnson, 1999) by developing and applying common teaching and learning objectives.

We should keep in mind that technology is not a problem solver for educational complexity. In fact, the belief that educational applications could enhance student learning is simply speculative. I would like to suggest that it is merely different, although not better, than traditional learning, especially when used with a selective group of students such as those studying medicine. What technology does offer is the opportunity to create a learning environment that extends and complements the traditional but still very useful environment such as books and classrooms, as well as offering yet undiscovered possibilities (Bransford, Brown, & Cocking, 2000). "The medical school of the future", Greenhalgh (2001, p. 44) writes, "may be one that can successfully offer (in collaboration with other educational providers) a flexible menu of both face to face and self study modules from which individual students can select to meet their own unique requirements".

Students may be more motivated to study when using dynamic visual, auditory, and tactile (in the case of high-end simulation) information that might help them to create a comprehensive representation of the subject to learn. Learning while also having fun is not better, just different and more stimulating. Technology also offers and is well-suited for peer-to-peer learning. Peer learning is qualitatively different than that from the interaction between teachers and students, and the design of peer-to-peer online activity may allow students to learn from each other (Davis & Harden, 2001). However, the assessment of student learning has to go hand-in-hand with the possibilities offered by new learning environments, and attention must be paid in the research design if we want to attain effective measures.

Research has demonstrated that deep learning predicts study success, and students who adopt a deep approach are also able to regulate their own learning and are more likely to adapt to the learning environments (Entwistle & Ramsden, 1983; Lindblom-Ylänne & Lonka, 1999; Marton & Säljö, 1976; Vermunt & van Rijswijk, 1988), and may consequently be more likely to adapt also to e-learning environments or simulating environments. Furthermore, the deep learning process adopted by learners could be more beneficial than the educational application itself for succeeding in the learning task.

Because minimally invasive surgery is becoming a preferred option for minor surgical procedures, high-end simulating environments, such as MIST (minimally invasive simulation trainer), are slowly entering the domain of medical education. Hence, it would be interesting to discover what relation deep learning has to spatial ability. This has strong implications for the learning of anatomy for radiology and surgery specialisations. Spatial ability is a predictor of success in anatomy learning (Garg, Norman, & Sperotable, 2001), and from our pilot study (Study III) we can hypothesise that the nature of expertise in anatomy may be three-dimensional in nature. However, more research would be needed to provide a more definitive answer.

In order to discern a brighter future for educational technologies we must first learn about good research methodologies that suit both technology and education together, learn about the best use of technology in education, and learn more about students' learning and teachers' teaching. Only then we can experience the enhancing potentials of technology in education (Bransford, Brown, & Cocking, 2000; Sims, 2000). As we learned in the *Background* section of this thesis, it is already possible to measure transfer that occurs in learners' behaviour due to technology capabilities. Ultimately, it is necessary to measure the impact of education on the delivery of healthcare (Harden et al., 1999).

A guideline for sustaining innovation in education is then to have clear, precise teaching, learning and technology objectives and to determine regulative mechanisms of the learning environment. While implementing innovative practices, it is critical to regularly collect data to then review the various hiccups and incidents that can either stop or slow down the success of the process. It is also important to place the actors with their competencies, culture and experiences at the centre of the implementation and to guide the latter by a collaborative approach. In this way the actors can gain a sense of ownership of the process of innovation and be more likely to provide essential actions for its success. Operational steps for resolving the sustaining on innovation in education could be the following:

- Start with an educational vision
- A proactive rather then reactive leading
- Flexible and evolutionary management
- Support for action as well as the availability of related resources
- Making sure that teachers are represented
- Better articulation between individual and organisational practice
- Reorganisation of work in terms of time and place of dialogue.

Usually funding is given for innovation that must succeed, and studies like those described in this thesis, where the aim is not to prove that one has created a tool that works, must also be able to point out weaknesses, so that funding was not provided in vain and from which others can learn.

To say that one method is better than the other or that one learning environment is better than the next is a meaningless trap. We saw that because of content and context of the learning environment, the subjectivity of students' learning processes, and subjectivity of teachers' teaching processes, that there is no single methodology and correct answer for an absolute educational approach. However, a plurality of methods can affect the manner in which education is conducted and the role played by educational technology in the process of education. Each answer or design can then be evaluated and each can provide constructive information for the sustaining of innovation in education.

History has shown that the impact of technology on education, from written material to radio and television, is impossible to predict, and that most advocates or pessimists have often been wrong in their forecast (Gumport & Chun, 1999). However, changes attributed to technology seem very hard to resist, and proceeding with caution is a must. Therefore, at present, small steps such as a blended approach, the introduction of small learning objects, and the use of change agents might help the understanding and acceptance of technology innovation in medical and general education.

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I want to end by thanking Anna, my life companion, Leonardo and Alexander, our two boys, for their unlimited source of fun and inspiration, for reminding me that there is, beyond any reasonable doubt, more to life than just work and self, and for sharing many laughs and simple moments to make my heart overspill. You are my life.

VIII. Summary in Swedish

Det har tagits fram en strid ström av datorapplikationer på alla undervisningsområden, i synnerhet under de senaste decennierna. Medicin är ett sådant område där informationsteknik på ett överväldigande sätt fått insteg i undervisningen. Detta har drivits av beslutsfattare som valt att anamma tekniken utan större övervägande. Studie I visar att detta förhållningssätt i själva verket fortfarande är rådande. Valet av en lärandeplattform gjordes endast på ekonomiska grunder, och resultaten från studien visade att studenterna uttryckte en beredvillighet för och en positiv attityd till informationsteknik i undervisningen samt visade på en potentiell fördel av dess användning på lång sikt. Likväl uttryckte de även negativa åsikter angående den utbildningsplattform (Learning Management System, LMS) som användes i deras kursarbeten och antydde att plattformen behövde ändras. Denna studie lägger fram bevis på att datorbaserade system måste designas och implementeras omsorgsfullt för att vara effektiva, annars riskerar de att ha en negativ påverkan på studenternas intresse och aktivitet.

I studie II undersöktes om studenternas förhållningssätt till lärande relaterade till deras uppfattning om den nämnda virtuella lärandeplattformen. Skalorna i ASSIST-frågeformuläret integrerades i en lösning med två huvudkomponenter, en ytinriktad och en djupinriktad. Vi upptäckte statistiskt signifikanta korrelationer mellan förhållningssätt till lärande och studenternas inställning till IKT (informations- och kommunikationsteknik). Vi drog slutsatsen att det troligen är viktigt att tidigt identifiera förhållningssätt till lärande och inställningar till IKT, för att hjälpa och underlätta övergången för studenter med olika individuella karaktärsdrag samt för att göra det lättare att designa nya lärandemiljöer.

Studie III innefattade en pilotimplementering av 3D Embryo, en interaktiv flerdimensionell animation. Studenterna var överväldigande positiva till applikationen. Likväl fanns det ingen statistisk skillnad mellan kontroll- och experimentgrupperna i ett prestationstest. En positiv tendens upptäcktes mellan djupinriktning och allmänna provresultat. Även statistisk signifikans upptäcktes mellan en djupinriktad och en tredimensionell uppfattning. Ett väsentligt resultat var att ett djupinriktat lärande var mer avgörande än själva den interaktiva applikationen i inlärningsuppgiften. Även om interaktiva multimedia kanske inte är förstklassiga pedagogiska hjälpmedel, kan de utvidga möjligheterna inom den traditionella lärandemiljön. Resultatet att studenter som antog ett djupinriktat förhållningssätt på det hela taget hade bättre resultat i allmänhet, och i synnerhet i den rumsliga uppgiften, är ett nyckelresultat som ger anledning till framtida studier om expertis inom medicinsk anatomi och överföring (transfer).

I artikel IV framställdes både ett teoretiskt och ett praktiskt ramverk, som försökte ge information och struktur till i första hand lärare, ”kursdesigners” och administratörer, som för närvarande konfronteras med implementeringsinitiativ i alla dess former inom undervisningsväsendet. Men artikeln borde även kunna vara lärorik för beslutsfattare och undervisningspersonal. Vi strävade i den att hjälpa alla dessa aktörer i analysfrågor, genom att gå i spetsen för och understödja förnyelse i medicinundervisningen. I artikeln presenterar vi den information som måste tas i beaktande vid varje steg i utvecklingsprocessen, för att man ska kunna fatta beslut och uppnå de uppsatta målen. Vi föreslog hur man ska behandla de data som genererats ur analysen samt hur man ska mata in resultaten tillbaka i utvecklingsprocessen. Dessutom gav vi aktörerna praktisk information om hur de kan analysera utvecklingen genom att använda sig av aktivitetsteori och implementera den genom deltagande aktionsforskning.

Denna sista artikel binder samman de andra studierna och infogar dem i flera teoretiska ramverk. Den pekar på att informationsteknik i utbildningen inte är svaret på våra utbildningsproblem, utan ett mångfunktionellt hjälpmedel som står oss till förfogande med läraren och studenten i centrum. Informationsteknik i utbildningen kan utan tvekan vara oss till hjälp i vår strävan att förnya medicinutbildningen. Följaktligen blir implementeringsfrågor av central betydelse för en framgångsrik användning av informationsteknik i utbildningen, men de måste vara baserade på välgrundade vetenskapliga synsätt, utbildningsteorier, metoder och tekniker.

IX. One last thought

I would like to use a small space in this thesis to express a few points which I believe were relevant to the development of this work and my studies. I must start by saying that the views expressed here do not necessarily represent the official views of either the Institution, the Department, the supervisors, or anybody else for that matter, but are solely my own.

A few years back when I started my doctoral studies I had both the fortune and misfortune to begin then in a 'sparkling' new centre which scope was very different from the rest of the other university specialities. The university is Karolinska Institutet (KI), a medical university, the department is Learning, Informatics, Management and Ethics (LIME), and the centre in which I work is the Centre for Cognition, Understanding and Learning (CUL). Being a newly established department, LIME has administrative and organizational problems like anyone just starting usually faces. In addition, the centre does not fit in the normal medical research domain like the rest of the university departments. Significantly, CUL was established for researching on how to improve the learning environment, to help the teachers improve their teaching, to help the students improve their learning, to assist in a step-by-step introduction of technology and new methodologies in the learning environment, and finally reform and transform the century-old medical curriculum of the institute. CUL is a 'change agent' that brings a wave of innovative changes.

KI is to date a very traditional medical university (Savage et al., 2002). As such, it has a clearly defined cultural tradition that is difficult to breach. Nonetheless, CUL is doing an excellent job in bringing awareness of and instruments for a necessity to change its medical education and curriculum to the various individuals composing the institution, from student to president. CUL is in this case a 'visionary innovator', even though it is not yet recognized as such, but as the likes it faces daily obstacles and is 'frowned upon'; who would not be bothered by someone who attempts to change your habits? As Bereiter (2002) writes, this kind of visionary has the potential to further develop the design research for sustained innovation; the design of new learning environments to suit the institution and all members to the best-evidence practice.

The toughest hurdle I had to personally overcome was to let a group of medical researchers and practitioners, reviewing my ethical application, appreciate the research I was going to conduct. With my line of research and academic language being different from theirs, once they read the ethical proposal and responded to it, I understood that very little of the proposal had been recognized of value. They asked me to perform statistical analyses that are not customary for the educational research domain nor would they provide any answer for that requirement, but of course those statistical analyses are standard procedure in the medical research line of work. Thus, it took about nine months of reciprocal correspondence and the involvement of senior personnel at the department to finally settle the issue. Not to mention that explorative studies where no medication is administered or harm done to the students, such as those I conduct, do not need in the majority of cases any form of ethical approval, as long as the students are aware and willing participants by signing an inform consent. Thankfully this one-time process is now recognized to all the new researchers coming to LIME, whose task is only to write a one-page summary of their research plan and methods and send it to the ethical committee for review and recordkeeping. This was just one small anecdote of the clash of two very different areas of practice within the same institution.

When I first started working on my doctoral research I had very clearly in mind that I wanted to focus on evaluating the effectiveness of technology for teaching and learning from both perspectives, technology and teaching and learning, how technology could help the process of teaching and learning, and when possible even learn the new technologies myself. Working in a medical university, the underling theme of my research was going to be medicine. Here comes another incongruence with being the first graduate at a centre that does not reflect the common practice of the institution: the title conferred to my academic degree is Ph.D. in Medical Education. I want to emphasize that I do work with education and I do work within the medical domain, but am in no way an expert in medical education in the literary sense, my background is experimental psychology and IT, and not physiology. The expertise gained during the years of my doctoral research is of a very interdisciplinary nature, and I can perform my line of research in any educational field without being restricted by a single domain. However, technology just tapped the surface of medical education and practice and a lot of work is now being generated, especially here at CUL, that I just started to enjoy myself, and this compensates for the distinct doctoral title, which the institution hopefully will decide to confer upon me.

Well then, you might ask, what is the point of this rambling? Yes, what is the point? The point is that changes are introduced because there is a necessity for them, and not because everyone else is doing it or more simply because we are told to. Learning technologies can bring changes to the curriculum and the way we teach and learn, but it is not the only answer: just one of them. We need to start a discussion within the institution so that we learn to understand each other's languages. CUL has the only professorship in medical education in Scandinavia to date, so it would be wise to exploit this to the advantage of the institution. We need to clarify why, where and how we want changes. CUL has well-trained, knowledgeable and experienced personnel in staff development and teaching and learning issues (I am one of them to a certain extent). We need some time to research, discuss and understand how to introduce innovation to enhance learning and collaboration. CUL has personnel with great understanding and know-how to proficiently implement innovation in general and medical education in particular, and to make the best use of research findings to advance innovation with the goal of enhancing learning. Finally, I hope this thesis will become the starting point for implementing innovation at the institution.

X. References

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