Developing educational computer-assisted simulations

Exploring a new approach to researching learning in collaborative health care simulation contexts

Lars O. Häll

Pedagogiska institutionen
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To M-B H (1946-2008)

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Abstract

Health care education is developing and simulations, in different guises, are gaining increasing attention as a means of overcoming tensions between instructional models and educational objectives. The role of simulations is, however, yet to be fully defined and will be dependent on the actual impact simulations on educational practice. Research need to better understand this impact and contribute to developing simulation practices. There is, therefore, a strong need for research that can balance scientific stringency and practical utility. This presents a challenge in a field that is biased in favor of laboratory experiments where theoretical accounts are also rare. This thesis explores a new theoretical and methodological approach, as a means of meeting this challenge. It draws upon Rose Luckin's Ecology of Resources framework for redesigning learning contexts (2010) and it attempts to explore relations between learning context, learner interactions, and learning outcomes, in order to identify opportunities for the development of educational simulation practice. In researching different types of health care simulations in their own right, arguments have been made that it is necessary to strive for smaller and more useful generalizations. In response to this challenge, this thesis delineates one type of simulation context: collaborative educational computer-assisted simulation (ECAS) in health care education. After reviewing previous research on related topics, a model of this type of context has been developed. Based on this general model, the particular subfield of collaborative radiology in ECAS has been analyzed and researched. Four articles on this topic present empirical contributions that address different relations between context, learner interactions, and learning outcomes in collaborative radiology in ECAS. The first one explores how moving from a static tool to an ECAS changes what learners talk about, how they talk about it, and how they develop during training. The second one explores in more detail relations between the features of ECAS, the content of learner interactions, and the impact on learning. The third one explores how context design impacts peer interaction, and the fourth compares more and less successful groups in order to identify needs and opportunities for development of the learning context. The empirical data are used to discuss relations between learning context, learner interactions, and learning outcomes, and how collaborative scripts may be potentially useful in the development of collaborative ECAS in health care education. Such scripts could support for instance explicit dialogue about relations between context-dependent doing and subject-specific principles, thorough engagement with simulation feedback and inclusion of all simulations participants. A new path for health care simulation research is suggested, including a move beyond laboratory experiments towards dealing with the messiness of actual educational practice, a move beyond universal

generalizations towards smaller-scale context considerate and more practically useful generalizations.

Reprinted publications

I Söderström, T., Häll, L.O., Nilsson, T. & Ahlqvist, J. (2012). How does collaborative 3D screen-based computer simulation training influence diagnostic skills of radiographic images and peer communication? *Contemporary Educational Technology*, *3*(4), 293–307. @ 2012 Contemporary Educational Technology. Open access.

II Häll, L.O., Söderström, T., Nilsson, T., & Ahlqvist, J. (2011). Collaborative learning with screen-based simulation in health care education: An empirical study of collaborative patterns and proficiency development. *Journal of Computer Assisted Learning, 27*(5), 448–461. @ 2011 Blackwell Publishing Ltd. Reprinted with permission.

III Häll, L. O., & Söderström, T. (2012). Designing for learning in computer-assisted health care simulations. In O. Lindberg & A. D. Olofsson (Eds.), *Informed design of educational technologies in higher education: Enhanced learning and teaching* (pp. 167–192). Hershey, PA: IGI Global. @ 2012 IGI Global. Reprinted with permission.

IV Häll, L. O. (2012). Exploring collaborative training with educational computer-assisted simulations in health care education: An empirical ecology of resources study. *Creative Education*, *3*(6), 784–795. @ 2012 Scientific Research Publishing. Open access.

Notable abbreviations

CSCL	Computer-supported collaborative learning. A research field focused on learning through computer-supported collaboration.
ECAS	Educational computer-assisted simulations. Constructed as a category of simulations applied within health care education.
EoR	Ecology of resources. A theoretical construct of learning context developed by Luckin (2010).
HCE	Health care education. The particular branch of education focused in this thesis.
LRiSE	Learning radiology in simulated environments. The research and development project that funded and produced empirical data underlying included articles.
MAP	More able partner. Interpreted as a role in relation to a learner that can be enacted by teacher, peer och technology.
SBME	Simulation based medical education. Considered to be a developing field of research.
ZPD	Zone of proximal development. A theoretical construct of development developed by Vygotsky (e.g. Vygotsky, 1978).

I. A developing context

Tensions lead to change, and within education they are abundant. They can manifest as tensions or conflicts within or between structural elements of human practices: means, objectives, stakeholders, and so on (Engeström, 1987). Educational systems must meet competing and changing societal needs. In times of stability, demands are different than in times of great change, and expectations and competencies differ among societal production systems. The need for reproduction can be contrasted with needs for innovation. Societies are changing, and so is education.

Any changes to the way we communicate greatly impact the way we relate to the world. Means for traveling, means for documentation, means for interacting across great distances—these have all changed the world dramatically and still are (Sundin, 2006). In the perspective of human development, it has not been long since the invention of written language, and it is just recently that we started to move from oral to written traditions (Ong, 2002). Today the Internet is fundamentally changing the way we relate to others. The long-term implications of the spread of, for example, smartphones on everyday activities remain to be seen.

During the past 150 years school systems in Sweden have seen great changes related to great societal changes. Answers have changed to fundamental questions—What needs to be the goal of formal education? How do we achieve it? Who is it for? What are the core subjects? What is the role of (information and communications) technology?—to name a few. The relations between learner and teacher, and our conceptions of those relations, have changed fundamentally, as illustrated, for instance, in the disputed expression “from the sage on the stage, to the guide on the side” (King, 1993).

Simultaneously, research on education and learning has developed, and not only in Sweden. It is intimately associated with and dependent on questions such as those posed above, and when they change, so must our theorizing about education. That is not to say that there is any simple and causal one-way relation from practice to theory; they clearly interact. And research is also subject to inner tensions. The 20th century saw furious wars between different conceptualizations of what educational science is or should be about, what learning is and how it can and should be studied. In his time, Vygotsky criticized conceptualizations of learning that paralleled botany and zoology (1978, p. 20). One of the central tensions that continue to motivate scientific learning activities is related to what is acceptable as scientific proof and what is considered to be useful in current practices. What is the point of controlled lab experiments if the outcomes are not useful for informing particular educational practices? What is the point of qualitative, highly context-oriented studies if the research cannot produce outcomes that can extend beyond a particular practice? These tensions and the dialogues between their representatives are of course much more complex than they here receive credit for. At times, the questions raised within or to a theory cannot be answered by less than a reformulation of theory, framework, and/or methodologies.

These tensions have been mirrored in the development of technological support for learning. Koschmann illustrated this in a now classic text about paradigms of instructional technology research. He argues that “seen from a Kuhnian perspective, instructional technology (IT) has undergone several such paradigmatic shifts in its relatively brief history” (1996, p. 2). These paradigms differ in their underlying conceptions of learning, instruction, and methodology and of what relevant research questions are. They illustrate a movement from objectivist behaviorist approaches over information processing, cognitive constructivist toward social constructivist approaches. This entails a movement from realist and absolutist toward relativist, fallibilist and revisionist perspectives, from conceptions of learning as acquisition to learning as construction, from conceptions of instruction as transmission to instruction as guiding collaborative construction, from research through experimental pre-/post-tests over think-aloud protocols to design-based research and conversation analysis (Koschmann, 1996; Cakir, 2009). Important to note however is that the preceding paradigms by no means are abandoned in favor of the new; rather, they develop in parallel.

In a Swedish context, experimental psychological approaches were dominant for the early part of the 20th century, to be followed by the context-oriented frame factor theory and sociological cultural reproduction currents in the 1960s and 1970s and a growing interest in historical studies in the 1980s (Englund, 1992; Kroksmark, 1992; Vislie, Popkewitz & Bjerg, 1997; Lindblad, Linde & Naeslnd, 1999; Härnqvist, 1997). At a recent symposium here in Umeå entitled “Informed Design of Educational Technologies” one of the central issues discussed was how to reach approaches that are equally useful and meaningful from educational research and from educational practice perspectives. This was not by chance.

One of the core ingredients of this thesis is one such educational technology, educational computer assisted simulations. These come in many variations of which some likely could be adopted by each of the paradigms mentioned above. The predominant focus on exploration and experience lends itself better for the constructivist perspectives, however. Simulations for discovery and inquiry into natural sciences are common in the literature (e.g., Hulshof & de Jong, 2006). In the following section I will discuss simulations in another educational arena, health-care education, and consider their history and function as well as the research being carried out on them.

Health care education in development – simulations as bridges

> *The past two decades—and especially the last five years—have seen a rapidly growing interest in using simulation for purposes of improving patient safety and patient care through a variety of applications.* (Gaba, 2004, p. 2)

A tension innate to health-care education (HCE) is that of teaching and learning professional skills without waiving patient safety. Trying, failing, reflecting, and trying again are important parts of learning processes. Transfer from safe educational practices to real clinical practices is not without complications (e.g., Packer, 2001). So how can we enable students to learn difficult tasks, such as surgery, without having them practice and potentially fail on real patients? Likely, few patients wish to be their surgeon's first patient. In fact, while medicine developed as a practical profession with clinical apprenticeship as a core learning model (e.g., Dornan, 2005), over time a resistance has developed in terms of, for instance, patient safety concerns (e.g., Gaba, 2004). Clinical mistakes are costly, not only for the patient, but often also for the hospital (e.g., Mello, Studdert, Thomas, Yoon & Brennan, 2007). What thus emerges from this tension is a motivation to separate learning practice from clinical practice. Of course similar separations are, for several reasons, represented in the majority of formal education; as is the problem of how we go about "bridging practices" (Rystedt, 2002) of formal learning and professional doing.

> *The interest in simulation for health care has derived in large measure from the long experience and heavy use of simulation for training and other purposes in non-medical industries. In particular, these include commercial aviation, nuclear power production, and the military—industries that share with health care intrinsic hazard and complexity, but are considered high reliability organisations that have a very low failure rate considering their inherent risks.* (Gaba, 2004, p. 126)

As a means to relieve this tension, simulation is today receiving a strong and growing interest from health-care education stakeholders. Simulations are, generally speaking "the technique of imitating the behaviour of some situation and process . . . by means of a suitably analogous situation or apparatus" (Simulation, n.d.). As such, they can enable training in/on/with realistic situations/tools without direct risk for patients. Whether patients are put at risk indirectly because of simulation inadequacies, in terms of fidelity or transfer, is a recurring issue in the literature (e.g. Issenberg, Ringsted, Ostergaard & Dieckmann, 2011). Although simulation may sound high-tech and have science fiction connotations, it is not a new phenomenon—far from it—and neither is it, as Gaba noted in the quote above, limited to health-care education.

Simulations have taken different forms throughout health care's history. For example: mechanical manikins for training cardiopulmonary resuscitation (CPR) were developed by Åsmund Laerdal in the early 1960s. The widely used Resusci Anne manikin was developed to help students understand when to apply CPR and how to administer it by giving them the opportunity to practice on a humanlike device. Its predecessors in terms of pure dummy dolls may be traced as far back as the 19th century (Nehring, 2006), and maybe even back to 17th-century France (McGaghie, 2010). Anesthesiologists were quick to catch on, and early attempts at computer-supported manikin training began in the late 1960s, called Sim One, where computer support enhanced the action-response interactivity (Abrahamson & Denson, 1969). The training had little success due in part to the high costs involved and the still-to-be-recognized need for an alternative to apprenticeship-based training (Bradley, 2006, p. 255). Renewed attempts within anesthesia were made in the 1980s at the universities of Stanford and Florida. With Stanford's Comprehensive Anesthesia Simulation Environment (CASE) focusing on teamwork in realistic training contexts, a first step was taken towards the high fidelity simulations we know today (Bradley, 2006, 255).

Today simulations encompass diverse forms, such as full-scale manikins, part-task trainers, and PC simulations (Bradley, 2006; Nehring, 2009). Their development has benefited greatly from the general information-technology advancements toward the end of the 20th century. But they have also been driven by an intensified need to resolve the tension previously described. In reviewing the forces driving the advancements and spread of health-care simulation, writers note factors such as a general aim of improving learning, performance, patient care, and safety, to reduce training on patients and reduce liability claims, a changing clinical experience, reduced time in training, a stronger focus on clinical skills and on skills assessment, needs for continuing education and so forth (Gaba 2004; Bradley 2006; Nehring 2009).

The expectations and hopes embodied in the health-care simulation enterprise are vast. From an educational perspective, which is the perspective of this thesis, it is about dealing with a complexity of demands by improving learning conditions.

Prior research on health care simulations dates back to the 1960s, starts to grow in the 1980s (Bradley, 2006) and takes off around the beginning of the new millennium. It is still a new field, with diverse outlooks and diverse quality. Realism, fidelity, validation, reception, and impact on learning are some important themes in the early research. Features and uses of efficient training became the focal point with the well-known Best Evidence Medical Education report for 2005. And today, with the field still growing, key actors seem to seek outside input from general educationalists, asking for instance, What can learning theory teach us? (Issenberg et al., 2011). Needs for development of research within the field has been identified, but the means to achieve it has not. This thesis represents an attempt from an educationalist to contribute something that is not yet well represented within research on the topic, and to explore a means for development of research within the field.

The Learning Radiology in Simulated Environments project (LRiSE), with its Radiology Simulator (e.g., Häll & Söderström, 2012), which funded the research underlying this thesis, can be understood in relation to the practical and scientific context described above. It contains all the core elements of the general health-care simulation narrative described above: (1) health-care students need to learn a complex skill with associated conceptual understanding; (2) clinical practice is limited because of the risk involved, that is, exposure to radiation; (3) conventional training appears to be insufficient; (4) simulation is suggested as tool for bridging formal learning and clinical experience; (5) questions are raised as to (a) whether simulation improves student performance; (b) how to enhance learning with this simulation, and (c) what unintended effects it may have on students' learning contexts.

Radiographic imaging is used within health care to photograph anatomical objects and structures that are hidden from plain view, such as cavities in our teeth. Learning to produce and analyze such images is a complicated endeavor and entails an understanding of three-dimensional anatomy, two-dimensional imaging, and the relationships between them. Because there are risks associated with exposure to radiation, for examiner as well as examinee, clinical practice is limited. Training is traditionally performed with a focus on the analysis of preproduced photographs. Finding this mode of training to be insufficient, teachers at the Dentistry Program at Umeå University developed (in cooperation with computer scientists) a PC-based virtual reality simulation. This enables students to operate a 3D model of a patient and allows them to take virtual X-ray images.

Initial studies of individual training showed promising results with the simulator; it seemed to be more efficient than the established alternative (e.g., Nilsson, 2007). Throughout the LRiSE project, the simulator and its application was analyzed and developed. My interest in the project and in this thesis is the interrelation between technology and application.

New studies of group training were initiated, in part as a means to complement the previously performed investigation of individual training with the simulator. Other researchers of computer-supported learning have argued that practical and economic circumstances often mean that students work in groups (e.g Crook, 1994, p. 121), and expensive simulation software should be no different. Methodological and theoretical considerations also were involved in this choice, however. From a methodological perspective, verbal interaction can open a window into the processes of problem solving enacted during training. From a theoretical perspective, the relationship between individual (and collective) development and a social and cultural context has been the subject of an increasing interest during the latter part of the 20th century and still is in the beginning of the 21st. One of the social resources for individual development that has been investigated within educational research is cooperative and collaborative learning in groups (e.g. Dillenbourg, Baker, Blaye & O'Malley, 1996; Dillenbourg, Järvelä & Fischer, 2009). For these researchers the idea is, in heretically short terms that peer interaction can motivate behavior that benefits development but that some support often is needed for this to happen. This thesis will be theoretically framed by the works of Rose Luckin (e.g., 2010), who in turn draws upon the works of Vygotsky. With this perspective I will try to understand learning as internalization of filtered interactions with resources in a context, or what she calls an Ecology of Resources, in which peers can play a significant role. I will describe this framework and its concepts more fully in the next chapter. Within simulation-based medical education (SBME) research, which I consider to be a developing field of its own, peer interaction and collaboration in support of learning have not and are not being given much attention (Issenberg, McGaghie, Petrusa, Lee, & Scalese, 2005; McGaghie, Issenberg, Petrusa, & Scalese, 2010; Issenberg et al., 2011), which incidentally leads me to the purpose of this thesis.

Purpose and aims

Motivated by the context outlined above, the purpose of this thesis is twofold:

1. to explore collaborative learning with educational computer-assisted simulations in health-care education, by exploring

relations between learning context, learner interactions, and learning outcomes, in order to identify opportunities for development of educational simulation practice;

2. to introduce to the field a new theoretical position, by grounding the thesis in Luckin's (2010) Ecology of Resources framework, in order to meet the current need for theoretical grounding that considers both simulation technology and its contextual application and in order to produce outcomes that are useful for educational practice as well as for research practice.

Disposition

The empirical core of this thesis is studies of a particular collaborative simulation in two particular contexts. I will interpret these as examples of a type of simulation in a type of context.

In chapter 2 I will introduce the theoretical framework that will support this process. This includes a description of its intended position in some important philosophical dimensions. I will present origins of the theoretical framework and illustrate its intended contribution to the field (i.e., what's new). I will also discuss how my usage of the framework may differ from others. Finally, I will discuss some additional concepts that are important in the thesis.

The following two chapters, 3 and 4, present my application of the theoretical framework. This includes performing a review of related research, which is then used to inform my analysis of the particular as an example of something general. This will also identify needs for empirical investigations, some of which will be met by my own empirical research.

Chapter 5 introduces the design, overall and particular, of the studies that produced the empirical foundation of this thesis. It presents the research and development project that motivated and structured the studies, the selection of data founding the four articles, and methodological reflections related to these studies, selections, and articles.

I will then summarize the articles and illustrate the empirical contribution to the overall objective.

Finally, I will reflect upon the different aspects of the thesis, its outcomes and contributions, and need for further research. I will comment on the usefulness of my application of the theoretical framework, and I will also discuss potential differences between it and its theoretical origins.

II. Conceptualizing learning in context

> *. . . (a) the Ecology of Resources model is a "mediating form of representation" and (b) its theoretical approach is the Zone of Proximal Development, its theoretical position is sociocultural, and its theoretical perspective is social constructivist.* (Luckin, 2010, p. 99–100)

This thesis draws heavily on the Ecology of Resources (EoR) framework developed by Rose Luckin (2010). It is used to conceptualize, guide, and reflect upon my investigations of collaborative training with Educational Computer-Assisted Simulation (ECAS) in health-care education. Luckin's framework is still quite new, still developing, and has to my knowledge never been previously applied in the SBME field, but it may be useful in meeting the current challenges to the field. Additionally, its focus on informed design and interventions—that is, improving practice—is well in line with what is sought after within the SBME field, which contributes to its relevance.

The quote that introduced this chapter should give readers a rough idea of the intended theoretical position of this thesis, and particularly that of Luckin's Ecology of Resources framework. Understanding this quote will take you a long way, but not all the way, in understanding Luckin, and there are some particular gaps that I will do my best to fill in. In this chapter I will introduce the central components and ideas of the framework and explain my particular application of it.

Zone of proximal development and Vygotsky

> *. . . what a child is able to do with assistance today she will be able to do by herself tomorrow.* (Vygotsky, 1978, p. 87)

One of the key components of the EoR framework is an interpretation of the Zone of Proximal Development (ZPD), a concept introduced by Lev Vygotsky. There are multiple interpretations of ZPD, and some of them (e.g., Chaiklin, 2003) open for further development of Luckin's interpretation, something I will return to later on.

Vygotsky elaborates on the concept of ZPD when discussing issues in the psychological analysis of teaching (Vygotsky, 1978, pp. 79–91). His approach was partly a critique of contemporary conceptualizations drawing on analogies from botany and zoology (Luckin, 2010, p. 20) about the relation between small-scale learning and larger-scale changes, or development of higher-order thinking in individuals; he argued that development must be considered dependent on learning and not, for instance, determined by physiological maturation. It was important for him to differentiate between *elementary functions*, which were genetically inherited, unmediated, involuntary, and isolated, and *higher mental functions*, which were socially acquired, mediated by social meanings, voluntarily controlled, and linked in a broad system (Luckin, 2010, p. 39). In Chaiklin's (2003) reading of Vygotsky, he referred to developmental levels lasting somewhere between one and four years. These levels were characterized by level-specific structural relations between different mental functions. Contradictions between capabilities and the needs and demands of the sociocultural environment encourage development. Some of the individual's activities will be directed at a leading activity, which can contribute to development. The periods are historical, created in practice and material through interactions with others. The ZPD will be defined by the sociocultural environment in which the learner participates. It is principally possible to identify an objective ZPD for a given age and context and an individual ZPD defined by the distance between the learner's current abilities and the next developmental step. The ability to *imitate* in Vygotsky's use of the concept, is the foundation of the individual ZPD and relates to "everything that the child cannot do independently, but which he can be taught or which he can do with direction or cooperation or with the help of leading questions" (1934/1998b, p. 202).

Vygotsky suggested that "properly organized learning" (Luckin, 2010, p. 90)—that is, teaching—can result in development if it is directed at that which learners can achieve only in cooperation with a more able partner (MAP). We must therefore identify not only what learners are able to do alone, but also what they are able to do with support. He defines the ZPD as

> . . . *the distance between the actual developmental level as described by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers.* (Vygotsky, 1978, p. 86)

In Vygotsky's eyes development of higher-order functions has a social origin and is the result of interactions with a sociocultural environment where interpsychological interactions could be internalized and become intrapsychological. He argued that "it becomes an important concern of psychological research to show how external knowledge and abilities in children become internalized" (Luckin, 2010, p. 91). This internalization is by some referred to as *appropriation* or *mastery of tools* (Wertsch, 1998).

The appropriation of socially developed tools includes a move from spontaneous, private concepts and direct interaction based on direct sensory experience to interaction mediated by socio-historically developed tools. This appropriation changes the way we understand and interact in the world.

Supporting this move from the naïve and context-dependent actions to principled mediated actions is in a sense what good teaching can achieve.

Understanding Luckin's use of the ZPD concept

Luckin draws upon the concept of ZPD, but she does not necessarily continue directly in the trajectory of Vygotsky, in part in part due to the circumstance that Vygotsky died young and left parts unspecified. She tries to pull together conceptualizations of contexts, scaffolding, learner modeling, design, and the like. The aim of drawing upon the concept will to some extent define the interpretation, just as any tool can be used for different purposes and different users will highlight different characteristics. Luckin's aim seems to have been to develop a theoretically grounded framework for analysis and design, initially of educational software (e.g., Luckin, 1998, 1999) and later of technology-rich learning environments (e.g., Luckin 2010). Her contribution is an attempt to expand the analysis to include context, which she considers to be in education "undertheorized in the development of technology to support learning" (Luckin, 2010, p. 34).

Luckin thus begins her work with trying to conceptualize context by drawing upon work from geography, architecture, anthropology, psychology, education, and computer science. Some prominent influence comes from sociocultural perspectives represented by, among others, Michael Cole, Bonnie Nardi, Victor Kaptelinin, and James Wertsch, all of whom interpret Vygotsky. She ends up with a conceptualization of context as something:

> *. . . complex and local to a learner. It defines a person's subjective and objective experience of the world in a spatially and historically contingent manner . . . dynamic and associated with connections between people, things, locations and events . . . in a narrative that is driven by people's intentionality and motivations.* (Luckin, 2010, p. 18)

Technology can help make connections, and people can help give them meaning. Learners are exposed to a single context "that reflects their interactions with multiple people, artefacts and environments." Meaning is distributed among resources that offer "partial descriptions of the world" and that can act as "hooks for interactions in which action and meaning are built" (Luckin, 2010, p. 18). It is the learner's internalization of these interactions that is central.

When trying to "identify a theory of learning that is consistent with the previous discussions of context" (Luckin, 2010, p. 19), Luckin identifies the ZPD as being "the most compatible" (Luckin, 2010, p. 27).

She argues that development occurs as a result of interaction between the "individual and their sociocultural environment" (Luckin, 2010, p. 20) and that the conditions for and character of these interactions influence the development. The ZPD is viewed as a "crystallization of this internalization process" (Luckin, 2010, p. 20). Spontaneous conceptions, often unconscious, are contrasted with scientific concepts with which learners have to struggle in order to make them their own and in this sense "instruction or learning pulls along development" and creates the basis for new, spontaneous concepts (Luckin, 2010, p. 21). Instruction must be directed, however, at what learners cannot achieve on their own. The ZPD is created by "instructional interactions" that "focus the dialogue" between learner and MAP. The learner is thus enabled to "reflect upon this dialogue and reformulate it into their own thought". And so, "provision of the correct environment" and creating interactions become central issues for designers (Luckin, 2010, p. 21).

Luckin's framework is focused on supporting learners wherever possible. It seems to be not innately focused on supporting the particular learning activities that will bring the learner to the next developmental level in a Vygotskian sense. It is also unclear to what extent it helps us understand the "objective" ZPD in Chaiklin's terms.

Luckin argues that "too much is left unspecified" in Vygotsky's definition (Luckin, 2010, p. 27). For instance, how do we identify the learner's ability level, and what assistance should be offered? (Luckin, 2010, p. 20). And it is against this background that she creates the concept of the Zone of Collaboration.

Learning in a Zone of Collaboration

Foundations of the Zone of Collaboration

The Zone of Collaboration is Luckin's interpretation or development of Vygotsky's zone of proximal development. In order to achieve this she draws upon previous work done in line with the ZPD.

One is an interpretation of the ZPD done by Wertsch (1984), in which he introduces some concepts to clarify aspects of the ZPD. These include situation definition, which refers to how multiple individuals construct and represent the context for their activity. Intersubjectivity refers to when multiple participants share a situation definition and know that they share it. Development then is viewed as "a fundamental situation redefinition" (Luckin, 2010, p. 27). Semiotic mediation is a means of "communication and negotiation to support intersubjectivity and situation redefinition" (Luckin, 2010, p. 27).

Another interpretation is the work on scaffolding introduced by Wood and colleagues (Wood, Bruner, & Ross, 1976; Wood, Shadbolt, Reichgelt, Wood & Paskiewicz, 1992) and picked up by, for instance, Mercer (1995) and Palinscar, Brown and Compione (1993). It is introduced by Luckin as tutorial assistance that involves hints, graded help, or "simplification of the learner's role" (Luckin, 2010, p. 26) based on the needs of the learner as identified through instructional interactions. Central issues are related to how much help should be provided, what help is appropriate given the subject, and how much effort learners should invest before receiving help. It is described as "guided construction of knowledge" and may require "careful analysis of the domain" (Luckin, 2010, p. 27). MAPs play a central role in the construction of interactions and context.

Aspects of the Zone of Collaboration

The Zone of Collaboration is Luckin's "interpretation of the ZPD, which explores the relationship between the identification of a learner's collaborative capability and the specification of the assistance that needs to be offered to the learner in order for them to succeed at a particular task" (Luckin, 2010, p. 28). It is concerned with "scaffolding learning through and in the ZPD" (Luckin, 2010, p. 28). One thing to note here is that whereas Vygotsky was focused on major developmental steps, Luckin's interpretation is focused on smaller-scale learning.

The learner's context, her zone of collaboration, is made up of two zones circling learner(s) and more able partner(s). This is illustrated in Figure 1. The outermost zone she calls the Zone of Available Assistance and includes all those resources that are potentially useful for a learner and that are available to her at a given moment. Consideration of the learner's interactions with these resources makes a starting point for identifying opportunities for scaffolding intended to support the construction of a Zone of Proximal Adjustment. This latter zone includes those resources that are particularly helpful for a learner at a given point of time.

Learning in the Zone of Collaboration is a movement from being able with assistance toward being able without assistance; it is about internalization of interactions in a sociocultural context and of becoming an autonomous wielder of contextual resources. It is about more able partners identifying and providing for learner needs made explicit through interaction or negotiation. I will use an example from radiology, a recurring subject in this thesis, to illustrate the Zone of Collaboration.

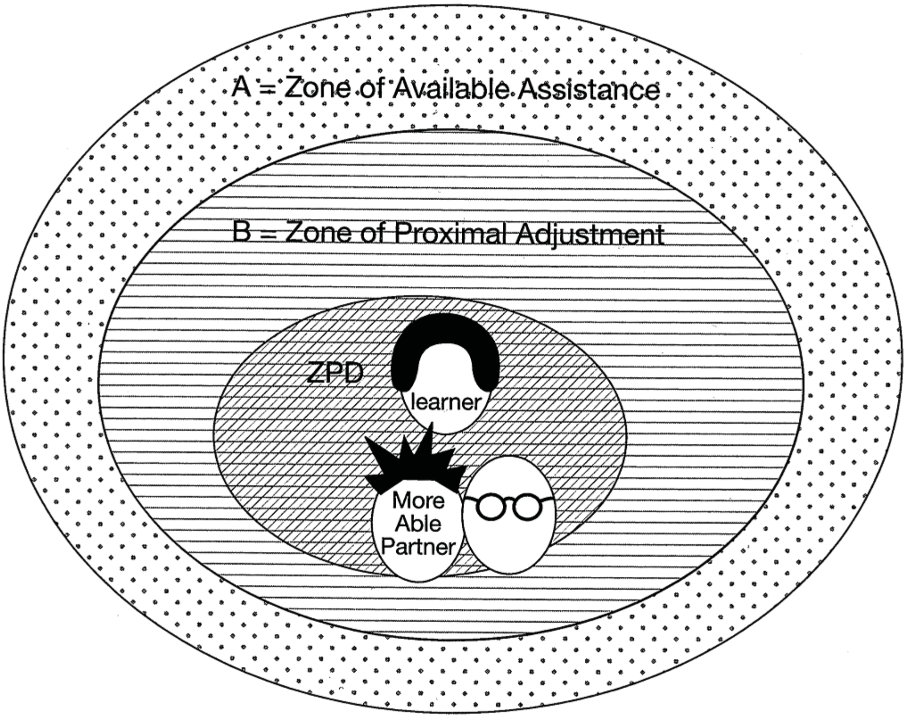

Figure 1. The Zone of Collaboration. Reprinted with permission from Luckin (2010), *Re-designing learning contexts* (p. 29, figure 2.1), London: Routledge.

Zone of Collaboration Exemplified by a Radiological Challenge

We can think of a radiology candidate performing a virtual examination of a patient's jaw; she first needs a lot of guidance and eventually is able to perform it by herself. In trying to perform an examination, the student will draw upon a number of resources available in her Zone of Available Assistance, which comprises "the variety of resources within a learner's world that could provide different qualities and quantities of assistance and that may be available to the learner at a particular point of time" (Luckin, 2010, p. 28). The student will "engage with partial and distributed descriptions of the world" (Luckin, 2010, p. 48). In all instances, some resources will be more "appropriate for learner needs" (Luckin, 2010, p. 28), and this subset of more useful resources is ideally drawn together to constitute the Zone of Proximal Adjustment (ZPA). The ZPA is constructed through interaction, a negotiation, where the learner "express[es] their current understanding and learning needs" and the MAP tries to "identify and possibly introduce . . . assistance", that is, to provide dynamic support (Luckin, 2010, p. 28). For instance, some resources that may be of particular interest for the student in our case would be dental anatomy and principles of radiological analysis, features of the radiology simulator, and the like. The role of the MAP includes "to scaffold the learner's construction of a narrative that makes sense of the meanings distributed amongst these resources" (Luckin, 2010, p. 48). This can mean providing "particular help interventions" (Luckin, 2010, p. 48) during task solving, for example, by focusing attention on particular resources (for instance, by asking relevant questions), by exemplifying their use, and so on. It can also involve "altering the complexity of the task or environment" (Luckin, 2010, p. 48.). A central idea is to give the student no more support than needed for her to solve the problem on her own. The scaffolded interactions are internalized and lead to "increased independent capability and self-awareness" (Luckin, 2010, p. 48).

A few things should be noted about more able partners and scaffolding. First of all, the scaffolding offered to learners can be achieved by not only a teacher, but also by other resources that can act as more able partners, including, for instance, peers and technology. For a designer, a central objective is to create and support scaffolding in the learner's Zone of Collaboration. It is important to note that the design of technologies such as a simulator will impact interactions not only with the technology but also with other resources, such as peers in a collaborative context (Luckin, 2010, p. 74). This circumstance, noted also by other sociocultural researchers (e.g. Säljö, 2010), must be considered in the design of learning technologies and activities. Conversely, the wider context will impact interactions with the particular technology. This interaction between resources is a central element of Luckin's design approach.

For a beginner facing a challenge, identifying as well as using the relevant resources appropriately is the challenge. Radiography students, for example, need to know not only about the existence and relevance of principles of motion parallax; they need to know how they work and how they relate to and interact with other resources, such as anatomy. How does the representation of anatomical objects on two-dimensional X-ray images change based on the angle from which the image was taken? New resources will be alien to the student, but through acting or interacting with them, they can become more and more familiar and their application proficient. That which first had to be carried out on an intrapsychological or social level can later be carried out on an interpsychological level. Interactions become internalized. An overarching goal must be considered development to the extent that the learner becomes autonomous in relation to the sociocultural context in which the challenges arise. This is a central part of Vygotsky's legacy of the Zone of Proximal development, upon which Luckin expands. Learning requires support.

From Zone of Collaboration to Ecology of Resources Models

Luckin's concept of the Zone of Collaboration is the theoretical basis for constructing the Ecology of Resources models and thus central in the Ecology of Resources redesign framework. These models are the mediating form of representation that was mentioned in the quote introducing this theoretical chapter. What they mediate are the efforts to analyse or redesign technology-rich learning ecologies. The EoR is considered a way of "simplifying complexity" (Luckin, 2010, p. 166), is less abstract than the underlying theory, and tries to bridge the social scientist's goal of description and analysis and the computer scientist's aim to generate design (Luckin, 2010, p. 100.). It is "neither idealized nor intended to be a complete and faithful representation of the objective reality of a learner's context" (Luckin, 2010, p. 111).

When Luckin first introduces the Ecology of Resources model (Luckin, 2010, p. 90–96), her argument is as follows. At the center of the Ecology of Resources we have a learner, or a group of learners. Available to her is a "network of resources" (available assistance) called the Zone of Adjustment (Luckin, 2010, p. 90). The learner interacts directly with some resources and indirectly with others. The resources are categorized as a means to "help us identify them and the relationship they bear to the learner and to each other" (Luckin, 2010, p. 91). These resource categories include Knowledge and Skills, Tools and People, and Environment. This is illustrated in Figure 2.

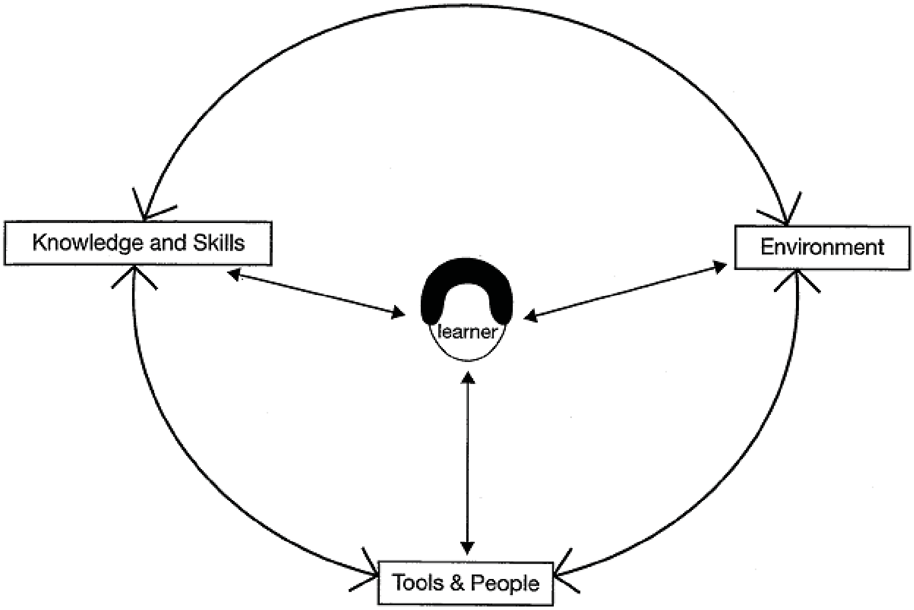

Figure 2. The resource elements in the Ecology of Resources. Reprinted with permission from Luckin (2010), *Re-designing learning contexts* (p. 93, figure 5.12), London: Routledge.

The Knowledge and Skills consist of the "stuff to be learnt" (Luckin, 2010, p. 91), which can be anything at all, but in formal education often is related to scientific concepts, such as for instance motion parallax, and skills, such as X-ray imaging in the particular context of this thesis. And of course concepts and skills may be intricately intertwined. Tools and People includes both technologies, such as a simulator or even books, and other participants (potential MAPs) such as peers or teachers. Finally the Environment includes "the location and surrounding environment with which the learner interacts" (Luckin, 2010, p. 91), such as a computer lab at a department. These categories of resources often have existing relationships and are mutually influencing—that is, what you learn, where you learn, with whom and with what tools. These relationships need to be identified, understood, and potentially explained to the learner. Relationships within resources can be of different types, including one of influence, one where one is a component of another, one that is a type of another, and social relationships (Luckin, 2010, p. 95).

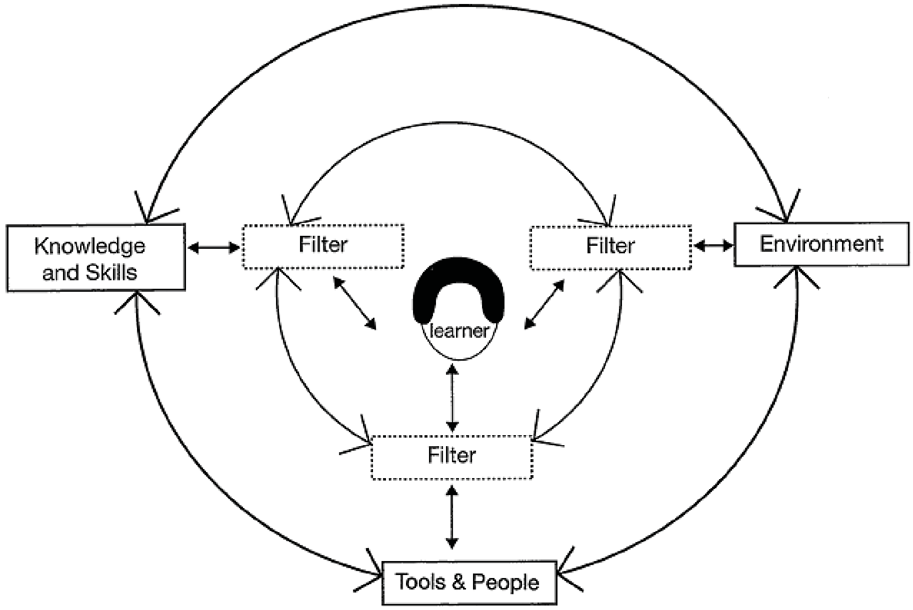

Figure 3. The Ecology of Resources elements and their filters. Adapted with permission from Luckin (2010), *Re-designing learning contexts* (p. 94, figure 5.13), London: Routledge.

The learner's interaction with resources in the ecology is filtered "by the actions of others" (Luckin, 2010, p. 93). Interaction with the subject matter can be filtered by curricula developed specifically for a certain population. Interaction with the physical location can be filtered by organizational factors like schedules and access. Interaction with a teacher can be filtered by, for instance, presence, relationships, and peers. Interaction with tools can be filtered by, for instance, access and peers. As with the resources, the filters can have existing relationships and have a mutual influence. Features of a simulator in combination with free collaboration may, as we shall see, interact. Also, the relationship between filters and resources may be mutually influencing. The filters are integrated in Luckin's final general figure, Figure 3.

The strength of relationships between resources, resource categories, and filters may vary. All elements, resources, or filters, including the learner, have their own history, which may impact the interactions. The general role for the MAPs is to support the construction of a ZPA, that is, to ensure that “an optimal subset of resources” (Luckin, 2010, p. 95) is drawn together based on the learner’s needs. The principles for how this is achieved through learner-MAP interaction have been discussed in the previous section. The role of the MAP can be fulfilled technologically, however, or by a peer with support. Learning within the Ecology of Resources is an effect of internalization of the interactions with the ZPA.

EoR as a Framework for Research

Luckin elaborates the ecology of resources as a framework for design or redesign of learning contexts, a theoretical foundation for improving particular learning contexts or activities. She does not discuss it as a framework for research, however. This outlook is a bit surprising given the current interest in design-based research (Andersson & Shattuck, 2012), and I find it likely that this is something that will be elaborated as the framework is further developed. The role of research in the redesign process is left out, and Luckin states that the framework is not prescriptive about the exact nature of how the steps are performed and on what grounds (Luckin, 2010, p. 118). This poses challenges for those, like me, who want to use the framework specifically for guiding research efforts.

Whereas there are similarities between Luckin’s redesign and research, there are important differences. Although this thesis needs to be grounded in, communicate with, and be useful for a research community, Luckin’s design framework is by necessity much more oriented to a particular practice. Whereas the outcomes of this thesis need to be generalizable, Luckin’s redesign outcomes do not. Using the ecology of resources framework for research will thus impact the *reasons for performing* an EoR analysis, from modeling and developing a particular practice to modeling and developing a general practice. It will change the *specification of focus* and identification of resources and filters. With a research approach, this will need to be a dialogue with previous research as much as it is with practice. Previous research must contribute to guiding the *fine-grained analysis* of resources and filters. The endeavor itself will also change from being particular to being (or intended as being) distributed over a research collective. It cannot end with the particular simulation practice. The outcomes will instead need to be both general and particular.

In my view, using Luckin’s EoR for research offers means both to unite a wide range of SBME research currently being carried out and to give it a theoretically grounded direction that makes it useful for practitioners as well as researchers. It could to some extent be compatible with the interest of SBME researchers in experimental methods, although it does strongly promote attention to process in addition to outcomes, which is well in line with current calls from the SBME field (Issenberg et al., 2010). It gives attention to technology as well as techniques for application, to a long-lasting investment in their continuous development and refinement.

The next chapter will explore the type of Ecology of Resources that collaborative ECAS in HCE constitutes grounded in a review of related research. Guided by this general type, the following chapter will begin to explore a particular ecology of a collaborative radiology ECAS. This will motivate new empirical contributions, the design of which is presented first, then followed by the outcomes. I end this thesis by discussing both the particular and the type and the particular ecologies.

Additional Concepts: Simulator, Simulation and ECAS

This thesis often uses the concept of Educational Computer-Assisted Simulation, abbreviated ECAS, to refer to a particular type of simulation. I suggest this concept as a way to support analysis of simulators that share important characteristics and to support limited generalizations among these.

In line with Gaba (2004) I consider the simulator to be, in the sense relevant to this context, a device that imitates (part of) a patient and “interacts appropriately with the actions taken by the simulation participant” (Gaba, 204, p. i2). Something is lacking in Gaba’s definition, however, as it is lacking in the often-cited *Oxford English Dictionary* definition, which states that simulation is a “technique of imitating the behaviour of some situation or process . . . by means of suitably analogous situation or apparatus” (OED online, 2006, Simulation. 1947. Retrieved 121203). And what is lacking is the process or activity that is enacted by the user and the simulator in intended interaction. It is possible to interact with a simulator without the user being immersed in any sense of this being an imitation of a real situation, for instance, when picking a simulator apart or just investigating its design. And so, as a means of distinguishing between the device and the process of intended user-simulator interaction, I call the former *simulator* and the latter *simulation*.

As discussed by, for instance, Gaba (2004), health-care simulators vary among several dimensions. One key dimension is the object or aim of the simulation, which can vary from, for instance, education, decision making, and research. It is reasonable to assume that the characteristics and outcome of the simulation vary significantly depending on objectives, and so it becomes relevant to be explicit about what sort of simulation is being discussed. This is why it includes the prefix *educational*. It is of course possible to distinguish among different types of educational purposes, such as learning skills, concepts, professionalism, and so on. I will return to this in chapter IV.

Another key dimension is the type of simulator technology, which may vary among, for instance, physical dummies and dolls, computer software, and virtual reality. Once again, it is reasonable to assume that the characteristics and outcome of the simulation vary significantly depending on the type of technology, and so it becomes relevant to be explicit about what type of simulator is being discussed. As a means to distinguish the particular type of simulator that is focused on in this thesis, the prefix of *computer-assisted* is added to Simulation. Again it is possible to distinguish between types of Computer-Assisted simulations, and I will return to this in chapter IV.

From this discussion emerges a concept that is used frequently in this thesis, Educational Computer-Assisted Simulations. It is used to refer to simulations that share the general object and general technology with the Radiology Simulator studied in this thesis.

III. Analysis of collaborative health care ECAS context

Grounding the ECAS EoR analysis in prior research

I have argued that in order for the Ecology of Resources (EoR) framework to be a useful tool for researching a type of ecology and its application, redesign efforts must include an analysis of related research. This means that a review of existing research is necessary to enable informed analysis and contributions to the research field. This thesis explores collaborative ECAS in health care education ecology. The problem, of course, is that little research exists with this very specific focus (which might otherwise cause it be considered an unsuitable topic for a thesis), and so, in addition to reviewing the existing research on my particular topic, I must draw upon research in related fields.

One way of branching out into related fields is to focus on separate parts of the ecology, e.g., collaborative training with computers; simulation-assisted learning in health care education; and ECAS training in higher education. Therefore, due to the paucity of research in my selected field, the review of previous research will be limited to a selection of existing research fields that explore related issues.

The review that follows will begin by gathering some experiences from research on computer-supported collaborative learning (CSCL) and simulation-based medical education (SBME) that explore issues related to the ecology under study. The questions we bring into this review are:

1) What are the key filters that may mediate the learner's interaction with tools, people, knowledge and skills, and environment, as described in previous research within the selected review samples?

2) What is the impact of these filters on interaction and learning?

This review is conducted in two steps. First, a selection of existing reviews conducted by others in the established and related fields of CSCL and SBME will be analyzed. Second, a new review will be conducted to complement these selections with more detailed research in a yet-to-be established subfield that is more closely linked to my specific research question. The outcome is a selection of relevant articles that will guide the analysis of collaborative ECAS in health care education ecology.

Experiences from research SBME

Reasons for the emergence of research on simulation-based learning were discussed in the introductory chapter. It was also argued that simulation-based learning most likely began in the early 1960s and started to pick up speed in the 1980s, according to Bradley (2006). However, a determination of a starting point would necessarily depend on what criteria are used to define the concept of simulation. The criteria vary in the literature from very broad to less broad.

Prior research on "high-fidelity" medical simulations is presented in the universally cited review by Issenberg et al. (2005). In using this high-fidelity definition, static artifacts such as task trainers are excluded in favor of "(a) realistic, three-dimensional procedural simulators; (b) interactive simulators, e.g. responds to prompts, probes and procedures; and (c) virtual reality simulators" (Issenberg et al., 2005, p. 15).

Using this definition, Issenberg et al. decided to seek out articles that presented empirical comparative research on simulation being used as an educational intervention in which outcome was measured quantitatively. According to these criteria, research began in 1969 and is very scant until the late 1990s and early 2000s.

This trend is illustrated in Figure 4, which presents Issenberg et al.'s selection of the number of review articles they reviewed per year.

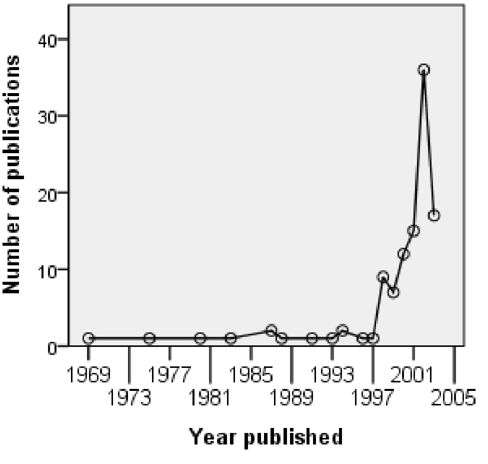

Figure 4. Publication year for articles reviewed by Issenberg et al. (2005).

The features and uses identified in the literature review by Issenberg et al. (2005), and which are stated to "...represent an ideal set of educational circumstances..." (Issenberg et al., 2005, p. 24) are listed below.

1) Feedback during or after sessions, provided by the simulator or by an instructor.
2) Repetitive practice focused on skill improvement.
3) Curriculum integration, so that simulation is not an extra-ordinary or optional activity.
4) Range of difficulty level, so that learners can start with basic skill levels and progressively move to more difficult challenges.
5) Multiple learning strategies, meaning variations in the number of participants and teacher presence.
6) Clinical variation in the ailments or the patients that are being simulated.
7) Controlled or safe environment, as an innate feature of simulations.
8) Individualized learning with active involvement in experiences that can be tailored to individual needs and be reproduced.
9) Benchmarks of learner performance in relation to defined goals.
10) Simulator validity or realism in representing a complex reality.

One criticism must be raised against the arguments provided by Issenberg et al. (2005): the features and uses identified are not always the result of scientific experimentation. They are issues discussed in articles that employ experimentation, often comparing simulation with non-simulation, but the features themselves have not always been subject to experimentation. Why include only comparative experimental research if one is not exclusively interested in these experimental comparisons? This is relevant in relation to the methodological aims of the Best Evidence Medical Education collaboration (BEME) which funded the review. It is also noteworthy that while comparative experimental research is strongly promoted in this review, the authors argue that "Qualitative studies also have a place on the high-fidelity research agenda in medical education," just not in their review that aimed "to cover the scientific literature comprehensively, with detail and rigor" (Issenberg et al., 2005, p. 25). This is a manifestation of an uncontemplated bias against the traditional experimental research that is prevalent in much SBME research.

Theoretical discussion is absent in the review, which contrasts sharply to the reviews in the field of CSCL presented in the next section. The diverse foundation of research in the field, noted by Bradley and Postlethwaite (2003), makes this an interesting state of affairs. It also contributes to shrouding the implications of the results. For instance, while it is reasonable to think that feedback can be a great support in a learning process, the opposite is also possible. It must come down to how and what feedback is delivered. And in order to understand that, theory would be helpful.

"A critical review of simulation-based medical education research"

A follow-up review written by the same authors intended to complement the original review with research produced between 2003 and 2009. It is intended to be selective and critical rather than exhaustive (McGaghie, Issenberg, Petrusa & Scalese, p. 51). Beginning with a revised list of "12 features and best practices, which every SBME teacher should know in order to use medical simulation to maximum educational benefit" (McGaghie et al., p. 51), the authors use selected literature to give these 12 features more informed consideration, and also to open avenues for further research. Some items are retained from the previous list and some are new. These are best thought of as terms and concepts that the authors consider to be of general importance to those involved in SBME research, rather than a guide to features and uses that have been proven to work given certain circumstances. The following is a summary of these twelve concepts.

1. Feedback. The authors stated that key issues were varieties, sources, and impact, and that formative feedback should be focused in order to improve performance (McGaghie et al., 2010, p. 54). The discussion on debriefing drew upon the works of Rudolph and colleagues (Rudolph, Simon, Raemer & Eppich, 2008), in which they described a few important components of debriefing. These components involved performance gaps being noted, information about the gaps being given, the causes of the gaps, and support in removing the gap being explored (McGaghie et al., 2010, p. 54). From Salas et al. (2008) they gathered twelve principles related to debriefing after team performances. They noted that debriefs should be diagnostic and take place in a supportive environment where members feel comfortable. Debriefings should be led by trained leaders who are supported by objective indicators of performance. The leaders should highlight a few critical incidents, describing and focusing on the interactions and processes with some attention to outcomes and giving individual as well as team-oriented feedback. They recommended that this process take place soon after performance and that the debriefing be documented, in order to support future debriefings (McGaghie et al., 2010, p. 54). Research has yet to guide

the choice of the model for feedback and the amount (McGaghie et al., 2010, p. 55).

2. Deliberate practice, a new addition to the list, was described as "an important property of powerful SBME interventions" (McGaghie et al., 2010, p. 55). It was based on K.A. Ericsson's work, and "grounded in information processing and behavioral theories" (McGaghie et al., 2010, p. 55) on expertise. The authors listed a number of requirements for deliberate practice including "highly motivated learners with good concentration...enagement with a well-defined learning objective or task, at an appropriate level of difficulty, with focused repetitive practice, that leads to rigorous, precise measurements, that yield informative feedback from educational sources....and where trainees also monitor their learning experiences and correct strategies, errors and levels of understanding, engage in more DP, and continue with evaluation to reach a mastery standard, and then advance to another task or unit" (McGaghie et al., 2010, p. 55). Research promoting the use of deliberate practice was stated to have been included in the original review, and was also found in the complemented review.

3. Curriculum integration. The authors added the concept that simulation "must be planned, scheduled, required and carried out thoughtfully in a wider medical curriculum" (McGaghie et al., 2010, p. 55) and that it should be thought of only as a complement to clinical training. Which combination of modalities is optimal and how to mix them has yet to be established (McGaghie et al., 2010, p. 55).

4. Outcome measurement. Performance measurements were deemed needed to "reach valid decisions, judgments or inferences about trainees" (McGaghie et al., 2010, p. 56). Observational ratings were often used but were considered unreliable. Performance on tests or on reports was considered more reliable. Haptic sensors were envisioned as a future possibility (McGaghie et al., 2010, p. 56).

5. Simulation fidelity. Matching simulation technology and educational goals was considered central. Some simulation modalities are more likely to match educational goals than others.

6. Skill acquisition and maintenance was claimed to be the modal learning goal in SBME research (McGaghie et al., 2010, p. 57). The implications of this were not discussed.

7. Mastery learning, grounded in the works of Benjamin Bloom, was suggested as a potentially beneficial approach to SBME learning, though little evidence has been put forth in favor of it (McGaghie et al., 2010, p. 57). The basic premise is to sequence a learning objective in units varied by difficulty levels and have all students start with the easiest unit and after mastering it, continue to the next level of difficulty.

8. Transfer to practice is important, but difficult to evaluate. Some examples of studies supporting the claim that simulation training can transfer to clinical practice were presented (McGaghie et al., 2010, p. 58).

9. Team training. Again citing evidence outside the field of simulation, the authors argued that communication, shared goals, role clarity, leadership, coordination, mutual respect, situation awareness, and debriefing are important issues for health care teams. Team training has “recently achieved recognition as an important educational goal” (McGaghie et al., 2010, p. 58). While the interest of this thesis was not group training for the sake of developing the group but rather group training for the sake of enhancing individual learning, it is possible that some lessons may be learnt from this research. According to Salas et al. (2008), who was referred to by the authors, there are eight important principles of team training. He suggested that it is important to:

> *. . . identify critical teamwork competencies and use these as a focus for training content; emphasise teamwork over task work, design teamwork to improve team processes; . . . let the team-based learning outcomes desired, and organizational resources, guide the process; task exposure is not enough . . . provide guided hands-on practice; . . . ensure training relevance to transfer environment; feedback matters. . . it must be descriptive, timely and relevant; . . . evaluate clinical outcomes, learning, and behaviours on the job, and reinforce desired teamwork behaviours . . . sustain through coaching and performance evaluation* (McGaghie et al., 2010, p. 58)

10. High-stakes testing, or testing where the result will impact participants’ careers, is an area of interest for simulation research. It does require a lot of simulation, and it is not of interest in this review.

11. Instructor training in supporting learners during simulation is demanding but “shrouded in mystery” (McGaghie et al., 2010, p. 59) as research is lacking. The authors argued that “effective SBME is not easy or intuitive; clinical experience alone is not a proxy for simulation instructor effectiveness, and simulation instructors and learners need not be from the same health care profession” (McGaghie et al., 2010, p. 59).

12. Educational and professional context was stated to be of the utmost importance for learning outcomes, more important than the “technical

features of simulation devices" (McGaghie et al., 2010, p. 60). Important key issues were "[f]aculty expertise in training with these devices, their motivation to succeed, the local reward system, and institutional support." The need for realism in simulation training and evaluation was restated, and it was argued that the implementation of something new would change the context as a whole (McGaghie et al., 2010, p. 60).

Summary

Taken together, the massively influential literature reviews performed by the BEME team have given us insights into what is and what has been occupying researchers on health care simulation. Figure 5 illustrates the lessons learned from the SBME field regarding resources and filters that may impact the interactive process and learning outcomes of collaborative ECAS in health care education (HCE).

This suggests that in order to understand the outcome of simulation training, attention needs be paid to some simulation features, such as feedback, progression, repeatability, clinical variation, instructors, realism, and fidelity and validity. It is also important to focus some attention on the ways that simulation is used, such as applying it to learning strategy, using it as a deliberate practice, using it in mastery learning or collaborative learning, using it for evaluative purposes such as high-stakes testing, and using it with or without an instructor. The learning objective, be it skill acquisition, conceptual development, professionalism, or team training, also deserves attention. Finally, some other aspects may also need to be considered, such as its place in relation to an overall curriculum, and to clinical practice (validity). The specifics on how these resources and filters may impact the interactive process and learning outcomes of collaborative ECAS in HCE training, and thus how they can be supported, are empirical questions that remain to be investigated.

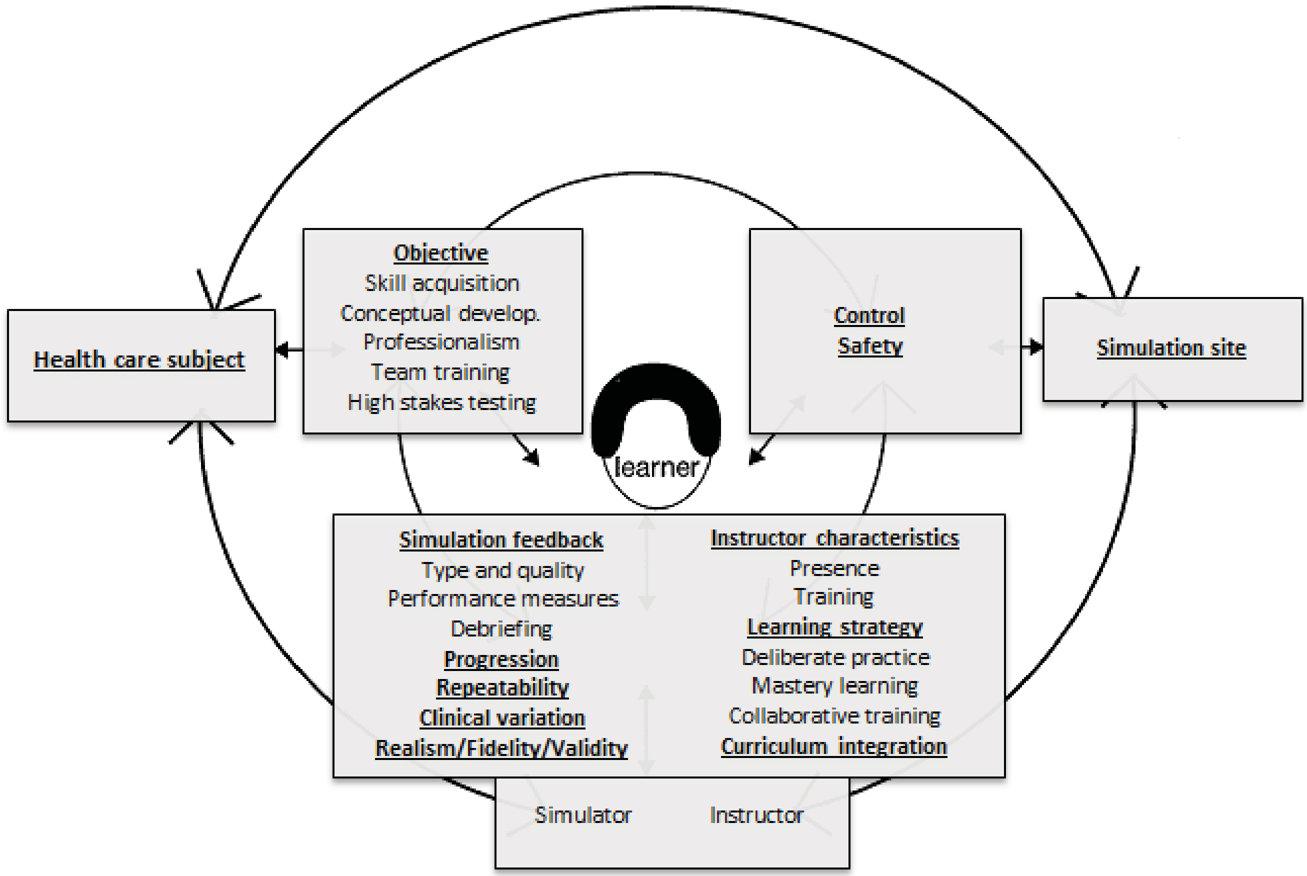

Figure 5. Outcomes of the SBME review from an Ecology of Resources perspective.
Adapted with permission from Luckin (2010), *Re-designing learning contexts* (p.94, figure 5.13), London: Routledge.

Experiences from CSCL

> *Computer-supported collaborative learning (CSCL) is an emerging branch of the learning sciences concerned with studying how people can learn together with the help of computers.* (Stahl, Koschmann & Suthers, 2006, p. 409)

Computer-supported collaborative learning is a research field focused on how computers can and do support learning in groups. Its overarching aim is to enhance learning through computer-supported collaboration. In order to achieve this, researchers in the field are attempting to understand learning during computer-supported collaboration in order to enhance existing support and develop new support.

CSCL is not limited to any particular subject, level of education, or specific hardware or software. However, while ubiquitous computer support, such as tables visualizing distribution of a word within a group, is represented within CSCL, one can say that PC software is the typical type of support. CSCL includes activities performed facing a computer as well as activities mediated through a computer such as online distance education. Crook would also include interactions around computers and interactions related to computer applications (Crook, 1994).

This makes CSCL relevant as a potential source for informing an Ecology of Resources analysis of collaborative ECAS in HCE training.

The evolution of research on computer-supported collaborative learning

This revisit of CSCL research is based on one classic review from the early days of CSCL (Dillenbourg et al., 1996) and one more recent review (Dillenbourg et al., 2009), which discuss the evolution of research on collaborative learning and computer-supported collaborative learning, respectively. I will focus here on the outcomes and try not dwell too much on the theoretical issues discussed within the field.

Three ages of CSCL

In 2009, Dillenbourg, Järvelä and Fischer (2009) identified three ages of CSCL research. The first age (1990–1995) included the establishment of CSCL and the conclusions that "collaborative learning results from the effort necessary for co-construction of a shared understanding" and that "productive social interactions can be engineered" (Dillenbourg et al., 2009, p. 4). The second age (1995–2005) focused on the engineering of social interactions, and the third age (2005–the present) integrates activities into educational contexts that include both collaborative and non-collaborative, technology enhanced and non-technology enhanced activities. The role of the teacher seems to have been clarified.

CSCL research can also be understood in relation to the questions that are being answered. Dillenbourg et al. (1996) identified three paradigms that could be ordered chronologically but to some extent also exist simultaneously.

The effect paradigm focused on the question of whether collaborative learning is more efficient than learning alone. Researchers often measured individuals in a traditional, experimental way, first when working in groups, and then when working alone. The results were somewhat contradictory, but more often than not collaborators outperformed individual learners. Dillenbourg et al. (1996) interpreted this as though collaboration in itself is not more or less efficient than non-collaboratoin, but instead that it works under certain conditions and that we need to identify these conditions.

The conditions paradigm focused on identifying the conditions under which collaborative learning is efficient. Experiments varied conditions such as group composition, task features, context of collaboration, and the technological medium. Group composition included group size, gender, and other member differences.

Group member differences, or heterogeneity, with respect to domain expertise, general intellectual development, or social status, was studied within the conditions paradigm. Both socio-constructivists and socio-cultural perspectives were applied. The former was interested in differing perspectives among equals, the latter in differing levels of skill. Finding a good amount of difference was one key issue, because when the difference was too small or too big there was little productive interaction.

Group size impacted heterogeneity, and closed groups, smaller groups, and even pairs were found to be preferable according to Dillenbourg et al. (1996). Individual prerequisites also impacted collaboration. Very young children may not benefit as much as older children. In peer-tutoring situations for children, the tutor must be skilled at the task, be able to assess whether mistakes are made because of instructions or because of the task. The learner must be able to reflect upon his or her own performance. Task features impact collaboration and learning. Some tasks do not easily lend themselves to collaboration, such as those where the involved processes are hard to verbalize. The tasks should not be purely procedural and should involve conceptual understanding.

These variables interact in a complex manner. For instance, how groups should be composed is impacted by the material to be learned and the tasks involved.

The interactions paradigm responded to the issue by exploring interactions between the variables. The question of what kinds of conditions create effective collaboration was split into two questions: under what kinds of conditions do specific interactions occur, and what effect do these interactions have? For instance, moderately heterogeneous groups seem to promote the interactive pattern of explanation. Providing elaborate explanations seems to promote learning. Receiving explanations is not always helpful, which may be due to the explainer's failure to give the right amount of explanation at the right time in terms that are directly graspable by the explainee. At the same time, providing an unexplained answer is not beneficial for either the explainer or the explainee. Control over the learning experience, in the sense of being explicitly included in the problem solving process, is more beneficial than participating in a successful solution without being in control. Some studies showed that this tended to happen more often in teacher-student cases than in student-student cases. Also, argumentation, negotiation, and mutual regulation "have been shown to facilitate learning" (Dillenbourg et al., 2009, p. 6).

At the end of their review, Dillenbourg et al. (1996) called for more specific and local research and asked whether research tools like conversation analysis, which are focused on language, can contribute advancing the field.

Since then, CSCL researchers seem to have given increased attention to the details of verbal interaction supported, for example, by psycholinguistics and guided by the question of how learners build shared knowledge (Dillenbourg et al., 2009). The process of collaboration became at least as interesting as the outcome. The effort required to reach shared understanding, "the intensity of the interactions required for detecting and identifying misunderstanding" (Dillenbourg et al., 2009, p. 7) was deemed important. However, students never build fully shared conceptions, and they infrequently share knowledge after training.

Experiences of conditions and interaction-oriented research led to the development of different tools for designing productive interactions. This included semi-structured communication tools such as sentence openers that provide participants with predefined expressions of questions, e.g., "Can you please explain...." The effect of this type of support was "rather poor" (Dillenbourg et al., 2009, p. 8). It also included microscripts that prompt participants to focus on something that is relevant in a particular moment of the process, such as providing counter-evidence. In contrast, macroscripts support group creation and the sequencing of activities. For instance, the Jigsaw (Aronson, Blaney, Stephan, Sikes, & Snapp, 1978) and the Arguegraph (Jermann & Dillenbourg, 1999) coupled students with diverging perspectives or opinions in order to increase the effort required to reach mutual understanding. The scripts seem to have rendered more positive outcomes and illustrate how support for productive interactions can be designed.

Some challenges emerge, however, regarding finding the appropriate level of support, adjusting it, and timing it appropriately. This can be achieved in part by supporting learners or teachers in their regulation of the activity, for example, by providing information about interaction patterns, contribution ratios, and other information. This can be partly automated.

Other lessons from CSCL that may be relevant to SBME research include the lesson that “Media effectiveness is a myth” (Dillenbourg et al., 2009, p. 6), and that it has been demonstrated time and again that the technological medium in itself does not produce a given outcome but, instead, that positive outcomes are decided by the conditions of use. In addition, a “greater resemblance to face-to-face interactions is not necessarily better” (Dillenbourg et al., 2009, p. 6). This is not to say that the medium has no impact on the process, as it clearly does.

In the early days of educational technology a guiding principle was “adaptation of instruction to individual needs” (Dillenbourg et al., 2009, p. 5). It has since moved from focusing on learner-system interactions toward the kind of social interaction that “balances out less individualization” (Dillenbourg et al., 2009, p. 5).

Motivation has emerged as a variable that may require more research. Dillenbourg et al. write that “the regulation of motivation and emotion at both the individual and group levels is critical for successful collaboration” and that it “reflects the social and cultural environment (Järvelä & Volet, 2004)” rather than being just something strictly individual and given (Dillenbourg et al., 2009, p. 10).

CSCL also has implications for the role of the teacher. The expression “from the sage on the stage to the guide on the side” (Dillenbourg et al., 2009, p. 14) reflects the focus of the research community on the interactions among peers. During collaborative learning sessions, classic teacher-led instruction is less useful in promoting intensive interactions among peers. However, this new role is not less important and seems to receive an increasing amount of appreciation in the third age of CSCL research (Dillenbourg et al., 2009) in line with the development of the concept of "orchestration." This refers to "the process of productively coordinating supportive interventions across multiple learning activities occurring at multiple social levels" (Dillenbourg et al., 2009, p. 12). This concept also clearly illustrates communities' increasing interest in viewing collaborative activities in a context of multiple activities which may or may not be collaborative or computer-supported. The teacher performs the orchestration with the help of scaffolds. Designing these scaffolds becomes an issue for the CSCL community, much in the same way that Luckin's redesign often aims at helping the more able partner (MAP) help the learner.

In practice, CSCL research moves between small-scale, face-to-face collaboration and large-scale online collaboration. Contexts vary from formal to informal, and subjects from children to adults. Research moves between quantitative experiments and ethnography. Theoretically, it moves between individual and collective constructivist perspectives. This has and will continue to cause entanglements in the empirical research base.

Summary

This review of CSCL research gives us a good illustration of what is and has been occupying CSCL researchers. Figure 6 illustrates the lessons learned from the CSCL field regarding resources and filters that may impact the interactive process and learning outcomes of collaborative ECAS in HCE.

These filters include: condition scaffolds or macroscripts related to, for instance, group composition (subject competence, general competence, gender, and social status). Process scaffolds or microscripts encourage productive interactions. Also task features, context of collaboration and motivation. It is, of course, possible to discuss in more detail exactly how these filters could impact collaboration in our radiology case. But, as noted already by Dillenbourg et al. (1996), generalizing from very different contexts must be done with care, so we will study these filters in context.

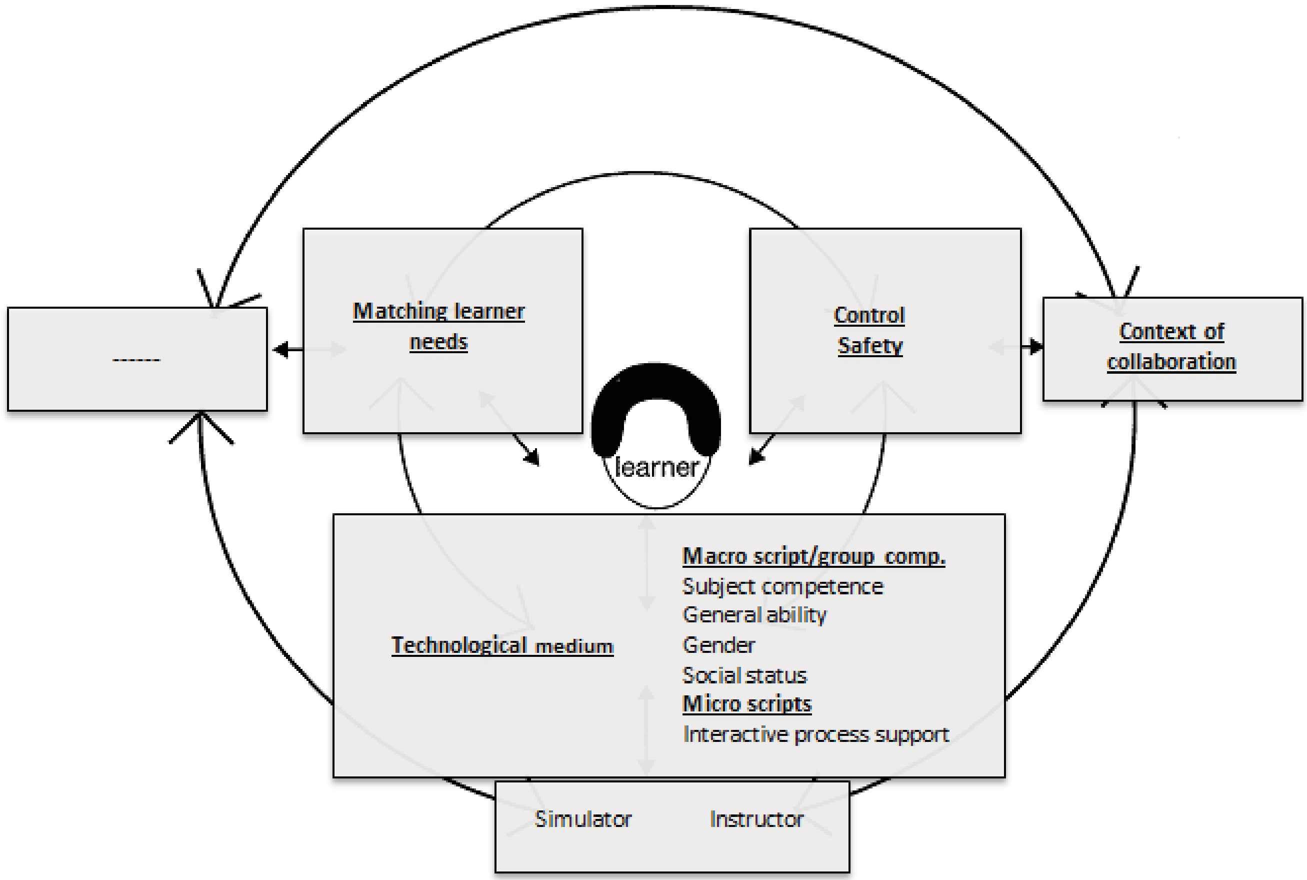

Figure 6. Outcomes of the CSCL review from an Ecology of Resources perspective.
Adapted with permission from Luckin (2010), *Re-designing learning contexts* (p.94, figure 5.13), London: Routledge.

Review of research on ECAS in higher education – context, interactions and outcomes

Because this thesis is focused on a particular type of health care simulation, collaborative ECAS, prior research on this topic would be very helpful. What does previous empirical research on collaborative radiological ECAS say about resources, filters, and the relationships between them, as well as peer interactions and learning outcomes? It has very little to say, because the research base is practically non-existent. However, widening the search from radiology to higher education results in some relevant sources. Since I have, during my years researching this topic, not been able to find a review with this particular focus, I have conducted one myself.

A Web of Knowledge review

I used the search engine, Web of Knowledge (WoK), and constructed the object of the inquiry as: empirical research on computer simulations in higher education focusing on the relation between context (resources and filters) and learning process learning and outcomes. The search was limited to English journal articles from 1985 onward in order to capture the previously noted rise in SBME research at the end of the 1980s. The end date was May 2012. The WoK databases included were SCI-EXPANDED, SSCI, and A&HCI.

In order to capture articles studying relevant simulations, previously suggested typologies of simulations were used (Gillaume 2007; Alinier 2007). Variations on the terms screen-based, virtual reality, computer simulation, computer based, software simulation, and personal computer were included. Explicitly excluded were articles focusing on other types of simulations, such as role playing, simulated patients, standardized patients, patient management problems, and full body mannequins.

No appropriate way was identified for limiting the initial search to higher education, empirical research, or focus on context, and thus the initial search in Web of Knowledge terms was the following:

TS=(educati* AND simulat* AND learn*) AND TS=(vr OR "virtual reality" OR "virtual-reality" OR "screen-based" OR "screen based" OR "computer simulat*" OR pc OR "personal computer" OR "computer-based" OR "software simulation" OR multimedia) NOT TS=("role-play" OR "role play" OR "simulated patient" OR "standardized patient" OR "patient management problems" OR "full body" OR mannequin)

Refined by: Document Type=(ARTICLE) AND Languages=(ENGLISH) Databases=SCI-EXPANDED, SSCI, A&HCI Timespan=1985-2012

This search generated 588 hits. These were manually filtered to compensate for the flaws just mentioned, meaning that the abstracts of all hits were read and those that could not be disqualified on the basis of information from the abstracts were selected. This left me with 71 articles. After reading these texts in full, a total of 36 articles remained that were deemed to fulfill the criteria mentioned above ranging from 1996 to 2011.

The content was summarized in a worksheet and included Authors, Year, Title, Journal, DOI, Citations, Subject, Simulator, Usage, Population, Sample, Questions, Method, Measures, Results, Conclusions, Comments, Theory, and Concepts.

Results

Themes common to the articles were identified in the process of reading and categorization. The themes included 1) impact of support during simulation, including human resources in terms of peers and teacher presence and different kinds of scaffolds; 2) impact of participant characteristics, including competence and more generic traits; 3) impact of the simulations' relation to other activities; and 4) impact of simulation characteristics. The following discussion of the articles will be related to these four themes.

The typical article was on medicine (19) and particularly about laparoscopy. Other medical subjects included endoscopy, endovascular surgery, intravenous cannulation, general surgery, oncology, radiotherapy, and urology. The typical science article (7) was on physics, and chemistry and genetics were also included. Also identified were social science (7) and simulations about business, teaching, statistics, and informatics.
A total of 19 unique journals were represented and in only one case did a journal have more than 3 hits: Computers & Education (11). Seventeen articles lacked explicit theoretical discussion, and 15 of these focused on medicine.

Article	Sample	Subject	Method	Conclusions
1) Impact of support during simulation				
Hmelo…(1999)	36 1st-year med. school students	Medicine: Diagnosis	Experiment 2-3h	Contextualized questions are helpful, however instructor training is needed.
Van sickle…(2007)	32 science students	Medicine: Laparoscopy	Experiment. Qualitative. ~20m	The type and quality of feedback impact development.
Yeh (2004)	149 teacher training students	Education: Teaching skills	Experiment. ~2h.	Support for mindful learning can be useful.
Nihalani…(2011)	127 university students	Social Science: Computer networks	Experiment. ~15min	Collaborative training is more beneficial with more prior knowledge.
de Leng…(2009)	47 4th-year med. school students	Medicine: Diagnosis	Experiment. Surv. Logs.	Degree of elaboration is the same for individual and collaborative training.
Dubrowski…(2006)	108 undergraduate med. schoolstudents	Medicine: Wound closure	Experiment 1h (2d)	The teacher-per-student ratio impacts development.

2) Impact of participant characteristics				
Brown… (2010)	25 med. school students	Medicine: Laparoscopy	Comparison 10 trials	Prior open surgical experience does not help development.
Hassan… (2006)	65 professionals	Medicine: Laparoscopy	Comparison 1 obs, 2 trials (part of a course)	Novices developed, adepts did not.
Stefanidis…(2006)	21 residents	Medicine: Laparoscopy	Comparison ~12h/325 repetitions.	Impact of visuospatial ability on baseline score and development is small.
Chen…(2006)	31 seniors and graduate students	Social Science: Network growth	Experiment. Pre/post survey3c. course	Age, formal and informal experience, learning approach support development.
Liu…(2008)	6 freshmen	Science: Chemistry	Case. Tests, logs,observations.Exams.~3h/3weeks	Group composition impact pairs interactions, high/low preferable.
Hsu…(2004)	29 students & professionals	Medicine: Endovascular surgery	Comparison ~30-60 min	Experienced perform better on pre/posttests but develop less.

Loukas…(2010)	30 med. 3-year vs recent graduates	Medicine: Intravenous cannulation	Comparison. Learning curves. 1 month, 9 scenarios	Novices need more time for development
Ritter…(2003)	14 med. Junior attending. fellows	Medicine: Endoscopy	Comparison ~1h (2d)	Novices developed, intermedians did not.
Martens… (2004)	33 psych and tech students	Social Science: Business adm.	Experiment. Survey. Essay. >3h	High motivation led to exploratory actions, but not improved development. Possible measurement issues.
Yeh (2007)	178 teacher training students	Social Science: Teaching	Correlational. Personality surveys. ~4h	Traits, intelligence, thinking styles, critical thinking impact development.
Prins…(2006)	44 psych.students	Science: Optics	Comparison. Pre/post test. Observat. ~90 min.	Metacognitive ability impact develop-ment. Usage varies with competence.
Hmelo-Silver (2003)	8 2nd and 4th yr. med.students	Medicine: Oncology	Comparison. Pre-test. Observation. ~4h	Prior knowledge impact interaction. More knowledge, more negotiation.

3) Impact of simulation relation to other educational or professional activities				
Trundle…(2009)	157 teacher training students	Social Science: Teacher training	Experiment. Full quarter.	Simulation training alone is as effective as realistic observation or a combination.
See… (2010)	80 nursing students	Social Science: Statistics	Comparison. ~35 min	Simulation is better suited as preceding lectures, rather than succeeding.
Zacharia… (2011)	234 physics students	Science: Physics	Experiment. 30min X 15 weeks	Simulation can precede as well as succeed real manipulations.
Holzinger…(2009)	96 med.students	Medicine: Hemodynamics	Experiment. Survey. ~6min (45)	Video-instructions before training is beneficial, and better than text.
Naughton…(2011)	20 junior residents	Medicine: Endovasc.surg.	Comparison. 14h/7 days	Work shift impact speed of development, but not the end result.
Persoon…(2006)	32 4^{th} and 6^{th} year med.students	Medicine: Urology	Experiment. 3 tasks (20min)	Low fidelity pre-training impact initial development, but the effect diminishes.

4) Impact of simulation characteristics				
Brunner…(2004)	12 2nd year med. students	Medicine: Laparoscopy	Comparison. Learning curves. 30 rep. X 12 tasks	Repetition up to at least 30 times renders improvement.
Aggarwal…(2006)	20 novice med.students	Medicine: Laparoscopy	Experiment 17x5-30 min.	Range of difficulty levels improves learning speed.
Smit…(2001)	63 non-surgeons	Medicine: Laparoscopy	Comparisons. Logs. 10 repetitions.	Repetition up to 3 times reduces completion speed. Precision continues to improve.
Kössi…(2009)	79 residents	Medicine: Laparoscopy	Log files. 2 years voluntary usage.	Voluntary usage varied between extensive and null. Compulsory use may be required.
Dalgarno…(2009)	95 novice chemistry students	Science: Chemistry	Descriptive. Survey. 40 min + voluntary	Voluntary usage dependent on perceived need.
Bridge…(2007)	42 pre-registered radiotherapy students	Medicine: Radiotherapy	Descriptive. Survey.	Perceived realism impact perceived development. Age, gender and clinical experience had no impact.

Lainema…(2006)	43 professionals, managers & scientists	Social Science: Business	Case. Interviews. 1 day	Simulation adaptability to local conditions impact acceptance, perceived authenticity and meaningfulness.
Rieber…(1996)	41 interactive media students	Science: Physics	Experiment. ~90 mins.	Using ‘meaningful’ analogies instead of an arbitrary one does not help development.

Table 1 summarizes key aspects of the selected review articles that will be discussed under the following headings.

1) Impact of support during simulation.

A common characteristic of the articles that pursue this theme is that they focus on the effects of different kinds of support during simulation training, including human resources in the form of peers and teacher presence and different kinds of scaffolds. The interventions are quite varied.

Support from scaffolds during training

The provision of contextualized questions during simulation can enhance the development of diagnostic skills, but it is important to give instructors sufficient training in applying the simulation and pedagogy. Hmelo and Day (1999) illustrated this with their experiment on 36 first-year medical students.

The type and quality of feedback during simulation can impact the development of laparoscopic skills. Van Sickle, Gallagher and Smith (2007) illustrated this by comparing the performance of 32 science students learning laparoscopy who were divided into groups with no feedback, automatic buzzer feedback, a human actor, and the buzzer plus the actor. A combination of human and computerized feedback outperformed other alternatives.

Inducing self-awareness and mindful learning during simulation can impact the development of teaching skills. Yeh (2004) illustrated this by comparing 149 teacher training students divided into groups with no support, self-awareness support, mindful learning support, or both together. Support for both together outperformed the alternatives.

Individual training with task-specific feedback is preferable for participants with less prior knowledge, and collaborative training with task-specific feedback is preferable for participants with more knowledge. Nihalani, Mayrath and Robinson (2011) illustrated this by comparing 127 students with and without computer-related education in individual and collaborative contexts who were learning about computer networks.

Presence of peers and teachers during training

Social context, i.e., individual vs. collaborative training, does not impact the degree of elaboration during diagnostic training.

De Leng, Muijtjens and van der Vleuten (2009) illustrated this by comparing 47 fourth-year medical students working either individually or in triads.

The teacher-to-student ratio during simulation has an impact on the development the skill of wound closure. Dubrowski and MacRae (2006) illustrate this by comparing 108 undergraduate medical students in groups with 1 teacher per 12 students, 3 per 12, and 6 per 12. Three teachers, or a 1:4 ratio, was found to be the most effective.

2) Impact of participant characteristics.

A focus on the effect of participant characteristics on the simulation and its outcomes is the common theme of this subfield. These characteristics are related to competencies, such as content experience as well as more generic traits like visuospatial ability, age, and metacognition.

Prior experience in open surgery did not help students develop during simulation. Brown, Miskovic, Tang and Hanna (2010) illustrated this by comparing 25 medical students who were training with a laparoscopy simulator, some of whom had experience and others of whom did not.

Novice professionals benefit more than adepts from laparoscopy simulation training. Hassan, Maschuw, Rothmund, Koller and Gerdes (2006) illustrated this by comparing 65 novices and adept professionals. While novices developed significantly, the adepts did not.

Visuospatial ability has a small impact on development in laparoscopic skills. Stefanidis et al. (2006) demonstrated this in a study of 21 medical student residents. Only one of their innate ability tests, cards rotation, had any predictive value.

Age, education, computer proficiency, prior experience, and learning style impact the development of transportation planning (network growth). Chen and Levinson (2006) demonstrated this in an experiment with 31 seniors and graduate students in a transportation systems analysis course. Development was improved in students who were older, who had taken more relevant courses, who had prior experience, or computer proficiency, and who had a constructionist, global, and reflective learning approach.

Prior knowledge impacted learning interactions during chemistry simulation. Liu, Andre and Greenbowe (2008) indicated this in their comparison of 6 freshman university students working in pairs of two students with a lower level of knowledge, two with a high level, and one lower-level and one higher-level student. Only in the pair with the low/high combination did the simulation seem to produce relevant interactions.

Prior experience impacts performance and development related to endovascular simulation. Hsu et al. (2004) demonstrated this in their study of 29 students and professionals. Those more experienced performed better on pre and post tests but developed less.

Prior experience impacts the time needed for the development of intravenous cannulation skills. Loukas et al. (2010) indicated this by plotting learning curves for 30 third-year medical students and recent graduates. Novices developed more slowly.

Content ability levels impacted development during endoscopy simulation. Ritter, McClusky, Lederman, Gallagher and Smith (2003) demonstrated this with their comparison of 14 medical students, junior attending and fellows. While novices developed during simulation, intermediates did not.

The level of intrinsic motivation impacts actions in but not outcomes of a business simulation. Martens, Gulikers and Bastiaens (2004) demonstrated this in their experiment involving 33 psychology and technology students. Highly motivated students are more exploratory and curious. The lack of difference in outcomes may be related to flawed outcome measurements.

Personality traits, intelligence, thinking style, critical thinking disposition, and skills impact change during teacher training simulation. Yeh (2007) demonstrated this in a study of 178 teacher training students. These traits and abilities were found to be positively correlated with change during simulation.

Metacognitive ability impacts learning during optics simulation. Prins, Veenman and Elshout (2006) demonstrated this in their comparison of 44 psychology students grouped by previous experience, metacognitive ability, and intellectual ability. For novices, metacognition was important during the simplest of three simulation phases. For advanced learners, metacognition was important in the intermediate phase. This is, in essence, a repetition of a previous study by the same authors, Veenman, Prins and Elshout (2002).

Prior knowledge impacts collaboration while learning to design clinical trials. Hmelo-Silver (2003) illustrated this by comparing two gropus with 4 participants each of fourth-year medical students who were grouped by levels of prior knowledge. Less knowledge led to more concrete discussions, and more knowledge led to more discussion as well as to more questions being generated. Both groups developed during training.

3) Impact of simulation relation to other educational or professional activities

The articles related to this theme focus on the effects of the relationship between simulation and other activities, such as combining simulation and “real” training, the sequential order of simulation and other educational activities, the usefulness of video-based instructions, whether participants work day or night shifts, and pre-training on a simpler model.

Simulation training alone is as effective as combining it with realistic observations, or realistic observations alone, during astronomy training. Trundle and Bell (2009) demonstrated this in a quasi-experimental study by comparing 157 teacher training students. All three interventions led to the same level of conceptual change.

Simulation is more useful prior to, in contrast to after, lectures when learning the central limit theorem of statistics. See, Huang, Chang, Chiu, Chen and Napper (2010) demonstrated this during an experiment with 80 undergraduate nursing students. The group using simulation as a preview developed more than the group using simulation for a review.

It does not matter whether simulation precedes or succeeds real manipulations when learning about basic laboratory knowledge, but a combination is preferable. Zacharia and Olympiou (2011) demonstrated this by conducting an experiment with 234 undergraduate physics novices.

Video-based introductions can enhance learning in hemodynamics (blood flow) simulation. Holzinger, Kickmeier-Rust, Wassertheurer and Hessinger (2009) illustrated this through an experiment with 96 medical students. Video-based instructions beat both the no instructions method and the text-book introductions method with regard to development.

While day and night shift workers achieve the same ability levels during endovascular surgery simulation, it takes the night shift workers a bit longer. Naughton et al. (2011) demonstrated this in a comparison of 20 junior medical student residents.

Pre-training on a simpler model impacts early learning curve development but then diminishes during urological simulation. Persoon et al. (2010) demonstrated this during a randomized experiment with 32 fourth- and sixth-year medical students. They also showed that those with pre-training were more satisfied with the experience.

4) Impact of simulation characteristics

The articles concerned with this theme consider the effect of simulation characteristics, including repeatability, range of difficulty levels, participation requirements, realism, adaptability, and representation.

The ability to repeat a simulation many times impacted the development of laparoscopy skills. Brunner et al. (2004) demonstrated progressive development in up to at least 30 repetitions for 12 second-year medical students by plotting learning curves.

The range of simulation difficulty levels impacted the learning pace of laparoscopic skills. Aggarwal, Grantcharov, Moorthy, Hance & Darzi (2006) demonstrated this in their experiment with 20 novice medical students. Progressing from easy to hard was more efficient than beginning with hard, and reduced the number of repetitions needed.

The usefulness of repetition in laparoscopy training is dependent on the aim of the simulation. Smith, Farrell, McNatt & Metreveli (2001) demonstrated this in their study of 63 non-surgeons. While the amount of time for completion of the task was reduced until the third repetition, precision continued to improve throughout the full ten repetitions.

Simulation training may need to be compulsory and competency-based. Kössi & Luostarinen (2009) indicated this in their review of two years of voluntary usage by residents of a laparoscopy simulator. The variation in usage between students was great, and it varied from no usage to extensive usage.

Non-compulsory simulation may need to address students' perceived needs in order for them to use it. Dalgarno, Bishop, Adlong & Bedgood (2009) demonstrated this in their descriptive study of 95 novice chemistry students learning basic laboratory knowledge in distance education contexts.

Perceived realism impacts perceived development during radiotherapy simulation. Bridge, Appleyard, Ward, Philips, & Beavis (2007) demonstrated this in a descriptive study of 42 pre-registration radiotherapy students. They found no correlation between perceived development and age, gender, or previous clinical experience.

Simulation adaptability increases acceptance, perceived authenticity, and meaning in a business simulation. Lainema & Nurmi (2006) came to this conclusion after their case-study of 43 professionals, managers, and scientists in a large business.

Meaningful analogies do not necessarily help development during physics simulation. Rieber et al. (1996) demonstrated this by experimentally comparing 41 interactive media students in groups who trained with different versions of the same simulation, one that was arbitrary and one that was presented as a meaningful analogy. Both groups developed.

Summary

The articles included in this review of empirical research have focused on different types of filters related to the impact of support during simulation, the impact of participant characteristics, the impact of simulation in relation to other activities, and the impact of simulation characteristics. As such, they explore features, uses, participants and context issues. I have noted that laparoscopy and physics are a recurring type content for simulation training, that the articles from medical journals often lack an explicit foundation in theory, and that they very seldom pay attention to the process. Both of these aspects of investigation and analysis are more present in articles from non-medical educational journals. The contribution of this review to the model is illustrated in Figure 7.

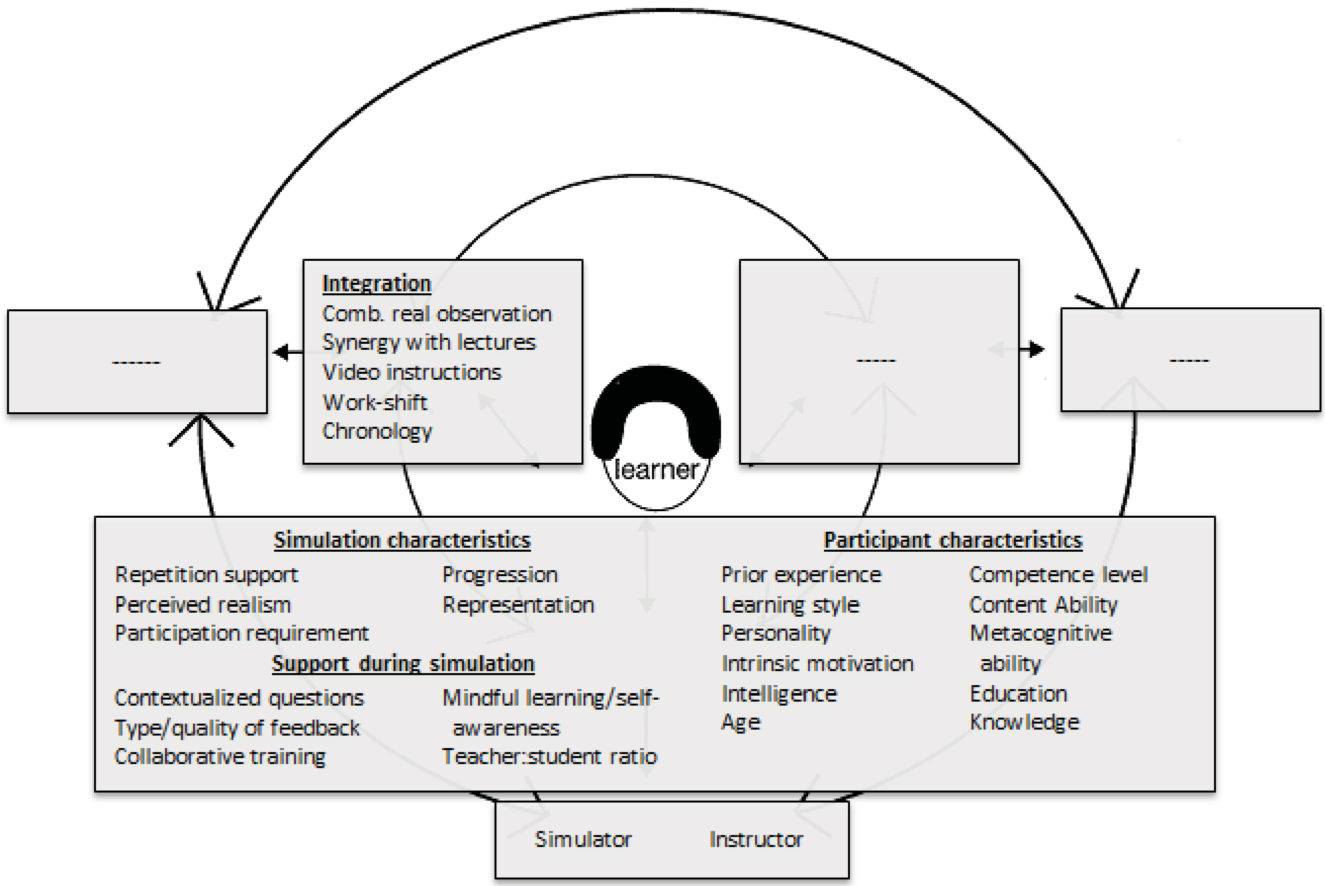

Figure 7. Outcomes of the review of ECAS in higher education from an Ecology of Resources perspective.
Adapted with permission from Luckin (2010), *Re-designing learning contexts* (p.94, figure 5.13), London: Routledge.

Implications for the collaborative ECAS in HCE ecology analysis

The aim of this review of prior research has been to inform the analysis of a type of simulation, the collaborative ECAS for health care education. It has drawn upon research from fields that are related to this topic: SBME and CSCL. It has also reviewed empirical research on ECAS in higher education, with a particular focus on the relations between context and learning outcomes.

Some common themes can be found in these three review areas: filters that may mediate the learner's interaction with tools and people, stuff to be learned, and environment. Factors that were identified as potentially relevant included characteristics of participants, characteristics of groups, characteristics of simulator and simulation, simulation activity integration, dynamic support, and static support.

To some extent, the review does not clarify exactly how these factors act as filters for interaction within the EoR, or even exactly what it is that they filter. They impact learning outcomes, and from an EoR perspective, this means that they somehow impact learner interactions with the ecology.

In the next section, I will integrate these findings into the analysis of the Ecology of Resources of collaborative ECAS in HCE, and guided by the results, I will analyze the particular simulation studied in this thesis, the Radiology Simulator.

Analyzing collaborative ECAS in HCE as an Ecology of Resources

Under this heading I will try to develop a first sketch of a general EoR model for collaborative ECAS in health care education. It will be based in part on an established definition of simulation (including the parts that make it a simulation), and in part on the literature review presented in the previous chapter.

Guided by this general model, I will then begin analyzing the radiology simulator. This analysis will contextualize and motivate the thesis' empirical contributions presented in Publication I-IV.

The collaborative ECAS in HCE from an EoR perspective

The first step is to map out the primary resources available to learners in collaborative HCE ECAS ecology. These resources will be organized in accordance with the generalized categories of resources put forth by Luckin:

knowledge and skills, tools, and people, and environment. While Luckin stresses that it is not necessary to relate resources to these categories in the early stages of analysis, I find them to be a great support in structuring the identification process. Based on the definition presented in the previous chapter, this becomes a straight forward endeavor.

The “Knowledge and Skills” that we will discuss are derived from different health care disciplines. The “Tools” will always include a computer-assisted simulator. The “People” will include peers, who may enact the role of MAP. The “Environment” will be a more or a less formal site, whether it is a computer lab or a simulation theater.

We also know that the learner’s interaction with these resources will be filtered. From Luckin we can surmise that interactions with knowledge and skills will be filtered largely by a curriculum, and by the specific stuff to be learned. According to the definition of ECAS, the objective will be learning; it is educational and not just for summative assessment, decision-support, research, or similar purposes. And from the review, we may infer that this learning is related to conceptual development, skill acquisition, professionalism, or team training. (This is a limitation in relation to the conceptual framework provided by Gaba in 2004). Interaction is affected by the extent to which it meets learner needs.

From Luckin, we can surmise that interaction with the tools, primarily the simulator, will be restricted by some administrative filter that is related, for instance, to access. The review suggests that filtering aspects include the technological medium or the type of simulator, the tasks and task features, the type and quality of feedback including performance measures and debriefing, the progression or the range of difficulty levels, the repeatability of simulations and tasks, the adaptability to learner needs, the clinical variation in stuff to be learnt, and the presence of scaffolds such as contextualized questions or support for self-awareness and mindful learning.

Learner interaction with people, peers, and teachers will also be filtered, as the review shows, according to participant characteristics such as content ability, visuospatial ability, metacognitive ability, and work-shift (Luckin mentions similar factors when discussing the identification of learners resources); group characteristics including group size, group composition in terms of general and subject ability, and gender and social status; and the instructor’s presence and the instructor-to-student ratio, the subject, and pedagogical competence.

Learner interaction with the environment is filtered by organizational factors including access and training schedules, local culture, and other factors. The review indicates that the safety of the environment and its level of support both impact outcomes. However, little attention has been paid to environmental issues in the research. An initial sketch of the model is illustrated in Figure 8.

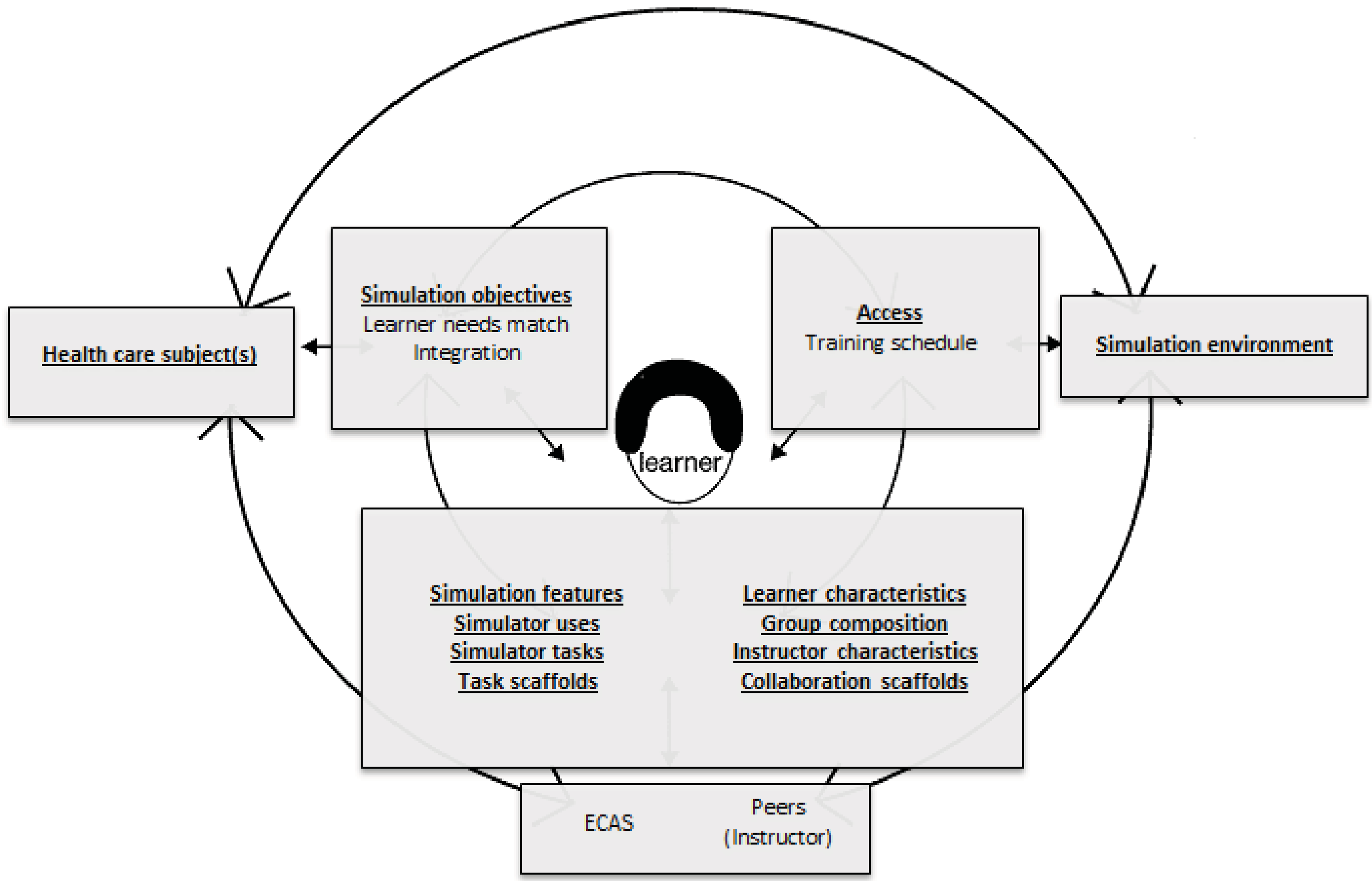

Figure 8. Collaborative ECAS in HCE – an Ecology of Resources model.
Adapted with permission from Luckin (2010), *Re-designing learning contexts* (p.94, figure 5.13), London: Routledge.

The role of More Able Partners in this type of EoR can be enacted by peers, who will be present in addition to instructors and others.

From Luckin we know that the learner's interaction with the context will be affected by interactions within the context itself, i.e., between and within the resources and the resource categories. How these interactions affect each other is unknown, and will be discussed in the following section.

The Radiology Simulation as an example of a collaborative ECAS in HCE

The radiology simulator is a PC simulator that allows radiology students to operate three-dimensional anatomical models and take virtual radiographs from different perspectives. The activity is guided primarily by a set of tasks implemented in the software that learners are able to select. Studies on group training with the simulator were first performed in experimental contexts with dentists and later as an integrated part of a course for nurses.

Knowledge and Skills of Radiology Simulator

Radiology simulation is offered to radiology students in radiology nursing and dentistry programs. The health care subject for dentistry students is oral radiology, and for nursing students it is spinal radiology, according to documentation on the curricula of the training sessions.

Curricula and teachers inform us that the primary disciplines that are applied to radiology are anatomy and projectional radiography. These constitute the pool of knowledge from which the stuff to be learnt are drawn. This means that students learn by interacting with anatomy, radiography, and the relationships between them in order to understand how three-dimensional anatomical structures and objects are represented in two-dimensional x-ray images.

Tools of Radiology Simulation

The sole tool is the radiology simulator. Its technology relies on PC hardware and software with some uncommon peripherals. It employs operable three-dimensional anatomical models, x-ray equipment, and two-dimensional radiographs. For the sake of this analysis I will consider the specific features and uses of the simulator to be filters that mediate students' interactions with this core.

People in Radiology Simulation

In LRiSE studies, students worked in groups of twos and threes, with the potential support of a teacher who is instructed to adopt a passive approach. Due to the limited nature of training sessions, these are the only people of interest in our case. Having students work in groups was based on ideas derived from complementing prior studies of individuals training with the simulator, specifically, that similar technologies have previously tended to be used in groups in the interest of collaboration. This interest will impact the analysis in considerable ways.

Environment for Radiology Simulation

The training was performed in a rather limited environment. The location for the training of the dental students was an office, which was new to the participants and had little more to offer than the simulation device. The training for the nursing students was located in a regular study and reading room where the simulator was temporarily installed. Both sites were located in corridors near teachers' offices.

More Able Partners in Radiology Simulation

There are three potential MAPs in radiology simulation: the supervising teacher, the peers, and the simulator. However, because the LRiSE studies had a particular interest in peer collaboration, the teacher was instructed to adopt a passive or reactive approach. The radiology simulator does provide a range of tasks that learners can select, and it provides feedback to learners after they complete tasks. However, the depth and complexity of this feedback is not related in any way to the learners' performance. It was not developed with the type of scaffolding or user modeling in mind that is required to enable it to act alone as a MAP.

The peers were not instructed to mutually enact the role of MAP, and were left to themselves to decide how to interact with each other. The extent to which they actually engaged in reciprocal MAPing is an empirical question.

Filters for Knowledge and Skills resources

The learners' interactions with knowledge and skills for this type of ecology were filtered by the objective of the activity and its place in a wider curriculum.

In the Radiology Simulation, the objective was conceptual development, and the selection of the type of anatomy selected was related to the jaw for the dental students and the cervical spine for the nursing students. The specific tasks that students engaged in limited their interaction to a set of challenges that were presented and performed with the simulator. The challenges included two types of conceptual challenges: 1) identifying the location of foreign objects, and 2) identifying the projection for or angle from which a radiograph has been taken. In order to achieve this, it was necessary for students to interact with knowledge and principles from anatomy and projectional radiography. This stuff is generic to the tasks. However, the groups decided amongst themselves which tasks to perform and repeat, which may have impacted what portions of the stuff that they interacted with. In other words, they were able to choose tasks that focused on only one of these challenges.

Filters for Tools resources

The learner's interaction with the simulation was filtered by the technological medium, or, that is to say, the hardware features. The representational media, including the two screens, as well as the peripherals, the keyboard, and the mice were the main interfaces through which students experienced the simulation, and they were likely to impact how students interacted with the simulation, how they operated the simulator, what drew their attention, and so on. Software features, notably the built-in tasks (but also the interface) also filtered their interaction with it, what they did, and how they did it. It is possible to repeat all tasks indefinitely and the 'starting position' of the task is randomized, which makes it meaningful to repeat tasks when the object is conceptual development. The nursing students were able to perform additional training sessions with the simulator after the compulsory one, which was an option that the dental students did not have. There is some support for progression and individualization, insofar as it was possible to engage with the two challenges separately or at the same time.

The radiology simulation is based on scans an actual patient, but of only one adult male with conformed anatomy and a set of virtual ailments. This renders it somewhat limited with respect to its ability to capture clinical variation and be a valid representation of a complex practice since the range of patients and conditions as well as simulator fidelity is important.

The simulator provides formative and summative feedback in the form of visual comparisons between student solutions and ideal solutions, accompanied by numerical information about the discrepancies between the two. This gives the feedback limited merit as a benchmark. It does not have built-in support for adaptation to particular contexts.

In the LRiSE studies, the simulator was developed for single-user application, but it had the ability to provide some support for small groups because of its visual nature.

Filters related to People resources

Regarding participant characteristics, the dental and nursing students were recruited from the same semester of their respective programs. However, prior to empirical investigation, we knew little about internal variations in general and particular ability, traits, or social status, either individually or for the groups. The group size was set to three for the dental students and two for the nursing students. The dental students had a passive teacher available throughout the simulation; the nursing students did not and had to seek out a teacher in the event of the need for assistance. The teachers were merited in their respective fields, though no fine-grained differentiation was available.

The simulator medium and tasks were not designed for specific support for collaborative training. However, the visual nature of the simulator and the actions performed on it made it possible to some extent for the training to be followed by multiple participants simultaneously. Its focus on conceptual development, rather than acquisition of psychomotor skills, gave the tasks some merit as a basis for collaboration.

Filters for Environment resources

The learners' interactions with the environment were filtered by formal administrative aspects such as the training schedule, and in addition, the booking system in the case of the nursing students. It may also have been impacted by an informal regulation, such as appreciation of the local culture or perceptions about what it is ok to do. As such, the environment may have impacted how supportive and 'at home' the students found it. This type of filter may be of more relevance when the circumstances for the simulation activity are a recurring and thoroughly integrated part of a learning activity such as a course.

The impact of the environment, or site, as Gaba (2004) calls it, is largely unexplored in relation to SBME research.

From model to empirical investigations

The first step in Luckin's redesign framework, which I am attempting to apply to research, is to create an EoR model. This includes the identification and categorization of primary resources, potential resources, filters, and learner resources, and the identification of potential MAPs. I have accomplished this by exploring a generalized collaborative ECAS in HCE ecology, supported by previous research on activities that share key features, and then exploring the radiology simulator as an example. This has uncovered key “elements that make up the resources and filters of the Ecology of Resources” (Luckin, 2010, p. 124) that are likely to filter learner interactions and impact what learners internalize.

However, we have yet to uncover “the relationships and interactions between resource elements and between learner and resource elements” (Luckin, 2010, p. 124), and to “identify opportunities for adjustments and scaffolding” (Luckin, 2010, p. 126). This is achieved in subsequent steps and requires a “fine-grained analysis of the details of a particular element and interaction, and also the consideration of how this particular element and interaction fits into the totality of the learner’s Ecology of Resources” (Luckin, 2010, p. 126). The use the EoR framework for research is where empirical studies come into play. The fine-grained analysis needs to consider ecology in action. These studies should contribute to a greater understanding of a particular ecology as an example of a type of ecology. In my case, the radiology simulator is a case example of collaborative ECAS.

Specifying a focus of attention

It will never be possible to investigate all interactions between resources and filters in a particular ecology, and a selection will always need to be made. This is also the case for the empirical studies that are the groundwork of this thesis: they will make a small contribution to what will ideally be a collective effort to understand collaborative ECAS in health care education. As the preceding analysis has shown, the potential foci are numerous. They can be performed with a range of instruments. The EoR framework is not prescriptive about how to complete the different phases of a redesign (Luckin, 2010, p. 118).

The empirical studies in this thesis are focused on the relations between resources and filters in a collaborative radiology ECAS ecology, learner interactions, and learning outcomes, in order to identify opportunities for the development of educational simulation practice. This focus is highlighted in green in Figure 9, which illustrates the collaborative radiology ECAS ecology as it has been described here.

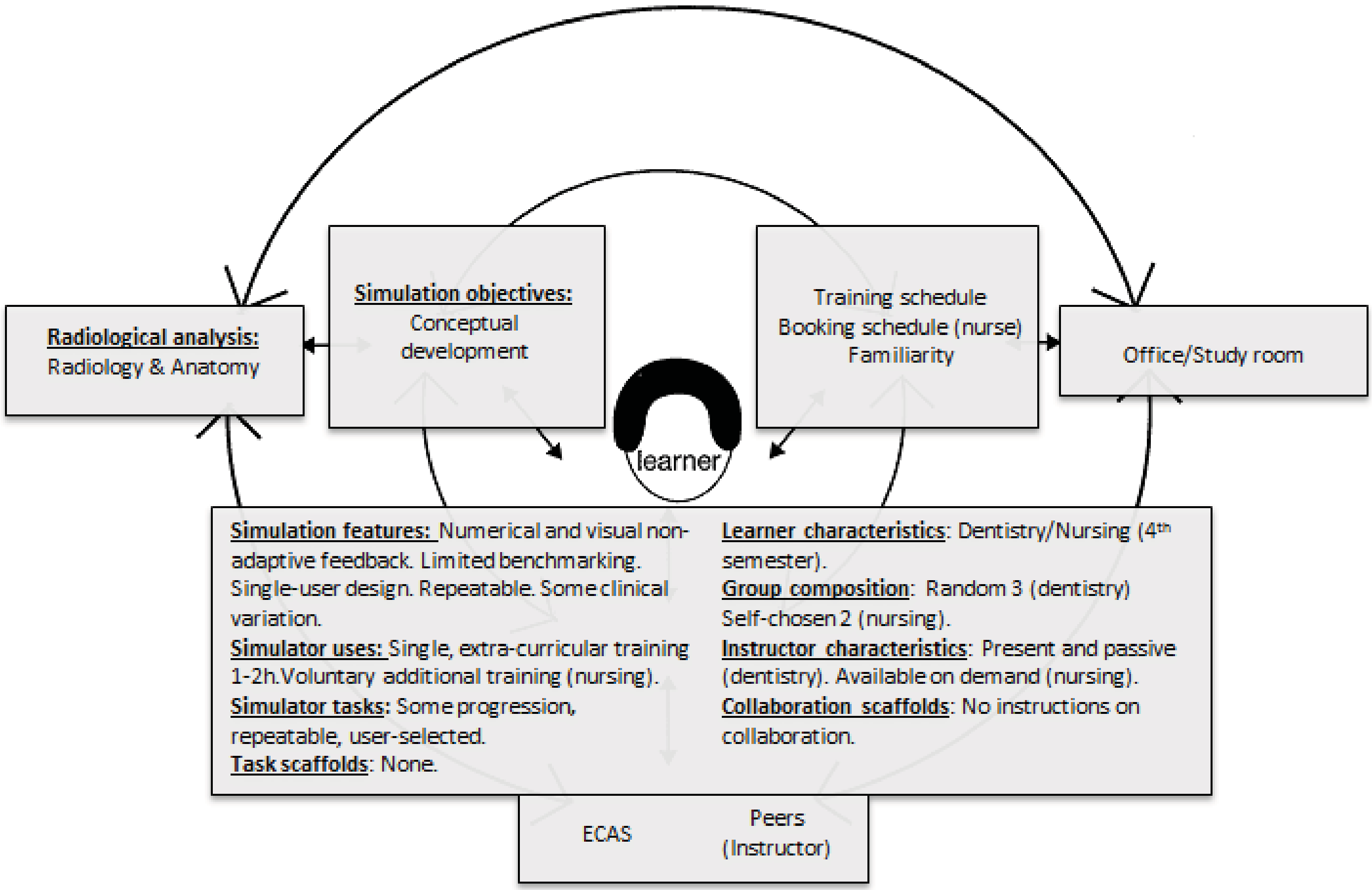

Figure 9. The collaborative radiological ECAS in HCE model. The empirical contributions focus the lower two boxes.
Adapted with permission from Luckin (2010), *Re-designing learning contexts* (p.94, figure 5.13), London: Routledge.

I do this in four studies that move from coarser to finer granularity, from describing to suggesting to adjusting to evaluating. As indicated by the preceding review, little attention seems to have been paid to collaborative learning with ECAS or other simulations in health care education, or even in higher education.

IV. Methods for investigating learning in context

Content and disposition

This chapter introduces the design, overall and particular, of the collaboration study that produced the empirical foundation of this thesis. It presents the research and development project that motivated the study, the selection of data founding the four publications, and methodological reflections related to the study, the selections, and the publications. I will argue that the empirical contributions represent the fine-grained analysis through which parts of the collaborative ECAS in the HCE ecology of resources are explored in the search for opportunities for adjustments that can motivate both further inquiries and redesign efforts.

Learning Radiology in Simulated Environments

The empirical foundation for this thesis was produced within the scope of the Learning Radiology in Simulated Environments (LRiSE) project running from 2005 to 2008. This was a joint research and development project involving, more or less, six software developers, six radiologists, and seven educational researchers at the universities of Umeå and Stanford. Funded 1 year at a time by the Wallenberg Global Learning Network, it was extended twice.

At the core of this project was the continuous conceptual and technological development of a simulator of radiographic imaging, the Radiology Simulator, as well as the use of this simulator. This included the refinement of an existing version of the simulator focusing on oral anatomy, and the development of new versions of the simulator focusing on the anatomy of the cervical spine and the abdomen. Uses of the versions of the simulator were evaluated in research studies, and selections from them were presented at conferences, in journals, and in book chapters (e.g., Häll, 2012; Häll & Södersström, 2012; Häll, Söderström, Ahlqist & Nilsson, 2009, 2011; Nilsson, Söderström, Häll & Ahlqvist, 2006; Nilson, Hedman & Ahlqvist, 2007a, 2007b, 2011; Söderström, Häll, Nilsson & Ahlqvist, 2008, 2012; Söderström, Häll, Ahlqvist & Nilsson, 2012).

My part in this project initially concerned the oral radiology version of the simulator. More specifically, it concerned student learning through group training with the simulator, investigated in what was internally called the "collaboration study" continuing through years 1and 2. This study was later expanded to include the cervical spine simulator in year 3, and the division of the collaboration study into the dentistry collaboration study and the nursing collaboration study.

The collaboration studies

The collaboration studies began as a comparison between collaborative simulation training and collaborative "conventional" training, which in this case meant image pair comparisons presented in PowerPoint. This was a direct extension of a previous study that compared the two techniques in studies involving individuals. This kind of comparison is common in medical education research. What is the impact on learning processes and outcomes? This question guided the first "dentist" study of the simulator. Through the second "nursing" study, it was expanded to include how different conditions impact collaborative simulation training and how the simulation works when integrated into an existing curriculum. An outline of the LRiSE studies' data construction is presented in Table 2. In the following sections I will first introduce the Radiology Simulator, then present the LRiSE collaboration studies, and finally discuss the respective means of data construction.

Table 2. Outline of the LRiSE collaboration studies, dentistry and nursing

	Study	Input	Process	Output
Year 1	Dentistry	Pre-test	Observation A/B	Posttest, Survey
Year 2	Dentistry continued			Follow-up Interviews
Year 3	Nursing		Observation	Survey, Interviews

The radiology simulators

The Radiology Simulator studied in this thesis is a sample of a type of ECAS; it is essentially software that runs on a PC. It differs from many common types of software in that it requires two screens, and interaction with it is performed with peripherals: mice that are uncommon but not unique for this type of software. Earlier versions, used in Publication I, also required 3D stereoscopic glasses. One core aspect is a three-dimensional model of a specific body part like a jaw or the cervical portion of a spine. This model is represented on the left screen in Figure 10. Also visible is the model of a virtual x-ray camera. Available, but not visible, are models of a film and of a ball used in simulator tasks. These models can be operated and positioned by means of the trackball or roller-ball, held in the left hand in Figure 10, and a pen-mouse, held in the right hand. The anatomical model is based on real patient data, retrieved from original x-rays.

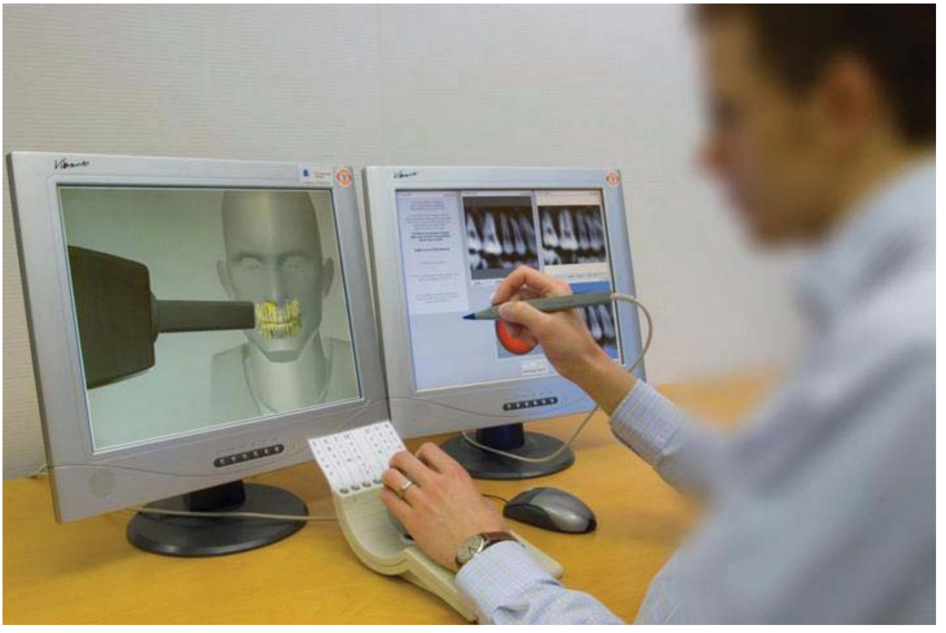

Figure 10. Illustration of a dental student working with the radiological VR simulator, jaw model.

Another core aspect of the simulator is the ability to produce virtual radiographs—i.e., to take x-rays of the model. These radiographs, depicted on the right screen in Figure 10, are based on the current position of the virtual camera and patient. They look and are anatomically valid.

The student has the ability to explore the simulation freely, and see how changes in patient-camera positions impact the radiograph in real time, but activity is mainly intended to be structured by tasks built into the simulator. These tasks include replication of standard views and replication of incorrect views, and include object localization and projection identification. The tasks begin with the learner selecting an area to explore that randomizes the position of the models and creates one radiograph. What happens next is dependent on which of the four tasks the learner engages with:

1. Analyze beam direction: A second radiograph is randomized. The student is tasked with interpreting from what angle the new radiograph is taken, and positions the camera model accordingly.

2. Ordinary radiography: The student is tasked with positioning the camera, producing a second radiograph, and deducing the location of a foreign object. The student positions a marker at this location.
3. Fluoroscopy: As ordinary radiography, but with real-time representation of the second radiograph based on the current camera-patient positions.
4. Object localization: Includes both tasks 1 and 2.

The dentistry collaboration study—years 1 and 2

The dentistry study was performed in two steps. First, we performed an experiment, complemented with observation and survey data. Later, we performed follow-up interviews with selected participants.

Aim and questions

The original aim of the dentistry study was to compare the impact on learning achieved by collaborative training with the Radiology Simulator with collaborative conventional training. What is the effect on learning outcomes? What is the effect on the interactive processes? How do the experiences of training differ between contexts?

Design

The participants in the dentistry collaboration study were undergraduate students at a dentistry program. The location was chosen due to practical circumstances. Thirty-six volunteers participated. The participants performed a pre-training proficiency test, and based on this they were randomly assigned into either simulation training or conventional training with a PowerPoint exercise. Within each training mode participants were randomized into workgroups of three individuals. Each group participated in 1 hour of video-recorded training. Directly after training students filled out a survey and completed a post-training proficiency test. Follow-up interviews were later performed with 18 participants, nine from each group.

Subjects

The participants, 20 females and 16 males, were fourth-semester dentistry students attending a course in Oral and Maxillofacial Radiology. This course shared, in part, the object of the Radiology Simulator, object localization using motion parallax. This is not the only course that shares objectives with the simulator, but it was the only one offered within the project timeframes.

One point should be noted about these subjects, and that is that two members of the LRiSE research team were teachers at the dentistry program in which they were enrolled. These members were also key developers of the Radiology Simulator, a fact presumably known by the students. How this may have impacted the outcome is not obvious. At the very least, it may have made recruitment easier.

Conventional training

The control group in the dentistry collaboration study worked with a PowerPoint slide created by members, odontologists, in the LRiSE research group. The slide consisted of eight question-answer slide pairs, as depicted in Figure 11. Questions and answers were presented in concise sentences. All slides included a one-beam trajectory task and one object localization task. Groups started with the first pair and worked their way through to the last one. This type of radiograph analysis training is common for dentistry students learning about this topic.

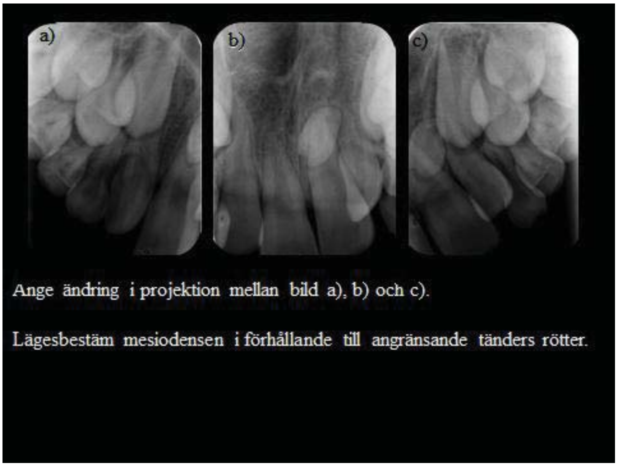

Figure 11. Example of an MS PowerPoint slide from the CON group. Students were asked to "state change in projection between images a), b) and c), and "determine the mesiodens in relation to the roots of adjacent teeth."

Training sessions for dentistry students

The conditions for the two training sessions, simulation and PowerPoint analysis, would ideally be equivalent, and close to how the simulator might be used in practice. And they were, in some respects.

Both training sessions consisted of three students working together on computer-based radiology tasks for 1 hour. How they distributed this time over the available tasks was up to them to decide. The decision about how to collaborate, if at all, was also left to the students.

Two different locations were used, an office for simulation students and a small conference room for the control group, both at the Department of Odontology and both with the same restrictions on access.

A teacher, one of the odontologists, was available during training, but was instructed to be more or less passive and to inform students of this approach. Teacher presence was subject to some discussion about whether or not it was plausible to assume that a teacher would attend simulation training in practice. In the end we decided to include one.

Training duration was also discussed. In a previous evaluation, the duration had been 90 minutes, and it was then suggested that 60 minutes might be sufficient.

Group size was decided based on assumptions about how it would be used in practice, economic efficiency, practical possibilities, and pedagogical interest.

Both groups received short introductions to the sessions immediately beforehand. For simulation groups, this information was a bit more extensive, as it was technically more complicated. Simulation groups received an introduction to the simulator with an overview of functions, tasks, and select features, a demonstration of some tasks, and a short try-it-yourself period.

The nursing collaboration study—year 3

Aim

The aim of the nursing study was to integrate and evaluate the Radiology Simulator in a real curriculum.

Design

The participants of the nursing collaboration study were a class of undergraduate students at a program for Diagnostic Radiology Nursing. Again, the location was chosen due to practical circumstances. A version of the Radiology Simulator was integrated into the curriculum. A class of twelve students participated in simulation training in self-made groups of two for a duration of up to 2 hours. After training, they filled out the survey developed during the dentistry study. All but one participant was later interviewed.

Subjects

The participants, nine females and three males, were fourth-semester specialist nursing students attending a course in Nursing Procedures in Conventional Radiological Procedures. This course considers care, methods, and technology in computer tomography and ultrasound procedures and conventional radiological procedures. It is divided into two parts, one part given in the third semester and one given in the fourth. It was into the latter that the simulation was integrated. It is a 10-week course with 8 weeks dedicated to clinical practice training at local and regional hospitals. The first week is dedicated to theoretical, methodical, and practical preparations, the following 8 weeks to training, and the last week to exams and closure.

Design adjustments to the new radiology simulator EoR

The nursing students used a version of the Radiology Simulator that focused on the cervical spine, and thus were exposed to slightly different stuff to be learned than in the dentist simulation. However, the version still fell under the category of anatomy and the difference should not have had a major impact. The cervical spine version was also adjusted so that it did not require 3D glasses.

The integration was a compromise between three factors: practical conditions framing the course, experiences from our previous experiments, and an aspiration to keep things simple. It was done in collaboration with course teachers and included a demonstration of the simulator and a meeting focused on practical conditions of the course and experiences from our previous research. In the end all decisions were made by the teachers.

Participation was compulsory rather than voluntary. In order to support collaboration, we allowed students to choose partners with whom to work (instead of randomization) during the obligatory training session, reduced group size to two, and removed the teacher supervision from the session. We also increased the duration of the simulation from 1 hour to 2 hours, and we let students themselves decide how much of this time to use. Finally, we enabled students to reserve the simulation for additional, independent training throughout the following weeks of clinical training.

Proficiency tests to measure ability and development—dentistry collaboration study only

Proficiency tests were used to evaluate the ability level of every participant in the dentistry collaboration study in performing radiological analyses before and after training. This test was developed by members of the LRiSE group, odontologists teaching at the dentistry program. It measures what counts as proficiency for this subject, in this course at the dentistry program.

The tests consisted of three subtests: a principle test, a projection test, and a radiography test; each part was graded from 0 to 8, giving a total of 24 points. The principle subtest aimed at assessing the participants' understanding of the principles of motion parallax. Comparing sketches of subject non-related objects was a key component. The projection subtest aimed at assessing the participants' ability to apply the principles of motion parallax. Comparing sketches of anatomical objects, this subtest requires basic understanding of anatomy. The radiography subtest sought to assess the participants' ability to locate object details in authentic radiographic images utilizing motion parallax. The participants were asked to report the relative depth of specified object details in pairs of radiographs. The proficiency analyses in this study are based on the total score from all three tests. The tests and further discussion of them can be found in Nilsson (2007).

Pretests and posttests are often used to evaluate the effect of treatments in experimental studies, and in educational and other social research. There are several threats to the usefulness of these measures, many of which may be prevalent but hard to control for in a study such as this one. Effects on proficiency development could, for instance, be due to (Gall, Borg & Gall, 1996):

- The novelty and disruption that the learner experiences during simulation training, more so than the familiar conventional alternative.
- The specific teacher or experimenter—these also being the developers of the simulator and at times judging student performance during the program.
- Having performed a pretest or posttest, it is possible that the effects of this are different for simulation and PowerPoint training.

- When, in relation to the treatment, the evaluation is performed. It is possible that different types of computer-based training (e.g., simulation and PowerPoint) are "digested" differently.
- The type and quality of the measurement. It is possible that learning in different contexts encourages different types of understanding and thereby impacts performance on different types of tests. Tests constitute an operationalization of the learning goal. Sometimes, however, as for some CSCL researchers, the treatment changes the learning goal. If collaborative learning impacts collaborative ability or some other skills, should these also be evaluated?
- Subjects knowing that they are being observed (Hawthorne effect).
- The particular time in personal history the treatment is given, e.g., in what semester simulation training is given.
- Interferences from other or multiple treatments.

Video observation of interactive processes

To enable analysis and comparisons of the interactive problem-solving process, the training sessions were recorded using a DV camera. The camera was placed so that the upper half of the student was visible while the computer screen was not. Ways of capturing the content of the screen were also discussed, but at the time no satisfactory solutions were identified. Twelve groups meant 12 1-hour recordings.

The observation analysis was inspired by content-analysis approaches, partly due to my previous experience in conducting a similar analysis, the massive amount of video data, and a lack of familiarity with qualitative video analysis. At this stage, macro differences between the two designs were of interest. Thus, developing a scheme for analysis became a central concern.

An observation scheme was developed inductively. Inspired by the work of Folger, Hewes and Poole (1984), a scheme was developed through two phases to capture content and the form of peer interaction. In phase one, three questions were answered by a number of randomly chosen video-recorded training sessions: 1) What are the participants talking about? 2) How are they talking about it? 3) How do they relate to each other and to the learning environment as a whole? From the detailed descriptions generated by these questions, thematic categories of group interaction were inferred. With regard to the first question, statements such as "We need to turn the head downward" or "Up more, up" grounded the category of "action proposals," which is a sort of suggestion for solutions that lack causal arguments. Other content categories were "interpretations," "functionality/technical issues," and "social/off-task." With regard to the second question, for instance, terminology and logical coherence were noted. With regard to the third question, the simulator operator, the speaker, and whether the talk was monologue-ish or univocal were noted. When we were unable to identify more categories (i.e., we had reached saturation), phase one ended. These questions were applied to a group level.

In phase two, all video data were split into 1-minute time segments and coded with the previously abstracted themes (see Appendix A). This meant that every minute of simulation is one observational unit, with a dominant content and shape. In the descriptive presentations of the observations, these time segments are the empirical unit of observation. This allows for conducting a highly structured analysis based on an understanding that was influenced by the current set of data. An alternative to this time-based horizontal segmentation would have been to identify in the material a common base for segmentation, such as turn taking or the beginning and end of tasks.

All coding of the training sessions was performed by me. In order to produce a measure of coding stability (Krippendorff, 2004), one of the sessions was re-coded and compared with the first for each category described above. The percentage agreement between first coding and re-coding was 97% for content, 92% for terminology, and 98% for operator, verbal space, and verbal activity, respectively. (The scheme is found in Appendix X.)

Video-recorded observation is a familiar method among researchers on health care education (Hindmarsh, 2010; Koschmann, LeBaron, Goodwin & Feltovich, 2011; Rystedt & Lindwall, 2004), and it is increasingly used as the "basis to more applied studies and interventions" in education and other disciplines (Heath, Hindmarsh & Luff, 2010, p. vi). This "cheap and affordable technology" allows us to "capture naturally occurring activities" that can be "repeatedly analysed" both coarsely and in "fine detail"; it can be "shown and shared" with other researchers and it allows for a "range of analytic interests" to be applied to the same material, simultaneously or as the researchers' perspective on the data changes over time (Heath et al., 2010, p. 2). Some of these qualities set it apart from, for instance, observation using field notes. However, it is completely dependent on the quality of the recordings, both relating to content and more technical issues. Simple things such as cellphone signals may severely damage parts of the audio track.

Video analysis of more and less successful dentistry collaboration groups

In order to gain a deeper understanding of the interactive processes of the collaboration groups, a qualitative analysis was later performed on dentistry study data. The recordings of selected groups' training sessions were transcribed, with a basic approach inspired by Heath et al. (2010). It was restricted to verbal actions, utterances, and interactions with the simulator that started or ended "phases" in the problem-solving activity. Some would argue that non-verbal interaction is equally or more important than verbal interaction (e.g., Jordan & Henderson, 1995), but in the end it comes down to the characteristics of the observation and the focus of the current analysis. Given the fact that there is no video recording of what the learners see on screen at a given moment, their verbal actions gain more relative relevance.

The video recordings were viewed repeatedly and loosely transcribed in full. Also information from the simulator log files was integrated, regarding what tasks participants were doing at a given time, how much time they needed or spent on it, and how accurate their solutions were. This allowed for typical interaction patterns of the groups to be identified and differences between the groups to emerge. From the full transcription it was possible to identify an instance where the two groups were engaging in the type of analysis of the same anatomical area, and with similar, unsuccessful outcomes. This instance, or snapshot, was transcribed in finer detail and analyzed further. This allowed for a comparison of two groups attempting the same task and similar feedback, making differences more readily observable.

Survey of background and experiences of training

As a means to complement the more objective observation analysis of the interactive problem-solving process, information about the participants' experiences and perceptions of this process was constructed by means of a survey of all participants (Appendix B-D).

The survey was developed for the dentistry study and reused with minor adjustments for the nursing study, based on the theoretical focus that the sociocultural perspectives offered, complemented by an unstructured literature review. It collected background information on computer skills, relationships with other group members, views on learning and collaboration, and also on the training experiences of the teacher, tasks, simulator, and group in relation to collaboration and learning.

Answers were given either by grading statements on a 5-point scale or choosing one "best fit" alternative, in most cases with the possibility of open-ended commenting. The survey was administered to participants directly after completed training and took about 15 minutes to complete.

Observation studies may benefit from being complemented by other data, strict qualitative research (Heath et al., 2010), and more quantitative research, such as my Publication I. The participants themselves may provide information that is hard to discern from the observations, or information that just is not there. This survey aimed to provide further insight into what happened during training and why it happened, with a particular interest in how different aspects of its resources and filters supported interaction and learning. The apparent advantage of using a structured questionnaire instead of, for instance, interviews is that it is possible to gather experiences from all participants even with limited time available, a restriction that was clearly present in our case. It also ensures that all participants answer the same questions with identical phrasing, and is easily quantifiable. Open-ended comment boxes provided an opportunity to clarify responses and so on.

Semi-structured interviews

Follow-up interviews were performed with participants in the dentistry and nursing collaboration studies (Appendix C1–2). The aim was to better understand the experience of participating in simulation training, and to get a better understanding of students' perspectives of certain issues.

The interviews took 30 to 50 minutes, were conducted individually over periods of two weeks at locations familiar to the respondents, and were recorded on tape. A semi-structured approach was chosen, which enabled comparisons based on treatment, activity level, and other factors that may be considered interesting during the analysis. While all respondents received the same questions, the formulations and the order became context-dependent. These questions, which were open-ended, included themes regarding the training, collaboration, teacher, and technology in relation to interaction and learning. These themes overlapped with those dealt with in the observations and survey from Publication I, but their specific content differed.

For dentistry collaboration participants, a recording of the respondents' training session was presented on a laptop computer. A section of it was played at the beginning of the session, and at times during the interview when it was obvious that the respondent was struggling to remember. This approach was inspired by the stimulated recall technique (Haglund, 2003) and used to partly compensate for the fact that the interviews were performed several months after training.

After transcription, a semi-qualitative approach was adopted in the analysis, focusing on constructing categories of responses. This was done in two steps. Inspired by the concepts of meaning concentration and meaning categorization (Kvale & Brinkmann, 2009), all transcripts were first summarized with respect to each question and the content. Specific questions were then posed to the transcripts, responses related to them extracted, and categories of ideas inferred from them. Interview guides is found in Appendix E-F.

Computer log files of simulation activity

Log files of the participants' simulator actions were automatically generated by the simulator during training sessions. These included time stamps for the start and end of the session and of each task and sub-task, and it recorded in numerical terms the distance between the students' solutions and an ideal solution. Ideally, these log files would enable, for instance, direct group comparisons and insights into relations between time on task, quality of solution, and, when combined with observations, the characteristics of the narrative driving the solution. However, technical issues with the log filing system resulted in empty logs for several groups, and for this reason they came to play only a small role in the thesis. They are only used in Publication IV. How they were used is explained later in this chapter.

Using project data to explore collaborative ECAS in HCE ecology—reflections on ontology, epistemology, validity, and reliability

Two years into the LRiSE project I enrolled in the PhD program with the aim of writing a thesis about the topic. And halfway into the thesis, Luckin introduced the Ecology of Resources framework to the research community, and I began reworking the thesis in line with this perspective. These circumstances make the thesis to some extent a development of the LRiSE project, and to some extent a reinterpretation of and development of an ecology-of-resources perspective on work already done. Table 3 illustrates how data from the LRiSE project is used in the four publications drawn upon in this thesis.

Table 3. Project data uses thesis publications.

	Pub. 1	Pub. 2	Pub. 3	Pub. 4
Proficiency	A	A		B
Observation 1	A	A	A	B
Observation 2				A
Survey			A	
Interviews		B	A	
Log data				B

Note. The approximate extent to which the data is in central to the results presentation in each publication is indicated by *A* for central and *B* for peripheral.

So, what does this perspective capture? What exists in the eyes of EoR as applied in this thesis, and how do we gain knowledge about it? Inspired by Conole and colleagues (Conole, Littlejohn, Falconer & Jefferym, 2005), Luckin claims, regarding the distinction between different levels of abstraction between model and theory, that "(a) the Ecology of Resources model is a 'mediating form of representation' and (b) its theoretical approach is the Zone of Proximal Development, its theoretical position is sociocultural, and its theoretical perspective is social constructivist" (Luckin, 2010, p. 99–100). For Conole et al. (2005), a perspective gathers fundamental assumptions about learning processes and outcomes, a position gathers the empirically grounded descriptions of variables and relations, an approach refers to more practical applications, and the mediating form of representation is a model with an intended user and purpose that visualizes relations not experienced directly (Luckin, 2010, p. 8). Given the focus on the ZPD I believe others would agree with this (Schuh & Barab, 2007), even though Vygotsky may have considered himself to be an ontological realist (Bakhurst, 2007).

What, then, is a mediating form of representation, what is being represented, and what is being mediated? According to Luckin, the ecology of resources model represents the "learner in terms of the interactions that form a learner's context" (Luckin, 2010, p. 115) by identifying:

1. "[E]lements that make up the resources and filters of the Ecology of Resources" (Luckin, 2010, p. 125) and that are likely to filter learner interactions and impact what learners internalize.

2. “[R]elationships and interactions between resource elements and between learner and resource elements” (Luckin, 2010, p. 124), meaning relationships between context elements and learner and context.
3. Opportunities for adjustments (Luckin, 2010) that support the learner's interactions.

This focus on learners interacting with parts of a cultural context or agents acting with culturally developed mediational means (Wertsch, 1998) is common to sociocultural perspectives in which neither part can be meaningfully studied separately (Strauss, 1993). In formal education, the ecology may be interpreted by other researchers as an instance of the “social practice” of education that learners aim to master (e.g., Bakhurst, 2007, p. 54). The aim of designers is then to develop or improve this practice with respect to supporting learners in this endeavor, and the aim of this thesis may be interpreted as contributing to the production of a resource or tool, an ecology of resources model, that may inform, or even transform (Wertsch, 1998, p. 42) the designers’ practice-bound, tool-mediated actions.

As representations of ecologies, EoR models are “neither idealized nor intended to be a complete and faithful representation of the objective reality of a learner’s context" (Luckin, 2010, p. 111). They are instead intended as resources, tools to be used in the practice of redesigning learning activities through cycles of analysis and intervention (Luckin, 2010, p. 116). This means that the models are tools that are produced and refined within the social practices of research or design. Like the learners, researchers draw upon collective experiences, and use tools developed in a cultural context. Knowledge creation is thus distributed (Prawat & Floden, 1994) and evolves through social negotiation (Savery & Duffy, 1995).

The EoR framework does not prescribe the exact manner in which the explorations are performed (Luckin, 2010, p. 118). With regard to design, it is influenced by participatory design ideas, and from the cases Luckin describes it is clear that we are always in the midst of a cyclic process of constructing knowledge and artifacts. However, Luckin herself does not elaborate the framework for research. The process will be influenced both by the researcher, the beneficiaries, and the particularities of the ecology to be redesigned and the current focus. In line with a sociocultural perspective, knowledge must be viewed as socially constructed and distributed among people and resources. This goes for the research as well as the learning outcomes of interactions in ecologies.

Ecology exploration for research will include different materials for data construction. In formal education, one relevant source of data will be formal documentation about the ecology, such as curricula, which may inform us of the subject content included, the objectives and aims, tools and tasks, and so on. These are important aspects of the ecology and may help in identifying elements that make up the resources and filters of the Ecology of Resources, especially in the initial phases of the analysis. Previous research and analysis of the particular or general ecology may be a great source.

In more design-oriented cases conducted by Luckin's graduate students and described on the companion site of the framework (eorframework.pbworks.com), other examples of sources and data construction are revealed. These include sources such as staff handbooks, field documentation such as field notes and photographs of ecology locations, informal conversations with teachers, structured interviews, workshops, learner narratives, and existing research on resources related to this type of learning. Another case is built upon auto-ethnographic data. With respect to the aim of this particular work, which is developing collaborative ECAS in HCE, some of these sources will be more useful than others, and one important guiding principle is transparency. Informal conversations, for example, are not suitable foundations of empirical research. In line with this, I believe that as the analysis progresses to finer grains, empirical studies will always be needed for the particular ecology "relationships and interactions between resource elements and between learner and resource elements" (Luckin, 2010, p. 124).

How then, are my empirical contributions, the publications, related to the exploration of the particular collaborative radiology, to ECAS ecology, and to the general collaborative ECAS in HCE ecology as it now has been described? Given the EoR perspective, how should they be regarded in terms of validity and reliability?

Ideally, this type of controlled experiment can produce valid and reliable knowledge about the effects of particular ecology resources, or interactions of resources, on the learner's interactive process and development. However, this is dependent upon the quality of the experimental design and upon the instruments of measurement. The next section includes a discussion of issues directly related to the research question.

Proficiency data

The validity of proficiency tests as measures of development, and indirectly of the quality of instruction, is primarily dependent on the extent to which they represent development in a relevant sense. In the dentistry study, the tests were developed by researching teachers at the dentistry program, and were intended to capture both the practical analysis of radiographs and the principles behind it. While odontologists can discuss among themselves the extent to which this is captured by the specifics of the tests, this is beyond my competence and the interest of this text. The tests are directly related to that which is common to the two training sessions. The design of the tests gives little room for interpretation from the examiner; answers are either right or wrong. This ensures high test reliability, and the likelihood that the outcome of the test is not random. For the purpose of the publication in this thesis, as indications of individual proficiency and development the tests are considered to be valid and reliable.

Video observation data on interactive processes

How do these video analyses contribute to exploring the collaborative ECAS in HCE ecology of resources, to identifying resources, filters, and/or interactions? First of all, the data permit comparisons between ECAS and conventional ecologies with respect to some basic aspects of interaction, i.e., aspects of the content and shape of learner interactions. As such, conclusions can be drawn about how different ecologies encourage learner interactions differently. However, the extent to which these differences can be generalized beyond the particular pair of ecologies depends upon the extent to which the differences are general to the population of ecology pairs with respect to the specifics of the analysis. Publication I compares learner interactions in an ECAS ecology with learner interactions in an ecology where the central tool offers much less learner-tool interactivity. Interactivity is an important selling point for simulations, but it is possible that when comparing ECAS ecologies with other equally interactive ecologies, the key differences may be different. Obviously this will be less of an issue when comparing different implementations of the same technology, as I do in Publication 3. However, as multiple aspects of the ecology are changed at the same time, inferring relationships between particular changes and particular differences in outcomes must be done with caution.

In Publication I, data from simulation and conventional training are compared with regard to some components of the interaction during training sessions, i.e., its content and form. The fact that the categories for the coding scheme were inferred from initial exploratory observation makes them more relevant for the particular ecologies studied here.

Video observation data on more and less successful collaboration

One limitation of focusing on tendencies in large data sets is that the identified tendencies may not be very well understood, and in which case they are less relevant. This is one reason why, in the fourth publication, a more qualitative observation approach is adopted to zoom in on one of the tendencies identified in the previous observation analyses. It focuses on a particular aspect of interaction in collaborative ECAS ecologies, and describes the interactive process throughout a meaningful whole—a task cycle. Instead of segmenting interaction with a pre-defined abstract measure of time, it follows groups from where they interactively decide to begin and end tasks. And instead of categorizing utterances, it describes them in the interactive context that motivated them. It exemplifies how two groups, similar in some respects and dissimilar in others, actually interact during the solving of a task. This can then be contrasted with what research indicates is better and worse and supportive interventions can be discussed.

One criticism sometimes raised by other perspectives against this kind of qualitative case study concerns generalizability. The quality of generalization is dependent, the argument goes, on the extent to which the case is representative to the population, and without complementing the study with quantitative data or theory, it is limited. This is an issue of debate within research that is related to mine, CSCL (e.g., Dillenbourg et al., 2009). While the quality and rigor of the particular design are to some extent taken as insurance, it is also partly dealt with by arguing for flexibility in the supportive interventions encouraged by findings in specific studies (e.g., Dillenbourg et al., 2009; Weinberger, Kollar, Dimitriadis, Mäkitalo-Siegl & Fischer, 2009). In terms of learner modeling and scaffolding, interventions need to identify and adapt to, for instance, learner characteristics. From this perspective, case studies are useful; we just need more of them.

Survey data

Survey data are used in the third publication by enabling comparisons of the experiences of dentists and nurses. They are used together with quantitative observation data and interview data to discuss the impact that changes and adjustments to the collaborative ECAS in HCE ecology have on the content and direction of learner interactions. The strength of a standardized survey in this scenario is the relatively reliable quantification of responses. Because of the simplification involved in the construction of questions, the full complexity of some questions may be hidden and thus reduce the validity of the question-data relation. In some cases this can be reduced by complementing with other data sources such as observations or interviews.

Semi-structured interview data

Interview data have been used in publications 2 and 3, in relation to specific questions and in order to answer questions that were raised by the observation analyses. The interviews considered the learner's perceptions of aspects of the interactive processes and related issues. It should be noted that the use of interview data, as with survey data, reflects only a small portion of their original content and much more could be written about them. Their use has also been limited to creating categories of answers to quite direct questions, rather than having respondents define the interview and then having the interpreters make inductions by reading between the lines. As such, it is similar to a survey approach, with one exception—being able to ask clarifying follow-up questions in order to reduce misunderstandings.

Computer log files

Computer log files were used in the fourth publication. They were complete for the compared groups and informed the choice of observational units to be analyzed by indicating instances where the groups were engaging with the same task, the same anatomical area, and with a similar outcome. Outcome is defined in the computer logs as the distance between the groups' solution, i.e., localization of a foreign object, and a correct solution. To the extent that the solution is decided by reason and not by chance this measurement is very reliable; the groups would end up with the same position every time if their reasoning is intact. As an indicator of reasoning, however, it is quite opaque and would need to be read by an expert judge—or, as in my case, a novice with transcriptions of the groups' interactive problem-solving process.

V. Four publications on learning in collaborative health care ECAS

Publication I: How Does Collaborative 3D Screen-Based Computer Simulation Training Influence Diagnostic Skills of Radiographic Images and Peer Communication?

> Söderström, T., Häll, L.O., Nilsson, T. & Ahlqvist, J. (2012). How does collaborative 3D screen-based computer simulation training influence diagnostic skills of radiographic images and peer communication? *Contemporary Educational Technology*, *3*(4), 293–307.

Publication I reports the initial attempt to explore learning with a collaborative ECAS in health care education, the Radiology Simulator, by contrasting it with learning supported by a more conventional, more static tool. It explored how a part of the learning conditions, the tool, impacts interaction patterns and proficiency development.

The publication was built around an experimental comparison of dentistry students training either with the Radiology Simulator or with a conventional alternative, a MS PowerPoint slide (the dentistry collaboration study). The groups were compared with regards to both processes—by video recorded observations and outcomes—as defined by proficiency tests. Other conditions were kept constant.

Analysis of the process reveals that the tool impacts both the content of learners' verbal interaction and its form. Groups working with the ECAS engage much more in talk, descriptive and regulatory, about action. This includes descriptive comments on the actions or operations taken by the learner or her peers, and suggestions for actions. This should be understood as contrasted to talk about interpretations, which is the primary content of talk in the conventional groups. These interpretations are directed at describing, sharing, or creating understanding of what is shown on screen.

Participants in the ECAS groups, being more focused on what to do or what is being done, tend to apply context-dependent vocabulary, referring to a higher extent than the conventional group to objects as things on the screen. The conventional groups were much more inclined to use subject-specific terminology in their talk, referring to anatomical objects, relations, or principles.

Talk in the conventional group also demonstrated a stronger sense of continuity between utterances, i.e., they were more inclined to explicitly refer to what previously had been said and to build upon that. Talk in the ECAS groups lacked this more often than not.

The impressions from repeatedly viewing the video recordings of ECAS and conventional training side by side were that the peer interaction in the conventional group was more in line with theoretical ideas about learning through verbal collaboration. These groups seemed to often have a more transparent reasoning process. And yet, the proficiency tests indicated a better development for the ECAS groups. The ECAS group developed significantly from pre- to posttest, while the conventional group did not.

It was tentatively argued that the differences in development may be related to the more direct feedback provided by the simulation, which may support students' self-evaluative abilities. It called for theoretical grounding of ECAS research and suggested computer-supported collaborative learning (CSCL) as a potentially useful framework.

Publication II: Collaborative Learning with Screen-Based Simulation in Health Care Education: An Empirical Study of Collaborative Patterns and Proficiency Development

> Häll, L.O., Söderström, T., Nilsson, T., & Ahlqvist, J. (2011). Collaborative learning with screen-based simulation in health care education: An empirical study of collaborative patterns and proficiency development. *Journal of Computer Assisted Learning, 27*(5), 448–461.

Publication II was influenced by CSCL research and the general CSCL-questions of "under what conditions do specific interaction patterns occur?" and "what interaction patterns predict learning outcomes?" It attempted to explain why the conditions of the ECAS produced different interaction patterns than the conventional training, and how particular interaction patterns were related to proficiency development.

This publication was built around refined analysis of existing data from observations and proficiency tests complemented by interviews with a selection of participants in the dentistry collaboration study (reported in Publication I) regarding learning and interacting with tools and peers during training.

One of the findings from Publication I was that learners' application of subject-specific terminology seemed to be encouraged differently by the tools. Publication II explored the reasons for this. With support from learner interviews, it was argued that the task structure/objectives as well as the feedback given on tasks might impact learner interactions. When revisiting observation data, a quite strong correlation between the content of verbal activity and the terminology applied was identified in both settings. When engaging in interpretation, academic terminology is more likely to be applied. No correlations between the extent of subject-specific terminology applied and group proficiency development were identified.

Publication I indicated that interaction with the ECAS was a core activity for simulation groups. This motivated an investigation of how learners' share control over the simulation, and what the implications of this sharing could have. From the observations it was clear that groups handled this quite differently, with some groups demonstrating turn-taking behaviors while others were more characterized by dominance. We were, however, not able to identify any correlations between mode of operation and proficiency development.

In a similar manner it explored if and how learners shared the control over the verbal space, the talk, and the implications of this. Observations revealed dominance behaviors as well as more dyadic ones. No correlations between how groups shared control over the simulator and how they shared control over verbal space were identified, nor were any correlations with proficiency development.

The students were asked in interviews about the distribution of control in their group. They were aware that control was shared unequally. They suggested a few factors—mostly characteristics of participants and groups—that could explain this. These included personality, social relationships, competence, position in front of the computer, and more random contextual factors.

It was argued that a more qualitative analysis, following the students' problem-solving processes, is necessary to make more useful associations between collaborative patterns of tool usage and proficiency development.

Publication III: Designing for Learning in Computer-Assisted Health Care Simulations

Häll, L. O., & Söderström, T. (2012). Designing for learning in computer-assisted health care simulations. In O. Lindberg & A. D. Olofsson (Eds.), *Informed design of educational technologies in higher education: Enhanced learning and teaching* (pp. 167–192). Hershey, PA: IGI Global.

Publication III was the first attempt to apply Luckin's Ecology of Resources as a means for analyzing, researching, and designing simulation training. It compared two different collaborative ECAS in HCE designs and explored how specific design choices may filter learner interaction with peers (people) and the simulator (tool).

This publication was written during the LRiSE project's third year. At this stage, a new version of the Radiology Simulator had been developed that focused on the cervical spine rather than the jaw. It was implemented into the curriculum of a course for students at a program for diagnostic radiology nursing. Nurses training with the ECAS were video recorded and their experiences were gathered by means of a survey and follow-up interviews (the nursing collaboration study). Process and experiences were compared to data from the dentistry collaboration study.

The design of the dentist and nurse simulations differed in a few respects. Participation was voluntary in the dentistry simulation, and compulsory for the nurses. Group creation was random for dentists, and student-controlled for nurses. Group size was three for dentists, and two for nurses. Duration was 1 hour sharp for all dentists, and up to 2 hours for nurses. A teacher was observing the dentistry simulation, and was available on request for nurses (they needed to walk to the teacher's office to get support). These design changes were thought to better support learners' interactions in the ECAS ecology.

With some assumptions about causes and effects, it was investigated how teacher presence and group creation and size filter learner interaction with peers and with the simulator.

The publication indicates that having a teacher present during ECAS training:

1. Decreases the amount of time students spend discussing technological issues.
2. Does not impact time spent on social talk.
3. Decreases the need for high-quality instruction.
4. Does not impact the perceived sufficiency in simulation feedback.
5. Does not impact engagement with the simulation tasks.
6. Increases the perceived need for having a teacher present.

The study also indicates that reducing group size and letting students choose partners themselves:

1. Increases the actual equality of distribution of control over the simulator.
2. Increases the perceived equality of the same.
3. Increases the inclusiveness in the verbal activity.
4. Increases the perceived inclusiveness in the verbal activity.

Based on these results it was argued that in ECAS training group creation and size clearly act as filters for learner interaction with both peers and the tool. Fewer members and learner-controlled choice of partner seem to be beneficial in important respects. It was also argued that teacher presence filters learner interaction with the tool. When learners' experience with the tool is lacking, the need for a teacher's presence may increase. Other than that, students seem to do fine or even better without a teacher present. The filtering effects discussed may be impacted by interactions with other resources and filters, such as the aim of the ECAS, the technology, type, and quality of feedback, and by participant characteristics.

Publication IV: Structuring Collaborative Learning with Screen-Based Simulation in Health Care Education: An Empirical Contribution

Häll, L. O. (2012). Exploring collaborative training with educational computer-assisted simulations in health care education: An empirical ecology of resources study. *Creative Education*, *3*(6), 784–795.

Publication IV explored collaborative learning with the radiology ECAS by comparing the interactive processes of a more successful and a less successful group during their solving of an ECAS task. Particular focus was on the relation between silent participants and their peers, which here was regarded as potential MAPs. In Luckinian terms it explored opportunities for adjustments in the relationship between more able partners and silent learners when using a radiological ECAS under free peer collaboration.

This publication was primarily based on an in-depth qualitative analysis of a selection of the process data (from the dentistry collaboration study), i.e., video-based observations. Two dentistry simulation groups were studied during the solving of the same task. The groups were chosen based on similarities in participant characteristics, pre-training proficiency, and distribution of control, combined with dissimilarities in proficiency development.

The transcript analysis reveals similarities and dissimilarities in the interactive problem-solving process for the two groups. I argue, however, that both groups are united by the central challenge of actually engaging in collaborative activity and learning, i.e., for the silent learner and MAPs to engage in interaction aimed at constructing a shared understanding of challenges and potential solutions in the problem-solving process. This is manifested differently in the groups. In the less successful group the MAPs, for instance, only contribute unelaborated conclusions, while the MAPs in the more successful group elaborate more but still pay less attention to the silent learner than to eachother. It is argued that excluding forces are at work, that students may have overconfidence in the sharedness of their understanding, that mutual responsibility for the result is disrupted, that solely beating the tasks is not enough for development to occur, that incentives and support for collaboration are necessary, and that collaborative scripts may function as such support.

As a means of overcoming the challenges identified in the study, a means of adjusting interaction between silent learners and MAP, collaborative scripts are suggested as potentially beneficial filters. It is suggested that these scripts could be built around a refinement of the learner roles identified through observations: operator and observer/regulator. It is speculated about what these roles could look like and how they could overcome the specific challenges.

Contributions to exploring the ecology of collaborative ECAS in HCE ecology

The four publications summarized in the previous section represent partial explorations of collaborative learning with collaborative ECAS in HCE, by exploring relations between the resources and filters of a collaborative radiology ECAS ecology, learner interactions, and learning outcomes, in order to identify opportunities for development of educational simulation practice. They are motivated by the preceding analysis of both the type and sample of collaborative ECAS for HCE. They are focused on how interaction between the people and tool resources of the ecology, primarily simulator features and peer group characteristics, encourage certain interactive patterns and result in proficiency development. Table 4 summarizes the results from an ecology-of-resources perspective.

Table 4. Summary of publications from an ecology-of-resources perspective.

	Ecology element		Filtering effect on		Filtering effect on
PUB I	Tool	→	Interactive process	+	Learning outcomes
	Whether ECAS or image-pair analysis is the applied filter…		…what learners talk about (content) and how they talk about it (terminology and pattern), as well as…		…proficiency development from pretest to posttest.
PUB II	Tool	→	Interactive content	→	Interactive patterns
	Simulator objectives and task structure filter…		…what learners talk about (content), which filters…		…how they talk about it (terminology and pattern).
	People	→	Emergent roles	=/	Learning outcomes
	Participant and group characteristic filters…		…the distribution of verbal space and control over simulation, but this does not decide…		…proficiency development for individuals or groups.
PUB III	People	→	Interactive content	+	Perceptions
	Teacher presence filters….		…time spent talking about technology and…		…perceived need for high-quality instruction, and
					perceived need of teacher presence.
	Group size and creation filters…		…who gets to talk and how much, equality, and inclusiveness and…		…perceptions about inclusiveness
PUB IV	People	→	Interactive process	+	Learning outcomes
	Lack of collaboration support contributes to…		…widely differing interactive patterns, lacking collaboration, unelaborated conclusions, exclusion, and…		…silent learner proficiency development.

Table 4 illustrates a sequential development, from Publication I-IV, from a coarser to finer granularity of analysis. As such it illustrates a variety of empirical foci encouraged by the interpretation of the Ecology of Resources framework adopted in this thesis. It illustrates that no single study captures the full complexity of a collaborative ECAS in HCE ecology; even taken together these four publications do not render a complete picture. It is an indication of the complexity of the approach.

The next chapter will discuss and analyze some of the key findings presented here. It will consider what it means to participate in collaborative ECAS in health care education. It will discuss challenges, opportunities and means for development and it will consider questions that will need to be answered through further research efforts. Finally, it will reflect upon the challenges facing SBME research and challenges to the approach adopted in this thesis.

VI. Prospect, retrospect

In this thesis the accelerated interest in health care education simulations has been interpreted as a manifestation of internal tensions and need for development, and challenges for research on the topic have been identified. To meet these challenges a new approach to conducting research on the topic has been explored by drawing upon Luckin's Vygotsky-inspired Ecology of Resources framework for analysis and redesign. It has been applied to an uncharted part of the field, collaborative learning with ECAS in health care education. In this section, the empirical and conceptual outcomes of my work will be discussed in retrospect, and prospects of future research and of future applications of ECAS in health care education discussed.

The empirical contribution

With the ecology-of-resources perspective adopted in this thesis, the learning of participating students of dentistry and nursing is an interactive processes situated in a context, an ecology of collaborative educational computer-assisted radiology simulation. Individual, conscious, goal-directed efforts of students are important, but they are always filtered by contextual resources. Students are acting in and through a context that they themselves contribute to upholding. Their interactions are guided by ecological structures, resources filters, and relations between them that surround them and they are part of. They are encouraged to engage with a tool that presents them with challenges related to some particular pre-determined bodies of health care-based knowledge, designed by others with particular characteristics to support their learning of skills and the concepts related to them. Other parts of this context are also influenced by previous actions of others; there are limitations in time available for this particular activity, it is located in a particular physical environment, and participants are expected to achieve goals interactively with other students and possibly instructors. To this context they bring already achieved learning, dispositions, competences, peer-relational identities, and an appreciation of heuristics guiding local practice.

The empirical contribution of this thesis is this exploration of a part of the ecology of collaborative ECAS in health care education. Further research efforts, of other parts of the ecology, are needed to reach a more complex description.

The empirical exploration has been guided by the questions, What are the relationships and interactions between resource elements and between learner and resource elements? and, How does this help us identify opportunities for adjustment and scaffolding? What follows is an analysis of the empirical findings from the perspective of an ecology-of-resources framework.

The empirical contributions show that the central tool, the simulator, and its characteristics have a great impact on the interactions that students engage in—both interactions with the simulation and interactions with peers. Publication I explored this filtering effect of simulator-on-peer interaction and development. It showed that moving from one collaborative computer-based tool, the established format of more static image pair analysis, to collaborative ECAS shifted the content and character of peer interaction. It changed the content from being more about discussing image-pair interpretations toward being more about actions with the tool, away from collaborative building of a narrative that explains differences toward finding a travel route from one virtual location to another through actions with the simulator.

It was not only the content of interactions that changed, but also their form. It was harder to identify and follow the trajectory of simulation talk. Whereas image-pair talk was more much based on explicit verbal dialogue, the simulation talk moved toward more sporadic contributions with directives for actions or comments about actions. It is as if part of the interactive thinking changed from being mediated by words to being mediated by simulation actions. But to what extent this mediated thinking was actually shared among participants is unclear; whether they shared understanding or just thought that they did is unclear. The terminology also changed, from being drawn from the knowledge and skills and being subject-specific to being more context-dependent or ordinary. For Vygotsky, the use and appropriation of scientific concepts, as opposed to spontaneous ones, played an important part in development. With Publication II, a close relationship between content and terminology was identified. When simulation participations engaged in interpretations, the use of these scientific concepts was significantly more frequent than when they were talking about actions. But the simulation ecologies' encouragement of action indirectly changed the terminology applied. However, looking closer at the specifications of the tools, this may not be fully a question of media but may be partly explained by adaptable features. Publication II suggested that the formulation of tasks and the feedback given about them could explain in part the content and shape of interactions. Receiving textual feedback formulated as relations between scientific concepts encourages, to a larger extent than feedback given as numerical information about the distance between an ideal solution and one's own solution, the application of these same concepts. While there are numerous ways of engaging with a body of knowledge, the specific tasks do filter the actions.

The simulator is one of the central resources in the collaborative radiology ECAS ecology, and seems to, through its tasks, encourage a focus on filtered simulator action. Another central resource is peers, and the filtering expectations of collaboration between them. The presence of others—equals in the sense of being students with the same formal level of program progression—changes things. Several very basic questions are actualized, including: How should we go about doing this together? Who should do what? If you do that, what do I do? The answers to these questions can in part answered by other structuring resources and/or filters in the ecology, such as the simulator. The Radiology Simulator, and perhaps most simulators except for those focused on team training, has not been designed for collaboration. It is designed to be operated by one person at a time. But like others it offers the opportunity for collaboration through the materialization of the product of thinking processes, i.e., that the simulator operations are visual and perceivable by others. This offers the opportunity for multiple participants to engage simultaneously. It is possible to negotiate actions and operations before carrying them out. This is, however, not explicitly encouraged by the Radiology Simulator, and the reasons for operations are hidden in the head of the operator to the point where he verbalizes them. Other resources could also filter this interaction, such as instructions on how to collaborate. These were not given in the radiology simulation, leaving students to rely perhaps mostly upon previous experiences of group work.

These publications illustrate the tension between tool and people filters, between simulator characteristics and collaboration, through the different ways in which groups end up interacting. The distribution of control over the simulation varies, from being operated by only one person throughout the training session to operators changing after each completed task. The distribution of verbal space varies, from everyone being almost equal to someone rarely speaking. The causes are partly hinted at in the empirical data; peers can encourage and discourage contributions of others proactively by asking questions and reactively by the responses given to them. Interviews also indicate that perceptions of relative competence, personality, and social relationships act as filters, as does the physical position relative to the simulator. When three people crowd in front of a computer, the spot you are in may actually impact your say in the activity. Being perceived as more competent gives you more say, as does being in a closer social relationship with one of the others. This is likely why, as Publication III indicates, being able to choose whom to work with and working in smaller groups can increase the objective and perceived inclusion in the collaborative activity. Also, more random factors such as having a bad day can also impact the role you adopt and the role you enable others to adopt.

Teachers or instructors can be an important resource and filter in simulation ecologies. They are often forgotten, and regretfully these publications do not consider their role in much detail. It has been indicated that teachers can play an important function as technical support when the something goes awry, and can substitute to some degree prior instruction. They may also keep students from asking “stupid questions”, which may in fact be very helpful.

What is attempted here is not a complete summary of all articles, but rather to construct a narrative grounded in the ecology-of-resources approach that gathers the central issues of learning in collaborative ECAS in health care education ecologies.

Examples of questions in need of further investigation include: What is the relative importance of the resources and filters of the interactions that students engage with and the learning that results thereof? How do they interact? To what extent should we leave students to themselves to discover and/or apply correct or good procedural principles? Is it possible to formalize and script them? If we adopt Vygotsky's law of cultural development, and the interpretation that what learners first do interactively and externally they are likely to later do individually and internally, how can we support expected or appropriate interactive behavior? How is, or should, learning in this ecology be related to the participants’ general development into professionals?

A general conclusion of this ecology-of-resources analysis is that when collaboration is applied as a structuring technique for ECAS training, it will benefit from and require specific support for peer interaction. Similar conclusions are repeated by CSCL researchers dealing with other populations and technologies (e.g., Dillenbourg et al., 2009). In the LRiSE studies, students were left to themselves in terms of deciding how to collaborate. The Radiology Simulator EoR obviously provides learners with guidance in many respects, through the features of the knowledge and skills, the tool, people, and even environment. It was, for instance, demonstrated that simulation participants are encouraged to engage more in doing than are the students in the image-pair analysis group. However, the Radiology Simulator EoR, and all other collaborative ecologies, will create particular interactive challenges for learners to overcome. These will need to be identified and further support needs to be developed to overcome them. The empirical studies in this thesis indicate that students training with the Radiology Simulator may benefit from additional filters for:

1. Engaging in explicit dialogue about relations between context-dependent doing and subject-specific principles and terminology.
2. Sharing control over simulation operation and over verbal space and avoiding exclusion.
3. Encouraging thorough engagement with feedback.
4. Dealing with technical aspects of the simulation when no teacher is present
5. Regarding collaborative learning as the objective of the activity, in contrast to individual or cooperative task completion.

These challenges may be overcome by developing adjustments to the collaborative ECAS in HCE ecology, which is the main content of Phase 3 in the EoR framework. Luckin describes seven types of interactions that can be subject to adjustments: 1) resource element interactions; 2) the relationship between learner and MAP, how bi-directional it should be, and so on; 3) interaction between and coordination with multiple MAPs; 4) interactions between different resource elements such as peers and the simulator; 5) interactions between resource filters; 6) interactions within resource elements, such as between tools and people; and 7) within-filter interaction. All these types of adjustments are useful to consider when developing collaborative ECAS in health care education.

Publication IV, for instance, discussed filtering peer interaction as a venture in line with the aim of collaborative scripts (e.g., Weinberger, Kollar, Dimitriadis, Mäkitalo-Siegl & Fischer, 2009), and argued that this line of research may work as a useful source of inspiration. Collaborative scripts have gained some popularity within the research community of CSCL research, at least in Europe (Fischer, Kollar, Mandl & Haake, 2007). This script research shares the interest of Luckin and SBME research in the development of technology as well as of techniques (Stahl, 2011). The scripts share some similarities with what is sometimes discussed as simulation scenarios (e.g., Kollar, Fischer & Hesse, 2006; Dieckmann, 2008). They can include, in general terms, a distribution of participant roles, sequencing of actions and activities, and a more or less detailed description of how the roles and scenario should be enacted (Weinberger et al., 2009). It is possible to differentiate between micro scripts and macro scripts, where macro refers to higher-level structural features of the ecology such as group creation and micro scripts are more directly focused on filtering dialogue (e.g., Dillenbourg & Hong, 2008). These collaborative scripts are often referred to as external (Kollar et al., 2006), in contrast to the internal scripts, which an individual already has embodied.

The scripts are materialized in cultural artifacts and filter the peer interaction. Micro scripts “represent the procedural knowledge learners have not yet developed” (Weinberger et al., 2009, p. 162) and are complementary to the experience of the participants, i.e., their internal scripts. Like training wheels, scripts are particularly important for students in novel situations, but they need to be adapted or faded out as the learners masters the tool, or become more competent actors or more self-regulated learners, so as not to impede learning (Dillenbourg, 2002). The basic idea is that the script acts as a scaffold, or filter, affording learners to do something they would not or could not do without support, to develop more, and to appropriate this external support. CSCL scripts are aimed at helping students build and maintain a shared understanding, supporting the collaborative process and conceptual development. Scripts are directed at inducing explicit verbal interaction, such as explanations, negotiations, argumentations, and mutual regulation (e.g., Weinberger et al., 2009).

Research on collaborative scripts is greatly inspired by the idea of scaffolding and in line with Luckin’s framework. For those like me with an interest in applying Luckin’s framework and with a particular interest in peer interaction, I believe that research on collaborative scripts can offer good resources both for identifying and developing filters.

However, the specifics of such scripts will be left to future research efforts. The curious reader may, however, refer to final section of Publication IV for some early speculations.

The conceptual contribution

The conceptual contribution of this thesis is the interpretation and introduction to the field of a new theoretical framework for analysis, redesign, and research. It has been applied in order to meet some of the current interests and needs of the field. These include a) a theoretical foundation for research; b) attending both to technology and to application, to simulator and simulation; and c) balancing between the need and interest in research that has clear usability in health care educational practice and the tradition of laboratory and experimental research that comes naturally to researchers schooled in medicine. Sociocultural perspectives highlight the situatedness of action and learning in contexts, which also highlights the limitations of laboratory education research.

Luckin's ecology-of-resources framework is a theoretical development of a combination of Vygotsky's zone of proximal development, Wood's scaffolding, and a range of conceptualizations of context. This framework highlights learners’ interaction with and through contextual resources offered in simulation, including the simulator. It is, as of today, not fully elaborated with respect to the relation between redesigning and researching ecologies of resources. This thesis explores one way of elaborating this relationship. It is an attempt to find a position between the complex and creative design-based research and classic experimental research. This includes a focus on learner interactions in context, or agents acting with mediational means in context (Wertsch, 1998); it accepts the idea of empirically focusing on more or less controllable variations in context design.

A weakness and strength of this approach is that it is focused on identifying and generalizing to a type of simulation context. It requires a delimitation of simulations and simulators of similar characteristics in order to allow for meaningful generalizations to a type of context. This is one step away from studying one particular application, and one step away from trying to generalize universally by ignoring contexts. The intended benefit of this is the opportunity to study educational practice in its complexity and still be able to develop concepts, models, and theories that are applicable beyond the particular.

Adopting this approach will be challenging, however, for several reasons. It will require researchers to identify, disentangle and reassemble a wide range of interacting variables, and do this by constructing and analysing side by side multiple, large datasets using both quantitative and qualitative methods. It is also essentially an iterative, longitudinal endeavor that encourages teams of researchers to collaborate intimately on a topic for longer periods of time. Also, its focus on improvements does not provide much guidance as to when to pursue and when to abandon a design.

One area that deserves further attention is the interpretation of Vygotsky's zone of proximal development that underlies Luckin's framework. There is an ongoing debate about how Vygotsky's works can or should be read, illustrated, for instance, by the *PsyAnima* journal, and there are interpretations that differ from Luckin’s. In Chaiklin’s reading of Vygotsky, the support offered by more able partners needs to be directed at that which takes the learner to the next developmental level. Just supporting learning in general would not be enough. This requires much more from the MAPs, not only identifying a learner’s need in relation to specific tasks, but in relation to the larger sociocultural context. This type of learning support may be easier for primary education, where one or a few teachers are in charge of teaching all subjects. At later stages, it will be more difficult for subject teachers to really see the whole picture. It requires a good analysis of the sociocultural environment and of the learner. The teacher would need to understand and focus on the whole sociocultural practice of which the learner is part, have a very good understanding of the learner in relation to this practice, and finally direct the learner to that which may help her to develop, and not just learn.

Prospects of future research and practice

When setting their research agenda for simulation-based health care education, key actors of the European and American communities (Issenberg et al., 2011) make several noteworthy claims. Referring to the current state of simulation HCE, they argue that research in terms of its impact on clinical performance is of the highest national interest and importance; that "this recognition extends beyond those educators in the simulation community" (Issenberg et al., 2010, p. 155) and that some institutions allow as much as 25% of clinical training today to be performed in simulated environments (Issenberg et al., 2010, p. 160). One fourth of clinical training is an indication of the developing magnitude of simulations in health care. Issenberg et al. (2011) argue that the research field is new and developing, but it needs to move beyond "descriptions of how local institutions use its simulation systems" and beyond "research that is intended to prove the effectiveness of our educational endeavors and towards research that aims to understand the complexity inherent in those activities" (Issenberg et al., 2010, p. 160). In other words, research on ECAS in health care education needs to become more complex; it has to open the black box of learning in context. It needs to be "grounded in a theoretical or conceptual framework" (Issenberg et al., 2010, p. 159). While this may seem obvious for a researcher of *pedagogik* in a Swedish context, this should not be regarded as trivial or uncontroversial. Research on medical education, just like research on primary and secondary education, is under continuous assault from other parties, often with the edge directed at methodologies that take steps away from laboratory experiments (e.g., Colliver & McGaghie, 2008) and thus toward dealing with the messiness of actual education and learning practices. Educational research is in direct crossfire by needing legitimacy from both educational practices and from (medical) research practices. When describing the evolution of American medical education during the 20th century, Cooke and colleagues describe a shift from a close interweaving between researching and teaching toward the molecularization of specialties and a "'publish or perish' culture" where "research quickly outstripped teaching in importance" (Cooke, Irby, Sullivan & Ludmerer, 2006, p. 1340). A conflict between the needs of teaching practice and the needs of research practice does not benefit anyone (except perhaps those writing about it). This challenge is at the core of SBME research. This gulf must be bridged, and external support from related research fields may be helpful for those trying to build this bridge.

While research in the field may be “still at an early stage”, as Issenberg et al. state (2011, p. 155), it can be argued that there is actually extensive research on related topics if we just look beyond the characterizing technologies, the simulators. There exists, for instance, a lot of research on other instructional techniques or methods within health care education, such as PBL (e.g., Hillen, Scherpbier & Wijnen, 2010), which have gone through cycles of development and may have made collective experiences worth learning from. Engeström, developer of the cultural historical activity theory, sums up the idea: “The distinctive feature of human activity is that it is continuous creation of new instruments which in turn complicate and change qualitatively the very structure of the activity itself” (Engeström, 1987). Simulation may be considered new (it may also not be), but the introduction and potentially revolutionary impact of a tool on an educational activity is not. It can be fruitful to consider health care simulations as an instance of technology-enhanced learning research, performed by researchers in the learning sciences. Over the last five decades, much effort has gone into studying the impact of digital technologies under the umbrellas of computer-assisted instruction, intelligent tutoring systems, logo-as-Latin, computer-supported collaborative learning, and more (e.g., Koschmann, 1996). At first glance, this may seem completely peripheral to simulations researchers in health care education, but looking back at the development of TEL research, or even a part of it such as CSCL, we can identify similarities with the development of SBME in terms of research communities—for example, the move from general media effectiveness comparisons to the more initiated questions of under which conditions does this work (e.g., Dillenbourg et al., 1996). Looking at the terminology of SBME research, it may seem similar to the earlier CAI and ITS research based on behaviorism and information processing theories. What lessons can be learned from this? What were the defining factors that led to the development of later approaches, ones toward which SBME may now be moving? What new challenges have emerged within later developments? I have in this thesis drawn upon some conceptual and empirical findings from CSCL, but I am fully convinced that much more can be gained by dialogue and exchange between general TEL research and SBME.

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Appendix A. Guide for observation coding (in Swedish)

Variabel 1 – Operatör

Noterar vem som primärt kontrollerar styrredskapen under tidsblocket. Antas, med viss underbyggnad, samspela med fördelningen av talutrymme.

Problemscenario 1: Olika deltagare kontrollerar olika styrredskap (ex. ’pennan’ och tangentbordet) under samma block. Har inträffat enstgaka gång; löstes genom att ta hänsyn till vem utförde handlingar med redskapet.

Problemscenario 2: Två deltagare kontrollerar samma styrredskap under lika stor del av blocket. Har ej inträffat.

Problemscenario 3: Ingen har synbar kontroll över redskapen. Har hänt i Bildgranskningsgrupp; löstes genom att notera den som senast haft kontroll över styrredskapet eftersom denne konsekvent var den som vid nästa tillfälle utövade kontroll.

Problemscenario 4: Deltagarna byter plats. Har hänt; löstes genom att notera bytet och låta benämningarna byta värde.

Variabel 2 – Primära interaktörer

Noterar vilka två deltagare som upptagit mest talrymd under blocket. Antas, med viss underbyggnad, samvariera med intern kommunikation mellan dessa två deltagare.

Problemscenario 1: De två deltagarna upptar mest utrymme, men talar inte med varandra. Har inträffat; löses genom kompletterande variabel Typ.

Problemscenario 2: Det är endast en person som talar. Har inträffat, men endast med Läraren som talare; löstes genom att ge läraren en särplats där denne kan noteras som enväldig Primär kommunikatör.

Problemscenario 3: Ingen talar. Har hänt; löses genom variabelvärdet Tveksamt.

Problemscenario 4: Deltagarna talar mycket sparsamt i en grupp/vid ett tillfälle och mer omfattande i annan grupp eller tillfälle, vilket alltså problematiserar direkt jämförelse. Har hänt; ingen lösning.

Variabel 3 – Mest talutrymme

Noterar den deltagare som upptar det mesta av talutrymmet. Antas samspela med kontrollen över styrredskapen och därigenom med inflytandet över aktiviteten i gruppen.

Problemscenario 1: Ingen talar. Har hänt; löses genom variabelvärdet Tveksamt.

Problemscenario 2: Två deltagare upptar till synes lika mycket talutrymme. Har hänt, löses genom variabelvärdet Tveksamt.

Variabel 4 – Innehåll

Noterar innehållet i deltagarnas kommunikation. Antas, med viss underbyggnad, variera mellan övningformerna.

1. *Lösningar*. Åtgärdsförslag som döljer tolkningen, exempelvis: Vrid den så. Gör så här. Gå tillbaka. Vi borde röra den 'distalt'.

2. *Tolkningar*. Verbalt artikulerade tolkningar av (primärt) skrämbilden, av den aktuella 'läget', av andra verbala utsagor o.d.. Inkluderar underbyggda lösningsförslag. Exempelvis: Den här linjen, är det tandfilsfragmentet? I så fall... Den här linjen är kortare på den undre bilden, alltså borde vi...

3. *Funktionalietet*. Diskussioner kring tekniken, hur den fungerar.

4. *Metareflektioner om lärande*. Uttalanden relaterade till lärandet i den aktuella miljön.

5. *Teori*. Teoretiska resonemang, med eller utan akademiska termer, som förklarar bakomliggande premisser eller tankemodeller. Exempelvis: Grundtanken är att utgå ifrån anatomiska strukturer som vi vet var de är. Alltså...

6. *Socialt*. Anekdoter och skämt m.m. utan tydlig koppling till träningen.

7. *Kommentarer*. Kommenterar handlingar, förlopp och skärmbilder, beskriver vad som händer.

Problemscenario 1. Kommunikationen skiftar kontinuerligt över hela övningen mellan två eller fler teman varför kategoriseringen blir obrukbar. Har ej hänt.

Variabel 5 – Typ

Noterar huruvida den verbala aktiviteten är av gemensam (dialog) eller individuell karaktär (monolog), samt om den aktiviteten är verbalt sammanhängande eller om den är segmenterad och därigenom svårgreppbar. Antas, med viss underbyggnad, variera mellan de två typerna av övningar där simulatorövningen medför mer fragmentarisk och individuellt tal.

1. *Gemensam segmenterad*. En flerstämmig verbal aktivitet som hoppar logiskt och/eller innehållsmässigt på sådant sätt att en lyssnare får mycket svårt att hänga med.

2. *Gemensam sammanhängande*. En flerstämmig diskussion, kring ett relativt tydligt avgränsat fenomen, som sträcker ut sig över tid. En eller flera kan uppträda under ett och samma block.

3. *Individuellt segmenterad*. Individer för självständigt/fristående från de andra en verbal aktivitet, kring ett fenomen, och hoppar logiskt och/eller innehållsmässigt på sådant sätt att en lyssnare får mycket svårt att hänga med.

4. *Individuellt sammanhängande*. En individ för självständigt/fristående från de andra ett resonemang, kring ett fenomen, som sträcker ut sig längre i tid.

Problemscenario 1: talet är sammanhängande i korta enheter, dvs det är sammanhängande, men normala avbrott som uppgiftsbyte avbryter sammanhanget. Har hänt; löses genom att se till enheterna.

Variabel 6 – Språk

Noterar det primära språkbruket under blocket. Antas, med viss underbyggnad, variera mellan de olika typerna av övningar.

1. *Vardagligt/starkt situationsbundet*. Utsagor och diskussioner förs i stort sätt uteslutande mha starkt situationsbundna hänvisningar till

fenomen. Exempelvis: Den där är under den där, så då kan vi titta på den där.

2. *Akademiskt/mindre situationsbundet*. Utsagor och diskussioner förs med starka inslag av icke situationsbundna, akademiska och/eller ämnesspecifika termer och resonemang. Exempelvis: Om du rörde den distalt, då borde bollen ha rört sig mesialt. Då är den väl buckalt?

Situationsbunden, inslag av ämnesspecifikatermer. Utsagor och resonemang är primärt situationsbundna, men ibland används en ämnesspecifik terminologi.

Appendix B. Questionnaire for dentistry simulation participants (in Swedish)

Namn:______________ Kön: ❒ Kvinna ❒ Man Ålder:____

____

1. Bedöm dina erfarenheter av följande:

	Ingen erfarenhet				Mycket stor erfarenhet
Att använda persondatorer (pc eller mac).	❒	❒	❒	❒	❒
a) Att använda eller spela 3d-simulatorer.	❒	❒	❒	❒	❒
b) Att arbeta med 3d-simulering (ex CAD, ’level editing’ eller dylikt).	❒	❒	❒	❒	❒
c) Att arbeta i smågrupper på universitetet.	❒	❒	❒	❒	❒
d) Att arbeta i grupp framför en dator.	❒	❒	❒	❒	❒

❒ Kommentar:

____

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2. Vilken relation skulle du säga att du har till de övriga deltagarna i din grupp? Välj *ett* alternativ.

❒ Jag är *bekant* med de övriga deltagarna i min grupp sedan tidigare.

❒ Jag brukar umgås med de övriga deltagarna i min grupp.

❒ Annat:

____

____

3. Vilken var din spontana reaktion på att ingå i simulatorgruppen? Välj *ett* alternativ.

- ❐ Jag tyckte att det lät kul.
- ❐ Jag tyckte att det lät jobbigt.
- ❐ Jag tyckte att det lät utmanande.
- ❐ Jag blev stressad.
- ❐ Jag blev mer motiverad.
- ❐ Jag var likgiltig.
- ❐ Annat:

____

____

4. Vilken typ av kunskaper och färdigheter anser du att de tidigare kurserna i din utbildning *framförallt uppmuntrat till* (i instruktioner, uppgifter, instuderingsfrågor, examinationer)? Välj *ett* alternativ.

		Instämmer inte alls				Instämmer helt
a)	Faktakunskaper.	❐	❐	❐	❐	❐
b)	Att förstå sammanhang, lösa problem och dra egna slutsatser.	❐	❐	❐	❐	❐
c)	Att kritiskt granska, själv ta ställning och producera ”egen” kunskap.	❐	❐	❐	❐	❐
d)	Att använda och utveckla den egna personligheten i arbetet med innehållet.	❐	❐	❐	❐	❐

❐ Annat:

____

____

5. Hur fungerar du i undervisningssammanhang?

	Instämmer inte alls				Instämmer helt
a) Jag försöker vara aktiv och delaktig i grupparbeten.	❒	❒	❒	❒	❒
b) Jag försöker, genom att diskutera, hjälpa andra att klargöra sina argument.	❒	❒	❒	❒	❒
c) Jag föredrar att arbeta självständigt.	❒	❒	❒	❒	❒
d) Jag känner mig obekväm i grupparbeten.	❒	❒	❒	❒	❒
e) Jag tar gärna initiativ till diskussion.	❒	❒	❒	❒	❒
f) Jag uppmuntrar andra att delta i grupparbete.	❒	❒	❒	❒	❒

❒ Annat:

____

____

6. Vad är viktigt för ditt lärande?

	Ej viktigt				Mycket viktigt
a) Inhämta mera kunskap.	❒	❒	❒	❒	❒
b) Lära mig att komma ihåg.	❒	❒	❒	❒	❒
c) Samla fakta och metoder som kan användas praktiskt.	❒	❒	❒	❒	❒
d) Förstå hur någonting fungerar.	❒	❒	❒	❒	❒
e) Växla mellan att uppleva och att tolka.	❒	❒	❒	❒	❒

❒ Annat:

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Frågor om lärmiljön

Under den här rubriken kommer vi att ställa frågor om dina upplevelser av läraren, uppgiften, simulatorn och av arbetsgruppen. När vi skriver ’övningen’ menar vi den simulatorövning som du nyss genomfört.

Frågor om läraren

7. Den här frågan handlar om din upplevelse av läraren som stöd för din grupp under passet. Hur väl stämmer följande påståenden överens med din uppfattning?

Läraren…	Instämmer inte alls				Instämmer helt
a) … var ett bra stöd för mitt deltagande i aktiviteten.	❐	❐	❐	❐	❐
b) … uppmärksammade oss på centrala element i det vi ägnade oss åt.	❐	❐	❐	❐	❐
c) … hjälpte oss att skapa en gemensam förståelse för målet med aktiviteten.	❐	❐	❐	❐	❐
d) … hjälpte oss att resonera med ämnesspecifika termer.	❐	❐	❐	❐	❐
e) … hjälpte oss att utnyttja våra skilda perspektiv för att förstå ännu bättre.	❐	❐	❐	❐	❐
f) … gjorde så att vi kände oss pressade av tiden.	❐	❐	❐	❐	❐
g) … gav oss inflytande över aktiviteten under arbetspassen.	❐	❐	❐	❐	❐
h) … hjälpte oss att reflektera över aktiviteten i gruppen och att utvecklas som grupp.	❐	❐	❐	❐	❐
i) … vägledde oss i gruppen med hjälp av i stunden relevanta frågor.	❐	❐	❐	❐	❐
j) … bidrog till att mitt självförtroende relaterat till ämnet stärktes.	❐	❐	❐	❐	❐
k) … spelade en ganska liten roll från början till slut.	❐	❐	❐	❐	❐

❐ Annat:

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____

8. Skulle du säga att lärarens insatser behöver förbättras på något av följande områden?

	Instämmer inte alls				Instämmer helt
a) Introduktion och instruktion.	❐	❐	❐	❐	❐
b) Motivation och stöd.	❐	❐	❐	❐	❐
c) Tillgänglighet och feedback.	❐	❐	❐	❐	❐
d) Hänsyn till tidsramar.	❐	❐	❐	❐	❐

❐ Annat:

____

____

9. Skulle du säga att lärarens närvaro under passet kan ersättas av…

	Instämmer inte alls				Instämmer helt
a) … skrivna instruktioner?	❐	❐	❐	❐	❐
b) … en hjälpguide i simulatormiljön?	❐	❐	❐	❐	❐
c) … en hjälpagent i simulatormiljön?	❐	❐	❐	❐	❐
d) … en tidigare student som själv genomgått kursen?	❐	❐	❐	❐	❐
e) … endast simulatorn?	❐	❐	❐	❐	❐

❐ Annat:

____

____

Frågor om simulatoruppgiften
[Dessa frågor berör den uppgift som ni genomförde med simulatorn, inte simulatorn som sådan]

10. Vad tyckte du om att arbeta med simulatoruppgiften?

	Instämmer inte alls				Instämmer helt
a) Den kändes meningsfull och motiverande.	❒	❒	❒	❒	❒
Den ställde krav på självständigt tänkande och kreativitet.	❒	❒	❒	❒	❒
Den inkluderade/föregicks av tillräckliga instruktioner.	❒	❒	❒	❒	❒

❒ Annat:

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____

11. Hur upplevde du simulatoruppgiften som stöd i ert grupparbete?

	Instämmer inte alls				Instämmer helt
b) Uppgiften fungerade som en mall inledningsvis och lämnade efterhand mer utrymme för våra egna idéer.	❒	❒	❒	❒	❒
Uppgiften gav en mycket strikt struktur åt aktiviteten i gruppen.	❒	❒	❒	❒	❒
Uppgiften hjälpte oss att resonera med ämnesspecifika termer.	❒	❒	❒	❒	❒

❒ Annat:

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12. Upplevde du att simulatoruppgiften fungerade som ett stöd för diskussion och reflektion?

	Instämmer inte alls				Instämmer helt
c) Uppgiften uppmuntrade till diskussioner i gruppen.	❒	❒	❒	❒	❒
Uppgiften uppmuntrade till samarbete och dialog.	❒	❒	❒	❒	❒

Uppgiften var ett bra underlag för reflektion kring ämnet.	❐	❐	❐	❐	❐
Uppgiften gjorde så att vi kände oss pressade av tiden.	❐	❐	❐	❐	❐

❐ Annat:

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Frågor om simulatorn

13. Gällande simulatorn, välj ett av följande alternativ.

❐ Det var mest person x som styrde simulatorn.

❐ Det var mest jag som styrde simulatorn.

❐ Ingen styrde simulatorn mer än de andra.

14. När det gäller simulatorns användbarhet, ange hur väl följande påståenden stämmer överens med din uppfattning.

Simulatorn…	Instämmer inte alls				Instämmer helt
a) … var för svårmanövrerad.	❐	❐	❐	❐	❐
b) … var för simpel, orealistisk.	❐	❐	❐	❐	❐
c) … gav feedback som ledde oss framåt.	❐	❐	❐	❐	❐
d) … 'förklarade' vad som var 'fel' när något inte gick som vi tänkt oss.	❐	❐	❐	❐	❐
e) … strulade ofta.	❐	❐	❐	❐	❐
f) … gjorde oss stressade.	❐	❐	❐	❐	❐
g) … var mycket välgjord.	❐	❐	❐	❐	❐
h) … lyckades engagera mig.	❐	❐	❐	❐	❐
i) … rörde sig ryckigt/hackigt	❐	❐	❐	❐	❐

❐ Annat:

15. Upplevde du att simulatorn…

	Instämmer inte alls				Instämmer helt
d) … uppmuntrade diskussion?	❒	❒	❒	❒	❒
e) … uppmuntrade dialog och samarbete?	❒	❒	❒	❒	❒
f) … var ett bra underlag för reflektion kring ämnet?	❒	❒	❒	❒	❒
g) … bidrog till att du lärde dig mer?	❒	❒	❒	❒	❒
h) … bidrog till att du lättare förstod?	❒	❒	❒	❒	❒

❒ Kommentar:

16. Skulle du säga att simulatorn behöver förbättras på något av följande områden?

	Instämmer inte alls				Instämmer helt
a) Utbud av funktioner.	❒	❒	❒	❒	❒
b) Funktionalitet.	❒	❒	❒	❒	❒
c) Grafiken.	❒	❒	❒	❒	❒
d) Möjlighet att anpassas efter våra behov.	❒	❒	❒	❒	❒

❒ Kommentar:

17. Värdera övningen med simulatorn med hjälp av följande påståenden.

Övningen…

	Instämmer inte alls				Instämmer helt
i) … var ett kul inslag i utbildningen.	❐	❐	❐	❐	❐
j) … stal värdefull studietid från mer meningsfulla aktiviteter.	❐	❐	❐	❐	❐
k) … var bra för mitt lärande.	❐	❐	❐	❐	❐

❐ Kommentar:

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Frågor om arbetsgruppen

18. Hur upplevde du talfördelningen i din grupp? Välj *ett* alternativ.

❐ Alla pratade ungefär lika mycket.

❐ Vissa pratade mer än andra.

❐ Det var bara en som pratade.

19. Hur upplevde du arbetet i din grupp?

	Instämmer inte alls				Instämmer helt
l) Andra deltagare gjorde mig stressad.	❐	❐	❐	❐	❐
m) Jag kunde säga vad jag tyckte och tänkte.	❐	❐	❐	❐	❐
n) Jag upplevde det som jobbigt om andra inte höll med om mina idéer.	❐	❐	❐	❐	❐
o) I min grupp stod diskussionen i centrum.	❐	❐	❐	❐	❐
p) Det fanns en känsla av gemensamt ansvar för att klara simulatoruppgiften så bra som möjligt.	❐	❐	❐	❐	❐
q) Det fanns ett behov av mer struktur och ledning.	❐	❐	❐	❐	❐

❒ Annat:

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20. Vad upplevde du att pratet i din grupp handlade om?
Välj *ett* alternativ.

❒ Allt och inget.

❒ Uteslutande om simulatoruppgiften.

❒ Uteslutande om sånt som inte hörde till simulatoruppgiften.

❒ Till hälften om simulatoruppgiften och hälften om annat.

❒ Vi pratade inte med varandra.

❒ Annat:

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Frågor av allmän karaktär

Är du nöjd med övningen?

	Instämmer inte alls				Instämmer helt
r) Jag hade hellre deltagit i vanlig undervisning än simulatorbaserad.	❒	❒	❒	❒	❒
Jag deltar gärna i relevant simulatorbaserad undervisning i framtiden.	❒	❒	❒	❒	❒
s) Jag har lärt mig sådant som är viktigt för min yrkesutövning.	❒	❒	❒	❒	❒

❒ Annat:

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21. Upplevde du att du var tillräckligt väl förberedd för den här övningen?

	Instämmer inte alls				Instämmer helt
a) Mina förkunskaper och erfarenheter har varit tillräckliga i relation till den teknik och de arbetsformer som använts under övningen.	❐	❐	❐	❐	❐
b) Jag hade velat ha mer erfarenhet av smågruppsarbete.	❐	❐	❐	❐	❐
c) Jag hade velat ha mer erfarenhet av simulatorstött smågruppsarbete.	❐	❐	❐	❐	❐
d) Jag hade velat ha mer erfarenhet av arbete vid en persondator.	❐	❐	❐	❐	❐

❐ Annat:

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	Instämmer inte alls				Instämmer helt
22. Den här enkäten tog för lång tid att fylla i.	❐	❐	❐	❐	❐

Tack för att du tog dig tid att fylla vår enkät!!

Appendix C. Questionnaire for conventional dentistry training participants

The questionnaire distributed to participants in the conventional dentistry training was practically identical to the one distributed to simulation participants. The exceptions include the following:

1. Rephrasing of references to the training session itself.
2. Rephrasing of simulation-based questions 16 a–b.

The removal of simulation-specific questions, including 9 b–c, 14 b–e, and 22 b.

Appendix D. Questionnaire for nursing simulation participants

The questionnaire distributed to participants in the nursing simulation was practically identical to the one distributed to simulation participants. The exceptions include the following:

1. Rephrasing references to the training session itself.
2. Rephrasing related to group size.
3. Rephrasing related to teacher presence.
4. Removal of questions 3 and 7.

Adding of three questions related to expected learning outcomes, impact on clinical practice, and the experience of being video recorded.

Appendix E. Interview guide for dentistry participants (in Swedish)

1. **Vilka de är, vilken grupp de tillhörde**
   Du kan väl börja med att berätta vad du heter och vilken övning som du deltog i.

2. **Synen på lärande och inlärning**

   a. Vad menar du med lärande? Vad är lärande för dig?

   b. Kan du beskriva hur och när, dvs i vilken situation som du lär dig någonting…eller i vilka situationer?

   c. I vilken av följande situationer lär du dig mest? (Föreläsning, individuell textläsning/praktiskt arbetande, grupparbete?)

   d. Skulle du säga att du lär dig något genom att diskutera med andra? Vad? Om det bara ibland är lärorikt, kan du då beskriva vilka omständigheter som krävs för att du ska lära dig något?

3. **Hur inverkar träningen i simulatorn/bildgranskning på ditt lärande?**

   a. Minns du om lärde du dig någonting under den här övningen? Vad, ge exempel?

   b. Kan du beskriva hur övningen påverkat ditt sätt att tänka kring det som övningen handlade om?

   c. Hur visste ni i gruppen att ni närmat er en korrekt lösning/tolkning av de enskilda problemen eller uppgifterna? Kan du ge exempel på hur detta går till?

   d. Det som du lärde dig i den här övningen, hade du kunna lära dig det på något annat sätt? Hade det varit lättare/bättre?

   e. **Bildgranskning:** var uppgiften utformad bra för att lära sig tolka röntgenbilder? Hade man kunnat göra annorlunda? Hur i såfall?

f. Så om du fick välja mellan det du nämnde och den här övningen, så skulle du välja…?

g. Skulle du säga att just den här formen av grupparbete vore lämplig även inom andra delar av din utbildning?

4. **Om deras agerande i relation till andras agerande**

a. Det finns tre olika stolar eller platser under övningen. Reflekterade du över var du skulle sitta? Hur? Var någon plats mer attraktiv än de andra? Tror du att någon av de andra reflekterade över att man kunde sitta på tre olika platser?

b. Det finns ett par sätt att styra datorn. Reflekterade du över vem som styrde mest? Varför tror du att xx styrde mest? Spelade det någon roll? Varför?

c. Vad har du för relation till de andra i din grupp? Är ni vänner, kompisar eller brukar ni inte prata med varandra?

d. Är alla deltagare inkluderade i arbetet? Är någon utanför? Är någon mer drivande? Varför tror du att det blev så?

e. Skulle du säga att du själv är mer aktiv eller mer passiv i relation till dina gruppkamrater? Hur kommer det sig tror du?

f. Skulle du agera annorlunda om den här typen av övning var ett reguljärt inslag i utbildningen? Varför?

g. Skulle du säga att dina gruppkamrater var ett stöd för ditt personliga lärande? Kan du utveckla det lite?

h. Var gruppens diskussioner givande på något annat sätt?

i. Bidrog du själv till att dina gruppkamrater lärde sig något tror du?

j. Tror du att du hade lärt dig mer eller bättre om du hade arbetat individuellt framför datorn?

k. Ni gjorde ett kunskapstest efter övningen. Tror du att det var en fördel på det här testet att ha arbetet i grupp under övningen?

Varför – varför inte? Hade du lärt dig lika mycket eller mer om du gjort övningarna individuellt?

l. Kan möjligheterna för lärande förbättras genom att vi manipulerar gruppen på något sätt? Exempelvis antal deltagare, ifall det är vänner eller inte som du arbetar med. Vore det enklare om gruppen endast bestod av kvinnor/män?

m. **Bildgranskning:** Ni använder ibland mycket specifika termer när ni talar om bilderna. Hur kommer det sig? Vilken funktion fyller de?

5. **Om lärarna**

   a. Fick ni några instruktioner eller något peptalk utav lärarna innan övningen började? Vad bestod dessa av?

   b. Vad skulle du säga att bidrog läraren med under övningen? Hade det fungerat mycket sämre utan lärare?

6. **Om uppgifternas utformning och om testet.**

   a. **Simulering:** Var det viktigt att se röntgenbilden direkt? Vilken funktion fyllde detta? Hade gått lika bra utan den direkta feedbacken?

   b. (Hur vet ni när ni är färdiga med ett bildpar/en uppgift? Vilka krav ska vara uppfyllda för att ni ska går vidare?)

   c. **Simulering:** Hur tänkte ni när ni arbetade med simuleringen? Tänkte ni ut strategier och hypoteser som ni testade? Prövade ni er fram genom att helt enkelt manövrera simulatorn?

   d. Skulle du säga att uppgifterna relevanta för ditt lärande i ämnet? Hur hade de kunnat göras bättre?

   e. Vad bidrog materialet med? Var det något som de inte bidrog med?

   f. Om vi återkopplar till kunskapstesterna igen. Skulle du säga att övningen var väl spenderad tid för att kunna prestera bra på testet? Hade det varit bättre att göra något annat?

7. **Om simulatorn, känsla av realism och äkthet m.m.**

a. Var det något som var särskilt svårt eller jobbigt med simulatorn?

b. Vad var svårt att lära sig använda/dvs navigera i simuleringen?

c. Skulle du säga att den här simulatorn lämpar sig väl för grupparbete? Passar den bättre för individuellt arbete?

d. Vad skulle du vilja göra för att förbättra simulatorn? Designmässigt, användarmässigt?

e. Tror du att övningen är relevant för din framtida yrkesutövning?

Egna reflektioner?

Appendix F. Interview guide for nursing simulation participants (in Swedish)

1. **Vilka de är, vilken grupp de tillhörde**
   Du kan väl börja med att berätta vad du heter utifall att jag skulle råka blanda ihop banden.

2. **Har studenten utnyttjat möjligheten att på egen hand öva med simulatorn under VFU-tiden eller på annat sätt kommit i kontakt med simulatorn utöver vid den schemalagda övningen?**

   a. Du deltog ju i den schemalagda tvåmanna övningen med spinasimulatorn, den som jag filmade, det jag undrar först främst är om du kommit i kontakt med simulatorn även efter den övningen eller om det var det enda tillfället.
   b. Simulatorn skulle ju vara tillgänglig för bokning och självständigt övande under VFU'n, är det något som du utnyttjat?
   c. Då blir jag förstås nyfiken, hur kommer det sig?
   d. Kan du utveckla?
   e. När du övade på simulatorn under VFU'n, övade du då ensam eller var ni flera? Kan du utveckla?
   f. Hur ofta och hur länge övade du/ni?
   g. Vad var det som ni övade på (bredden i övandet)? Varför?
   h. Gav simulatorövandet det som du hade hoppats på?

3. **Har studentens behov av övande med simulatorn tillfredställts?**

   a. Har du känt eller känner du nu ett behov av att få öva ytterligare med spinasimulatorn?

   b. Var tillgängligheten ett problem, att det fanns 1 simulator, att den stod på radiologen och att bokningsförfarandet såg ut som det gjorde? Hur tror du att tillgängligheten kan förbättras?

   c. Hade du velat se fler schemalagda övningar med simulatorn?

d. Tror du att du har 'fått ut' det som du kunnat av simulatorn inom ramen för den här kursen?

e. Det simulatorövande som du genomgått under kursen, skulle du säga att det har bidragit till att uppfylla kursmålen? På vilket sätt?

f. Om du fick helt fria händer att omforma kursen, hur skulle simulatorn användas då? Omfattning, frekvens, former m.m.

2. Motsvarade själva simulatorn studenternas behov?

a. Om vi betraktar simulatorn som ett redskap eller verktyg eller läromedel, har den motsvarat dina behov under den här kursen?

b. Var det något sätt, eller något annat ytterligare sätt, som simulatorn brast på eller skulle behöva utvecklas på för att kunna stödja dig i ditt lärande?

c. Saknade du några funktioner, instruktioner, uppgifter/övningar eller tester i simulatorn?

d. Var svårt att lära sig använda/dvs navigera i simuleringen? Blev ni stannade på grund av tekniken någon gång? Hade ni behövt instruktioner eller träning för kunna fokusera på uppgifterna snarare än tekniken?

e. Om vi tänker oss att simulatorn rent funktionellt kommer fortsätta se ut som den gör idag, kan vi kompensera för dess brister eller begränsningar på något sätt? Instruktioner, kompletterande uppgifter, återkoppling eller något annat?

3. Hur har studenten uppskattat övningen?

a. Vad minns du från övningen? Minns du vad övningen gick ut på? Vad ni skulle göra? Var det något som du särskilt uppskattade eller mest om respektive minst om?)

b. Minns du om lärde du dig någonting specifikt under den här övningen? Vad, ge exempel?

c. Kan du beskriva hur övningen påverkat ditt sätt att tänka kring det som övningen handlade om?

d. Skulle du säga att dom uppgifter som ni arbetade med var relevanta för ditt lärande i ämnet, i det som kursen som helhet handlade om? Varför inte?/På vilket sätt?

e. Skulle du säga att dom uppgifter som ni arbetade med bidrog till att uppfylla kursmålen? Hade du hellre sett andra uppgifter? Hur skulle de se ut? Brukar studenten ha koll på kursmål? Om du inte minns kursmålen kan du läsa om dom i det här pappret *visa kursmål*

f. Skulle du säga att övningen som helhet var väl spenderad tid för att nå kursmålen? Hade du hellre gjort något annat?

g. Ni arbetatde två-och-två, hur tyckte du att det fungerade? Tror du att du hade lärt dig mer eller bättre om du hade arbetat individuellt framför datorn? Hade det varit bättre att vara ännu fler? Ni fick ju själva välja vem ni skulle arbeta tillsammans med, tycker du att det är bra ur lärandehänseende? Hur borde man ha gjort istället?

h. Hade det varit värdefullt att ha en lärare närvarande under övningen? Hade det varit nödvändigt? Kan du utveckla?

i. Är det möjligt att understödja gruppens diskussioner på något sätt tror du? Kan du utveckla?

j. Du angav i enkäten att du brukar umgås med din labpartner (merparten gjorde det), är det något som underlättade eller försvårade under övningen? Kan du utveckla?

k. Styrde ni simulatorn ungefär lika mycket? Är det viktigt att få styra själv? Påverkar det ditt lärande på något sätt? Kan du utveckla?

l. Skulle du säga att det var värdefullt för dig under praktiken att först ha deltagit i denna övning? Kan du utveckla? (Lärande, kursmål, yrkespraktik.)

m. Vore det värdefullt för dig under praktiken att ha möjlighet att öva på en simulator? Kan du utveckla/på vilket sätt?

n. Vore det värdefullt för dig efter praktiken att återigen få öva med simulatorn?

o. Tror du att simlulatorer som denna är relevanta även för yrkesverksamma inom området? Kan du utveckla?

p. Tror du att simulatorövningar såsom denna är relevanta för ditt framtida yrkesutövande?

4. **Var studenten tillräckligt förberedd för att öva med simulatorn?**

   a. Skulle du säga att du var tillräckligt förberedd inför övningen med spinasimulatorn?

   b. Var lärarnas instruktioner och introduktioner tillräckliga? Vilka instruktioner/introduktioner hade ni behövt?

   c. Hade ni tillräckliga ämnesförkunskaper? I vilket skede i er utbildning tror du att ni har tillräckliga ämnesförkunskaper för att få ut något av simulatorövande? Är det relevant att ha simulatorövande som ett återkommande inslag i olika kurser?

5. **Fick studenten tillräckligt med återkoppling på simulatorövandet?**

   a. Upplevde du att det inom ramen för kursen skedde någon återkoppling eller uppföljning på simulatorövandet?

   b. Hur såg den uppföljningen/återkopplingen ut?

   c. Hade du velat ha mer uppföljning/återkoppling? Hur skulle den se ut?

   d. Hade du velat ha något test eller liknande efteråt för att tillämpa/testa dina eventuellt nyförvärvade kunskaper?

Egna övriga relfektioner?

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vid Pedagogiska institutionen, Umeå universitet

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