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Developing nursing expertise in simulation-based learning environments

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ABSTRACT

The work of nurse anaesthetists is carried out in a highly technological environment, where patient care is provided in close collaboration with other members of hospital staff. The expertise of these nurses and how this is developed is of vital importance. Furthermore, the use of computerised pedagogical tools to support learning within an educational setting is of special interest. The main aim of this paper is to investigate how the use of one of these tools, a simulation based learning environment, can contribute to learning in the domain of anaesthesia care. The study is carried out within the framework of socio-cultural theory. From this perspective, learning is viewed as being situated in communities of practice, where interaction between individuals, and between artefacts and individuals, is considered as central in the learning process. Here, we will present results from a study of how trainee nurse anaesthetists use computer simulations and discuss issues concerning their learning processes. The planning, implementation and debriefing phases of one training session are scrutinised with respect to the framing of problems and implications for learning. The results support the assumption that work in computer based learning environments can influence assessment procedures and decision-making skills in significant ways, and that computer-based learning environments provide productive means for goal directed collaborative learning activities.

Introduction

The characteristics of knowledge inherent in the work of professionals is an issue that is of vital importance. Research on the development of this knowledge may have crucial implications in future professional education. Furthermore, new computer-based technologies change the conditions for the work of professionals and also provide new tools for learning and the development of professional expertise.

This paper is focused on the professional work of nurse anaesthetists, where certain main features can be identified: 1) The care of patients comprises a wide range of tasks, including communicative activities, as well as the maintenance of the patients physiological functions. 2) Patient care relies, to an increasing extent, upon the extensive use of medical-technical equipment, and computer-based technologies. 3) This work is carried out in collaboration with others in teams with a clear division of labour. The teams consist of other nurses and physicians with specialised functions.

In the study presented in this paper, we will explore how simulation-based learning environments can contribute to the development of professional expertise in the domain of anaesthesia care. The study is carried out within a socio-cultural framework (Wertsch, 1995; Lave and Wenger, 1991) and the activity under scrutiny could be regarded as an instance of Computer Supported Collaborative Learning, CSCL (Dillenbourg, Baker, Blaye & O'Malley, 1996; Koschmann, 1996).

Lave and Wenger (1991) have formulated a theoretical basis for studies of learning from a socio-cultural perspective. They describe learning as a move from peripheral participation in communities of practice towards an increased level of participation and involvement. Learning is regarded as situated and includes the development of identity. Interaction between individuals is central in the learning process, but interaction with artefacts also contributes to an understanding of what is going on in a certain practice. Lave and Wenger use the term *transparency* which, in connection with technology refers to, "the way in which using artifacts and understanding their significance interact to become one learning process" (p. 102). In this way, artefacts are objects of, as well as tools for learning. A central concept is *structuring resources*, which is defined as the structuring effects of activities in social practices on learning processes, that

is, how activities in a situation come together, shape each other, and generate qualitative differences within specific ongoing activities. This means that attention must be paid to how experiences from well-known situations are used to frame the situation and the way in which activities are carried out. Thus, how people make use of structuring resources is decisive for an understanding of learning processes (Lave, 1988; Lave & Wenger, 1991). The term *framing*, when used here, refers to how our definition of a situation is built up in accordance with principles of organisation, which govern events and our subjective involvement in them. Thereby aspects of events that otherwise would have been meaningless are transformed to something meaningful (Goffman, 1974).

Dillenbourg et al. (1996) observe that research on computers and learning has shifted its focus from the potential for individualised learning towards collaborative learning. Instead of the individual, the group and the emergent, socially constructed properties of interaction have become the units of analysis. Collaborative learning is described as “a co-ordinated synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem“ (p. 190). In research, *negotiation* – how individuals come to an agreement about the important aspects of a problem through interaction – is often central in the analysis. When collaborative interaction is mediated by computer systems, the design of these systems has an impact on the activity. Researchers interested in CSCL mainly focus on how the introduction of computer tools changes the interaction and the learning processes.

The main aim of this study is to investigate how the use of simulation-based learning environments can contribute to learning in the domain of anaesthesia care. The results are based on data from the introduction of a computer-based simulation in a course in anaesthesia care for nurses. We will focus on how nurses during their training to become nurse anaesthetists use computer simulations and discuss what this will mean for their learning processes.

Computer-simulations in the education of nurses

A computer-simulation can be defined in general as a program that consists of a model of some aspect of the world. It allows the user to make inputs by changing the parameters of the model, run the model and make conclusions about the results displayed. That means that, “a simulation is possible for

anything that can be implemented as a model relating two or more parameters, where changes to one parameter produce changes in another“ (Laurillard, 1993, p. 132).

Two main categories of computer-simulations have been used in nursing education. The first category includes simulations where the model responds to manipulations of some physical components, and the results are displayed on a screen or on authentic monitors. In the second category, the underlying model is represented on the screen and the user interacts with the software using the keyboard and mouse. Both of those main categories can be further subdivided with respect to the specificity-generality of the simulated events and the nature of the tasks that can be trained with them. This categorisation is illustrated in figure 1:

	Specific areas	General areas
Simulations with physical components	Q1. Interaction with medical-technical equipment; training for specific tasks and technical skills	Q2. Environmental training (for example for work in operating rooms); training for technical skills and in recognising general patient reactions; training for collaboration and decision-making in teams
Simulations on computer screen	Q3. Training for skills in interpretation of results from different forms of medical examinations (laboratory measurements, electrocardiograms etc) and interpretation of symptoms related to specific diseases	Q4. Training skills in recognising general patient reactions; apprehend what is important in relation to different situations; decision-making and priority giving

Figure 1. Categorisation of different forms of computer-based simulations used in the education of nurses.

Merryl and Baker (1996) describe a simulation that can exemplify the type in the first quadrant (Q1). The purpose of the simulation is to train manual skills in the handling of intravenous needles, which is a common task in the work of

nurses. Fletcher (1995) and Bower (1997) describe a simulation of the type in the second quadrant (Q2). The simulation includes an entire operating room with medical-technical equipment. A mannequin represents the patient. The underlying model responds to the user/users' actions by displaying reactions on the monitors and on the mannequin. It is stressed that the simulation affords good opportunities for the realistic training of teams in different critical situations. The interpretation of electrocardiograms (ECG) is an example of the type in the third quadrant (Q3). This type of simulation is presented by Wright (1995), but its use has not been reported in recent years and can be considered as an early form of application. An example of a simulation belonging to the fourth quadrant (Q4) is a soft-ware program developed for the examination of nurses in the US by the National Council Licensure Examination for Registered Nurses (NCLEX), as described by Krawzac & Bersky (1995) and Erickson Forker & Mc Donald (1996). The simulation consists of a series of case scenarios that simulate nurse-client encounters. Each scenario starts with a brief introduction to the client situation. The examinee then carries out nursing activities that include the gathering of relevant data about the client. The client's status changes over time in response to the user's actions and as the underlying health problem unfolds.

Experiences from the use of computers in nursing education suggest that new technologies improve goal-directed learning. Studies of learning effects have mainly been concerned with test results showing that the students perform better with computer-aided instruction (Bloom & Trice, 1997; De Amicis, 1997). However, although the reported evaluations by trainees have been unanimously positive (Bower, 1997; Fletcher, 1995; O'Donnell, Fletcher, Dixon & Palmer, 1998), there is still a lack of empirical data showing that even the use of advanced simulators supports any improvement in actual job performance. Helmreich (1999) addresses the issue of evaluations of group functioning in simulator training. One of the conclusions that can be drawn from aviation research, according to Helmreich, is that training through simulation is not sufficient to effect significant behavioural change in either flight crews or medical teams. He suggests that more formal didactic training in human performance issues is needed in order to place simulator training in a meaningful context.

In conclusion, the results indicate that there is a potential for developing important aspects of a nurse's work by using computer-simulations. One limitation of the research presented above is that issues about how nursing expertise develops have not been fully addressed. Another is that the collaborative aspects of learning have not been elucidated. In this study we will address both of these issues.

Method

The simulation software

A Swedish simulation software in anaesthesiology, Anestesi Simulator 3.0, was introduced in a one-year anaesthesia care course for registered nurses. The simulation included 12 case scenarios of different degrees of difficulty, and provides training in the accomplishment of general anaesthesia.

When a case scenario is chosen, the *record* of the simulated patient is displayed, including results of laboratory tests and a short description of the medical history. As the record is closed, different alternatives for pre-medication are displayed in a dialogue box. When one of the alternatives has been chosen, another dialogue box, for the choice of different medical equipment to be used during the anaesthesia, appears. After those choices have been made the real simulation starts, which implies that a time factor is included. A schematic picture of a patient on an operating table is shown as well as the monitors usually available in an operating room, which also display different readings (Figure 2). The user can now administer drugs and infusions from the menus in the upper margin and, when choices are made, dialogue boxes appear where the doses and rate of infusions can be stated. The anaesthesia machine is monitored by moving the levers on it with the mouse cursor. Decisions about intubation¹ and the start of the surgical operation are also performed from the menus. The condition of the simulated patient is controlled by the monitors displaying ECG², heart rate, blood pressure, saturation of oxygen in the blood et cetera. The user also gets access to laboratory data from the menus. By clicking on the symbolised patient, it is possible to see the size of the pupils, the breathing rate

¹ Insertion of a breathing tube through the mouth or nose into the trachea to maintain the airway free and for the delivery of an anaesthetic gas and oxygen.

² Electrocardiogram, chart of the electric activity of the heart muscle. Allows diagnosis of specific cardiac abnormalities.

and if the simulated patient becomes cyanotic. The grade of consciousness is displayed by text and is divided into five levels. The amount of bleeding and rate of urinary output can also be checked by a click on the symbolised containers under the depicted operating table.

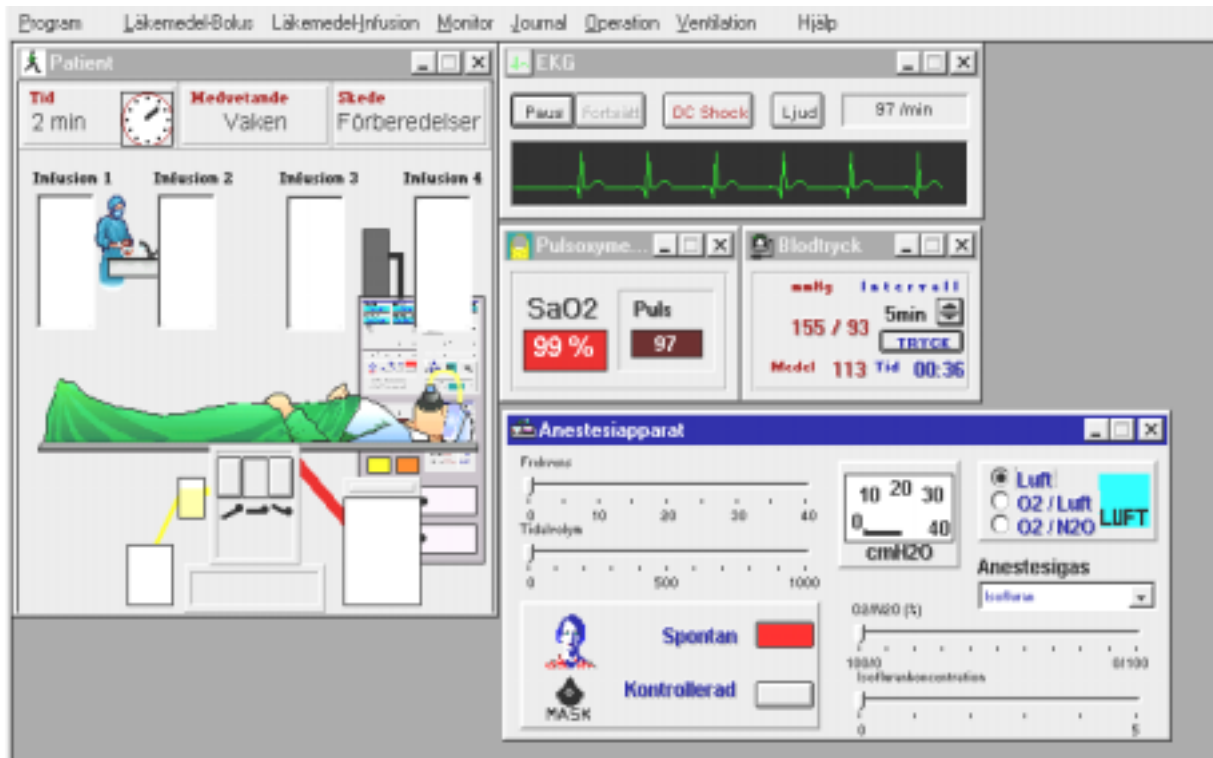


Figure 2. Appearance of the screen from the start of the simulation with the exception of the anaesthesia machine down to the right, which is activated by an icon.

By choosing *advanced monitoring*, the user gets access to readings for central venous pressure and arterial blood pressure (continuous) as well as several other parameters of the imagined patient's physiology. There is also a function showing the remaining effects of the drugs administered (in percent). Furthermore, it is possible to check readings of laboratory tests during the anaesthesia, and also the composition of the expired gases.

The time factor in the program represents real-time, as regards how long the operation lasts, the effects of drugs et cetera. There is a function for temporarily stopping the simulation, and the speed of the simulation can be altered. A function for evaluation is available, which is based on the extent to which a sample of parameters has been kept within certain limits during the simulation. Graphs of parameters, like blood pressure and heart rate, are automatically

registered in an *anaesthesia record*, as well as most of the interventions undertaken during the simulation. The record can be printed out during the simulation or after the simulation has been finished.

Subjects

The subjects of this study were 7 nurses, 6 women and 1 man, attending a one-year anaesthesia care course. Their average length of their working experience was 7,3 years, ranging from 3 to 12 years. None of them had experience of work as nurse anaesthetists. Four of them had been working within closely related domains, such as emergency, critical or pre-hospital care.

Procedure

The simulation was introduced as part of the general instruction on anaesthesia care of the beginning of the course. This study was conducted in the second semester, that is, during the trainees' specialisation in anaesthesia care. About half of that semester was practical training at hospitals. After 7 weeks of theoretical studies in the second semester, just before the period of practical training started, a new case scenario was introduced under supervised training. The learning environment was structured as three two-hour lessons and the nurses trained with the simulation in groups of two or three. The participants themselves arranged for the formation of three groups, which were the same in all lessons. The course teacher was present, and the trainees could ask her for advice or explanations whenever they wanted. They were told, however, to create strategies for the anaesthesia by themselves, to try to carry them out and ask for support only if they could not manage. After the simulation was finished, the teacher and the trainees had the opportunity to discuss alternative solutions to the problems that had occurred during the training session and other issues of interest. The course of events during the lesson was divided into three phases: 1) The planning of the anaesthesia for the patient; 2) Implementing the anaesthesia; 3) Debriefing by the teacher.

Data collection

All three groups were videotaped during three of the sessions. The positions of the cameras are described in figure 3. To capture the trainees' interaction, both verbal and gesticulative, three different recordings were undertaken. One camera (1) was situated immediately behind the trainees, directed towards the

monitor, and which captured their pointing to different elements on the computer screen (4) as well as the dialogue between the trainees and the teacher. Another camera (2) was positioned at the side, a bit in front of the trainees, for registration of their non-verbal interaction and of their use of literature, notes etc. This camera angle also made it possible to tape most of the teacher-trainee interaction. The picture from the computer screen was taped directly on a video-recorder (3), mainly to make it possible to observe details visible in the simulation, even if someone were to move in between the camera and the monitor.

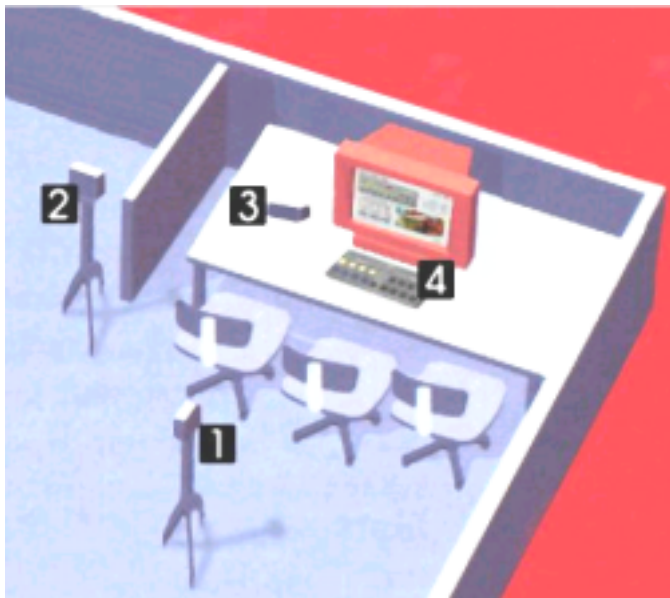


Figure 3. Equipment for the registration of data and camera positions in relation to the trainees and the computer screen.

Data analysis

Data was analysed within the framework of CSCL (Dillenbourg et al., 1996; Koschmann, 1996), founded on the theories of learning of Lave (1988) and Lave and Wenger (1991), with the focus on Lave's concept, structuring resources. Videotapes from the first occasion of training were studied and episodes for analysis were segmented from the tapes. The idea was to find episodes, where the trainees' attempts to come to an agreement of how to manage the unfolding problems were salient. One episode from each of the different phases of the session was then transcribed. The results, presented below, are based on an analysis of the participants' interaction in those episodes and their verbal and

non-verbal communication, as well as the role of the artefact in this interaction. Excerpts from the episodes are presented and discussed with the aim of demonstrating the most typical interaction situations. Furthermore, the usefulness of the software for collaborative learning activities is scrutinised as regards the three dimensions: interface, representations, and function (Kolodner & Guzdial, 1996).

Results

The results presented here are based on the analysis of the first training session for a group of three participants. The session was conducted after they had been in hospital practice for one week out of nine in their last practice-period.

Collaborative learning and the framing of the activities

As previously described, there are three phases in the lesson: 1) The planning of the anaesthesia for the patient; 2) Implementing the anaesthesia; 3) Debriefing by the teacher. Each phase will be described shortly and examples from them will be presented. Different aspects of the training are salient in the different phases, and the results will be structured accordingly. In the planning and the implementation phases, the focus of analysis is on the use of structuring resources in the participants' framing of the problems. In the debriefing phase, the implications of training with the simulation for collaborative learning activities are highlighted.

The planning phase

A case scenario simulating a man undergoing a laparoscopic cholecystectomy³ was selected. Before the real simulation started, the trainees are confronted with the *medical record* of the case scenario, which forms the point of departure for the planning of the anaesthesia. This planning includes an inventory of the patient's medical and surgical history, allergies, current medication and the results of laboratory tests. The trainees start with a discussion of what kind of situation they are confronted with. There was

³ Surgical removal of the gallbladder performed to treat inflammation in the gallbladder or to remove stones in the bladder and the bile ducts.

obviously a need for framing the situation, to decide how to look upon the simulation, which is demonstrated in the following excerpt:

- Anna: Should we assume that he is treated in hospital or that he is an outpatient?
John: What did you think about then?
Anna: I just thought that if he is an inpatient you may have more time for the preoperative talk and maybe check up a little bit more. In this case you may only read the journal and the papers [documents] in that and about previous anaesthesia.
Teacher: Even if he is treated in hospital he could be coming from his home in the morning.
Anna: We will meet him in the morning then.
John: That's the way it usually is anyway. Its not often we visit the patients [on the ward] in advance.
Anna: But if we follow what we have learnt in our education we should try to introduce these preoperative interviews.

From the medical record it was not explicit if the patient was an outpatient or if he was treated in hospital. Why was it necessary for them to know if he was an outpatient then? There are some possible reasons. For example, it is important for the anaesthetic nurse to know if the patient has been eating or drinking anything before the anaesthesia. If he has been treated in hospital, they may get indications that such conditions are under control. However, the main reason for their attempt to frame the situation seems to be a need to establish consensus about how to look upon the simulation, if it should be regarded as a knowledge object in itself, or as if the object is a real patient behind the simulation. To be able to conduct the preoperative actions needed in the simulation there is obviously a need to rely on other experiences, going beyond the simulation itself. In this case, one of the trainees, Anna, refers to a specific task they had been instructed on in their course in order to structure the problem. A question by Anna in the beginning of the lesson, when they were confronted with the case scenario reveals this:

- Anna: Now we will undertake a little preoperative [inaudible] and we go through the whole thing?
Teacher: Exactly.

There is, however, a conflict between the trainees concerning the extent to which they should deal with the situation as a *pretended reality* or as *running a*

simulation. The previous discussion reveals such a conflict, and it is yet more salient in the following excerpt:

Anna: He must have a newly recorded ECG.
John: Presuppose that it is assessed.
Maria: It has to be assessed and accepted, so that is...

Although the question is relevant in the actual practice of nurse anaesthetists, the simulation could be run without access to all the information needed in authentic settings, as the comments of John and Maria indicate. There are also different opinions about which of the structuring resources to rely on: those supplied by activities in educational settings, like instruction and reading literature, or those supplied by activities at work. Anna relies on the content from their course, but Maria and John do not find this relevant. John refers to how it usually is in work practice. In both cases, however, their familiarity with activities outside the actual situation helped them to frame the problem, which can be looked upon as an instance of utilising structuring resources (Lave, 1988).

After that, they continue to check if different data is available in the medical record of the case and discuss what consequences different pieces of information may have for the planned anaesthesia. They now conduct the preoperative preparations based on data available in the simulation. They had come to an agreement on how to manage the situation at hand. The agreement, however, does not mean that a full consensus has been established; rather they agree upon important aspects of the problem (Dillenbourg et al., 1996). As the *preoperative interview* was rejected as a relevant form in the simulation situation, and their attention was directed to the data supplied in the simulation, the conflict between education and work practice as structuring resources faded.

The need to frame the situations appears in several events as they talk about where in the operating unit actions are undertaken, for example whether they are in the preparation room or in the operating room. The clarifications about localisation are triggered by questions of what to do on certain occasions, for example if it is possible to administer oxygen or not, but also to give a sequential order to different steps before and during the anaesthesia.

The implementation phase

The implementing phase begins when the participants start the simulated case scenario. They administer the drugs they have planned in the previous phase and start the operation (after 10 minutes). The task includes balancing the administration of drugs and intravenous fluids in relation to their effects on the patient's physiological condition, as displayed by the monitors and laboratory readings represented in the simulation. In the training situation, no explicit statements are made in advance of the goals for a successfully implemented anaesthesia. When they are running the simulation, however, this turns out to be a central problem. Many anaesthetics lead to decreasing blood pressure, but the blood pressure could also decrease for other reasons, for example hypovolemia or heart failure. Furthermore, the heart rate is related to variations in these parameters, but a rapid heart rate can also be caused by pain or the low saturation of oxygen in the blood. Low saturation of oxygen, in turn, could be caused by the insufficient ventilation and exchange of gases in the lungs, as well as by poor blood circulation. The running simulation confronts the trainees with problems that include a complex interplay of all those parameters. In the first event, scrutinised here, the low blood pressure of the patient is identified as a problem. The low blood pressure had been commented upon previously by the trainees, as an effect of the anaesthetic gases and as requiring larger amount of intravenous liquids, and dealt with by reducing the gas flow (Isoflurane⁴). Initially they also increased the speed of the infusions (2 minutes after starting the simulated surgery). Now (about 15 minutes later), the teacher directs their attention again to the low blood pressure (current pressure is 92/55):

- Teacher: You had problems with a significantly low blood pressure in the beginning, with a patient that was in very deep narcosis. What could you have done to be in a better position?
- Anna: The low blood pressure...
- Maria: What you begin with, it is giving half a litre Hess⁵ before... filling them up, and then it is that you do not give as much [inaudible]. Maybe a little smaller dose.
- Anna: Eeh... I maybe... or I do not think I would have been giving Hess, rather Ringer⁶ instead, and filled up then. Or administered that instead of Hess.
- Maria: It works very well. There were no problems with the pressure.

⁴ A type of anaesthetic gas, which side-effect is vaso-dilatation that causes decreasing blood pressure.

⁵ A plasma volume extender

⁶ A balanced saline liquid

Anna: Maybe it is not the first you choose.
Teacher: No [agrees with Anna]

The event demonstrates how the trainees try to manage the problem of low blood pressure and make sense of the situation by relying on different resources. It seemed to be obvious for these experienced nurses that the blood pressure was too low. One of them also compared it with the initial blood pressure in order to get a point of reference for what to expect in this particular case. The trainees did not discuss further if the pressure was unacceptably low or not. There seemed to be an unspoken agreement about that. Two proposals are made by the trainees to explain why the situation had unfolded in this undesirable way. Maria says that they should have administered Hess in order to *filling up* the patient and Anna suggests another form of infusion. Attempts to increase the blood volume in the case of low blood pressure can be regarded as reasonable as there is a physiological relation between volume and pressure. The other suggestion, to give a smaller dose of anaesthetics, is also reasonable considering that the narcosis was too deep and that the drug in use also causes vasodilatation, which will decrease the blood pressure. In this situation, it is likely that increasing the blood volume can compensate for the vasodilatation and thereby contribute to keeping the pressure on an acceptable level. So, what resources did they rely on in order to make sense of the problem? Maria's suggestion, to give Hess, refers to experiences from events occurring during her practice in hospital, where, as she said, *it works very well*. The explanation given, which Anna adopts, also has a feature of work-talk like filling up. Their line of reasoning could just as well be supported by physiological theories from their education but, as they run the simulation, they frame the situation in terms of events in their work practice and give their reasons using work phrases.

The teacher gives recommendations as to how the undesirable situation could have been avoided. She suggests that it would be better to begin with higher doses of analgesics, wait and see, then give a smaller dose of anaesthetics and start by giving less gas (Isoflurane) than the trainees did. The suggestions include giving the anaesthetic drugs slowly, a function that is not available in the actual program, which is commented upon by Anna. She also stresses that there are better conditions for regulating the consciousness of real patients than for managing that task in the simulation. Until then, the discussion of the simulated episode of low blood pressure has been conducted as if there was a real patient

to be taken care of. Now, however, this mode is interrupted by one of the trainees pointing to the discrepancies between the simulation and reality.

The event described in the implementation phase demonstrates the dynamic character of the simulation: how many factors interact and how actions undertaken at one point of time influence the subsequent course of events. This contributes to the difficulties confronted by the trainees, and the multiple possibilities to interpret why the simulation unfolds in the way it does. Because of the complexity of the simulation, a full account of how the different parameters interact was impossible to produce, even for an experienced anaesthetist like the teacher.

In summary, the way of managing the situation could have been better, according to the results of the evaluation provided by the software. Several episodes during the session demonstrated the trainees' reliance on quite divergent experiences from work practice. This fact, in combination with their short experience of anaesthesia care, might have contributed to their difficulties in coming to an agreement on a common strategy. A possible way of resolving those conflicting strategies could have been by reference to the theoretical content of their course. Such references, however, were not explicitly made. One exception though, is the reference to *preoperative interviews* mentioned in the planning phase. Conclusions about why theoretical concepts and models were not utilised to a greater extent, as a means for arriving at a common understanding, could not be made from the data provided in a single example. Difficulties, however, in applying concepts and sets of concepts on ill-structured knowledge domains have been attended to by Feltovich, Spiro, Coulson and Feltovich (1996), who describe an ill-structured knowledge domain as characterised by the tendency of many dimensions to interact and of the meaning and interpretation of concepts to depend on the particular situation. Feltovich et al. argue that clinical medicine is an example of such a domain and describe several types of difficulties in learning this. First, they argue, there is an over-reliance on a single basic form of understanding and analogy. Second, the learning of complex material involves the misunderstanding of situations in which there are multiple, co-occurring processes or dimensions of interaction. In those cases, learners often rely on a limited number of the dimensions, rather than the many that are pertinent. The reasoning of the fairly experienced trainees

in this study demonstrates a capability to manage a multiplicity of dimensions, but also instances of a restricted perspective.

The debriefing phase

After finishing the simulation, the trainees and their teacher assessed the outcome of the simulated anaesthesia together concluding with a discussion of alternative ways of carrying out the anaesthesia. In this debriefing phase, a discussion starts about what working together with the simulation has been like. The discussion is initiated by John, who says that in running the simulation on his own he is accustomed to administer certain anaesthetics that he feels safe with and knows how they work. In the present situation, he argues, they had to compromise and so it was impossible to find out why things went wrong. The teacher, on the contrary, argues that it is positive from an educational point of view to call into question this feeling of safety. Her argument is that it is too early to come locked up in routine patterns. Maria, however, supports John's view as she says that, in reality at least, there are not three nurse anaesthetists suggesting different things during the same anaesthesia. One of the trainees, however, adopts the teacher's line of argument and the different opinions among the nurses are exemplified in the following excerpt:

- Anna: At the same time I agree with you that this is a good thing [referring to the teachers' argument], that you are not stuck in routine patterns. Those things that happened now...
- John: Yes, but I think it is hard to grasp [what is happening], because I might not have done it in your way, that is just what's wrong then.

On the one hand, a need for openness towards other alternatives is important. On the other though, there is a need for feeling safe and testing one's own hypotheses. The conflicting opinions reflect upon and relate to the issue of whether training with the simulation supports collaborative work and learning.

Obviously there was a great deal of discussion among the trainees in order to come to an agreement as to how to manage the different problems. During their discussion and as the simulation unfolded, new problems emerged and old ones were aggravated. The possibility to take time out by making use of the pause-function in the simulation was not utilised. Furthermore, the trainees, as was apparent in the low-blood-pressure episode, were not able to manage the problem in a desirable way, reflecting the fact that they did not fully

comprehend the behaviour of the system. From that point of view, the trainees were, to a certain extent, able to achieve a shared understanding of the problem. In the actual situation, however, the simulation did not afford sufficient possibilities for the nurses to gain an understanding that that could have served as a foundation for proper actions.

Usefulness of the software

Kolodner and Guzdial (1996) argue that a deep understanding is the explicit goal in the use of CSCL software, and that it is designed to promote a kind of reflection that can lead to successful learning. They emphasise three important facets of the software as being critical for its usefulness: interface, representations, and function.

Interface. The forms of interactions allowed in the actual simulation provide opportunities to carry out actions that are possible in authentic anaesthesia care. The symbols on the screen also have a great deal in common with the monitors in actual operating rooms. From the talk between the trainees, it is demonstrated that these refer to items such as *anaesthesia machines, drips, operating table* et cetera, as if they were real objects. As the symbols are easily recognisable and they may use a terminology that the nurses are familiar with, it can be assumed that communication is facilitated. Furthermore, the most important aspects to act upon are in the foreground of the interface, and there were few problems of finding proper ways of managing the functions in the simulation. The software also provides guidance by means of explanations of what the users are supposed to do in the preoperative phase, i.e. which actions to carry out and the sequencing of these actions.

Representations. According to Kolodner and Guzdial, the representations in the software are decisive for how the collaboration will turn out. That is, how they function as a foundation for discussions and further elaboration. In the software in this study, there is a model of the human physiology, which is represented by readings on tests, monitors et cetera. These representations can be looked upon as a selection of data provided in authentic anaesthesia situations. Feltovich et al (1996) argue for the value of multiple representations as offering increased opportunities for discussion. These discussions, they mean, can provide opportunities to overcome oversimplified forms of understanding:

In particular, an example where there is a need for an alternative explanatory framework involves system levels of biological systems – because of multiple, simultaneous processes, co-dependent causality, synergistic effects, and so fort. (p. 32)

In the training session described above, the software obviously provided sufficient data to elicit intense discussions about problems relevant for the practice of nurse anaesthetists. As described in the low-blood-pressure-problem, the representation also offered a situation that was complex enough to be regarded as a realistic problem. Of course there are limitations in how human responses can be represented. As demonstrated in the session described, the selection of parameters represented in the interface directed the trainees' attention to central aspects of the causes of the simulated patient's physical condition and for further medical actions. Using feedback from the simulation, the trainees could see the effects of the actions carried out. In the session presented here, however, they were not able to fully understand the underlying relationships. Even their use of the available *physiology* and *effects of drug* functions, did not in this case indicate any contributions to arriving at such an understanding. The circumstances in this particular session did not invite the experimentation with different alternatives, which might have provided an opportunity to achieve a deeper understanding of the relationships between the different dimensions. However, the simulation seems to have a potential to demonstrate the ill-structured and complex nature of the knowledge domain. Since the participant's discussions were largely focused upon this complexity, the simulation can function as a tool for its management.

Function. By confronting the trainees with realistic case scenarios that promote sense making and inquiry, the simulation provides opportunities for the discussion of central aspects of the practitioner's work. The software functions as a common object for their attention and serves to structure the learning activity. When the trainees were running the simulation (in the implementation phase), their attention was primarily focused on the responses of the simulated patient. The patient's condition was then the point of departure for determining what actions to carry out. For instance, the low blood pressure triggered a discussion of possible causes, such as how to manage the problem and how to act on it. Their ways of handling the problems that occur, in turn elicited new simulated patient responses that had to be managed. In conclusion, both activities outside the current setting and the simulation itself, in the prevailing

situation, provided the means for the framing of the task, which are thus means that can be regarded as different forms of structuring resources (Lave, 1988).

There is another function of the simulation, not in fact considered by Kolodner and Guzdial. In this case the software in a significant way mediates an understanding of situations and events in the trainees' work practice. They are, as demonstrated, not focusing on the underlying model in itself. Rather, their attention is directed to as to concern authentic patient problems. In the situations studied here, the simulation functions as a mediational means, to use the terminology of Wertsch (1998), in two ways. First, it is mediating between the participants and the work practice. The software presents issues of how to handle problems common to the nurse anaesthetist's work. As feedback is provided, an understanding of human physiology, as well as effects of drugs and other interventions, is possible. Second, objects and processes in the software are used by the participants as a means for communication. Utterances like *what is happening here*, pointing to the figures displaying the decreasing pressure of carbon dioxide in the expired gases, was enough to elicit a common attention to ventilation problems. That demonstrates how the simulation-based learning environment can, in a way, afford possibilities to use mediational means such as linguistic and physical artefacts, in the culture of anaesthesia practitioners. In that way trainees may learn their use in that culture and the training in the simulated practice could contribute to transparency in the sense that Lave & Wenger (1991) use the term. This however presupposes that the trainees are familiar with the culture or have access to an experienced anaesthetist, since the simulation per se does not provide the conceptual tools of the culture.

Concluding remarks

By using the concept of structuring resources (Lave, 1988) focus is directed to how the trainees and the teacher made use of experiences from work practice to frame the situation at hand. This framing was necessary to make sense of the case scenario that was initially presented. It was also necessary for the trainees to be able to come to an agreement as how to act with respect to the case and the events unfolding in the simulation. The simulation, in turn, also functioned as a structuring resource as such, as it structured the participant's activities within the educational setting.

The results indicate that training with the simulation influences collaboration and goal directed learning in significant, if somewhat contradictory, ways. The simulation provided a common ground for collaboration directed to highly relevant aspects of the anaesthetic nurse's work practice, such as balancing the administration of different drugs and other medical interventions in relation to the unfolding condition of the simulated patient. The simulation offered feedback on the interventions carried out and thereby possibilities for the trainees to draw conclusions on co-dependent causality and synergistic effects. On some occasions, however, it was not possible for the trainees to understand the dynamic processes. A reason for that could be the difficulties of keeping track of the different actions and their plausible effects, as those interventions were sometimes the results of compromises grounded in the rather limited and divergent experiences of the trainees. This, however, is the result of the nurse's first training session, after just one week of their practice period, and the outcome could be different when they accumulate experiences that are more comprehensive. As hypothesised by Feltovich et al. (1996), learning of complex knowledge domains is difficult because of the reliance on single analogies.

The participants' talk about the objects symbolised in the simulation, and the imagined patient, as well as the unfolding events, demonstrated that the problems in the simulation were looked upon as realistic. This feature of realism in the training was disrupted, however, by the structure of the educational setting. Here, three nurses collaborated on an equal level on tasks, which in work practice, are carried out within a hierarchy with a certain division of labour. In work practice, the team members have different roles and responsibilities, and the flow of activities is not an object for negotiations to the same extent as in an educational setting. Although this study demonstrates instances of how a simulation-based learning environment gives rise to insights and solutions that would not have come about without collaboration, there are also instances of how the authenticity of the situation is disrupted by the collaboration process as such. By using the terminology of Schön (1983), one may conclude that collaboration in the educational setting implies a shift in focus of the learning process from *reflection-in-action* to *reflection-on-action*, as the trainees take up a distanced position in relation to the simulated problems.

One further issue, in analysing data from the entire study, is in which ways a simulation-based learning environment, as a form of simulated practice, can

improve goal directed learning by affording an arena for trainees to make use of structuring resources of real work practice. In a wider sense, this could elucidate whether a simulated practice can contribute to learning in the terms of Lave and Wenger (1991), i.e. a movement from peripheral participation in communities of practices to an increasing participation and involvement.

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