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ABSTRACT Simulators that represent human patients are being integrated into medical education. This study examines the use of a haptic-enabled, virtual reality simulator designed to allow training in minimally invasive surgery (MIS) techniques. The paper shows how medical practices and practitioners are constructed during a simulation. By using the theoretical tools that situated learning and communities of practice provide, combined with the concept of reconstituting, I broaden the discussion of medical simulators from a concern with discrete skills and individual knowledge to an examination of how medical knowledge is created around and with computer simulators. The concept of reconstitution is presented as a theoretical term for understanding the interplay between simulators and people in practice. Rather than merely enacting simulator training, reconstituting creates a different context, different actors and different techniques during the simulation.

Keywords apprenticeship, medical education, medical practice, minimally invasive surgery, simulators, reconstituting

Surgical Simulators and Simulated Surgeons:

Reconstituting Medical Practice and Practitioners in Simulations

Ericka Johnson

In this paper I argue that when skill-training occurs during an apprenticeship, there remain elements of the apprenticeship that can be situated within the learning that otherwise occurs during work practices. Specifically, this study examines practices that surround simulations. Theoretically, it asks how a 'different' context can be created during training sessions to shift from training to doing. Analytically, the study conceives of practice as a combination of reified, materialized simulations and participation in situated activities (Wenger, 1998). By doing so, the paper explicates how a different context is created for training with simulators by reconstituting different actors and techniques through gestures, deployment of participants' bodies and verbal cues. This reconstituted participation does not automatically happen; it is a result of who the participants are and what they do with (and without) the simulations.

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The case described here shows how medical participants and medical techniques are reconstituted through the use of a minimally invasive surgery (MIS) simulator.¹ Focusing on actual simulator practice, I examine how learning and knowledge about MIS are constructed; that is, how medical students and instructors create meaning out of the simulations. This contrasts with a focus on skill transferred from the simulator to the students. Instead of looking at *what* the simulator may teach, I show *how* the participants create medical practice when using it. By creating medical practice, simulation users also reconstitute elements of the medical apprenticeship. In this connection, I address the question of what implications replacing patients with simulators would have for an apprenticeship that traditionally has been based on close interaction with other doctors and patients in a clinical setting. The idea of apprenticeship means that skills are learned through practice in actual settings, and this may seem incompatible with using simulators in separate simulator centres, particularly without the assistance of instructors who are practising doctors. While a full analysis of this problem is beyond the scope of this paper, I will show how elements of the medical apprenticeship are reconstituted during medical simulations. The observations presented in this paper aim to show how medical practice can be constructed out of simulator practice.

To understand this process, I apply the idea of situated learning in apprenticeships (Lave & Wenger, 1991) and the duality of participation and reification as components of practice (Wenger, 1998). I examine interactions among student, instructor and simulator, looking closely at how the simulator is presented and how the participants speak and move while using the simulator. My analysis shows how *reconstituting* participation, a specific type of participation, creates medical practice from simulator practice, and medical practitioners from simulator users. I develop the term 'reconstituting' by examining who participates in the practice, what they do, and how reconstituting is related to the integration of simulator technology with existing medical education practices. I will discuss what reconstituting contributes to the MIS simulations, and how it can help us understand the use of simulators in the medical apprenticeship.

Method

This paper draws from a larger project on the integration of two medical simulators into an existing medical education programme during the fourth year (eighth semester)² of basic medical training at a large teaching hospital in Sweden (Johnson, 2004). Using observations of simulator training, conversation analysis of video material from the simulations, interviews with students and instructors about their experiences, and a period of shadowing the students as they treated patients in the wards as a part of their medical training outside of the simulator centre, the larger study examined how simulations were deployed in medical practice rather than in training sessions alone. My larger study (Johnson, 2004) emphasizes the way parts of medical practice and medical apprenticeship were integrated into the simulations. In this paper, I narrow the focus to the way instructors teach with one

of the simulators. Strips taken from videotapes of 46 simulations on an MIS simulator were analysed with a conversation analytical approach to embodied action (C. Goodwin, 1980, 1986, 2000; Heath, 1986; M. Goodwin, 1998; Hindmarsh & Heath, 2000). Excerpts from this video material are used here to discuss the techniques the instructors use to present the simulated medical practice for use on specific types of patients. The simulations were part of a prearranged, non-compulsory exercise during a nine-week course in surgery. The students were taught by an instructor, who was also a practising surgeon at the hospital and with whom they could meet while working in the wards. Although the students did not otherwise have the opportunity to manipulate MIS instruments outside of the simulator centre, many of the students would have the opportunity to observe MIS later in the course, and some students even assisted during MIS surgery by handling instruments that already had been inserted into patient bodies by surgeons.

The Simulator

Located in a large room that was part of the hospital's simulator centre, the MIS simulator sat on a two-tiered table, one tier supporting the instrument panel and the other holding the simulator's keyboard and computer screen (see Figure 1). The handles of two surgical instruments extended out of a green surgical blanket, which covered a bump on the table about a foot square. This bump was in front of and slightly lower than the simulator's computer screen. The simulator user in Figure 1 holds onto the instrument handles with her hands, manoeuvring them in 'real space' while watching on the computer screen what she is doing inside the virtual body.

The instrument handles on the simulator are the ends of an endoscope³ and a probe,⁴ both of which are used during the simulation to explore the human anatomy. Underneath the blanket, these handles are attached to a motor and computer that keeps track of the movements in the virtual body. This motor produces a force that is designed to simulate the resistance experienced when the probe encounters bone or soft tissue, depending on where the user is in the simulated anatomy. This is called haptic feedback. If the user bumps the probe or endoscope up against the virtual liver, which is programmed to be relatively solid, the motor exerts a harder force against the handle and it feels to the user as if she is bumping against a firm, internal organ. If the probe or endoscope pushes into the virtual stomach, slight pressure is placed on the handle and the user feels as if she is pushing into a soft organ with a high level of elasticity. At the same time, the computer generates graphics on the screen that match the position of the 'endoscope'. This displays what the endoscope would be viewing inside the body: the anatomy and internal organs at the ends of the instruments.

The same simulator can be used to simulate the movement of surgical tools in three different human anatomical regions: the upper abdomen, the knee and the shoulder. This is a benefit, because the simulator is flexible enough to allow for several simulations on a very expensive machine, but it also is a drawback, because it is not always obvious by merely looking at the

FIGURE 1
The MIS simulator. © Huddinge media department



simulator which part of the body the student is going to be working within. The computer-generated images on the screen change, depending on the simulation selected, to represent the different body parts, and the handle-motor mechanism is slightly adjusted to mimic the points of entry for each anatomical area, but the external appearance of the simulator is very similar, regardless of which part of the anatomy is being simulated. To adapt to this representational flexibility, the instructors work before and during the simulations to align the student's understanding of the simulator with the correct simulated anatomy.

The half-hour simulator exercises analysed in my study consisted of finding and probing a series of virtual blue spheres in the three anatomical regions, while the simulator kept track of the students' speed, economy of movement and precision. Students had to manipulate both the endoscope and the probe to conduct the exercise. The spheres were located throughout the virtual patient's body, in places that were visible with the endoscope and accessible with the probe, thereby leading the student through the virtual anatomy. Taken by itself, this aspect of the simulation could be considered more like a computer game than surgery. Each student was allowed one or two trial runs before taking a test in which the computer generated a score out of their movements. By finding and probing the spheres, the students were supposed to 'get a feel' for MIS. In particular, they were supposed to practise seeing with an endoscope, aligning the coordinate system and translating the two-dimensional (2-D) image to a three-dimensional (3-D) virtual anatomy, thus learning to adjust for the fulcrum movement that affects instruments inserted through a small hole in the body.

Medical Simulators and Medical Education

Computer simulators are gaining ground in medical education. Animals, human cadavers and patients have long been used as training media for medical students, and they can sometimes provide a better and more practical model of the body than a computer simulator does (see Collins & Kusch, 1998: 88). But these bodies have begun to be replaced by or complemented by simulators, in part because of ethical issues – training on a simulated patient is said to be more ethical than training on animals or patients (Berwick & Leape, 1999; Dawson et al., 2000) – but also for economical reasons – while simulators are reusable, pigs and cadavers are not. Simulators are also ‘sold’ to decision-makers with the promise of cost-savings: many teaching hospitals make more money when their surgeons are operating on patients than when those same surgeons are instructing new students. In theory, a simulator can replace at least some of the instruction time, thereby freeing up more time for the surgeons to perform surgery (Bridges & Diamond, 1999; Gorman et al., 2000). According to this rhetoric, students can learn the basic skills of medicine from a simulator and then spend time with the surgeons and patients working on more complex aspects of surgery (Haluck & Krummel, 2000: 791; Neumann et al., 2000; Kneebone et al., 2003). In this case, MIS students can theoretically learn how to navigate with the endoscope, manipulate an instrument, suture a wound or tie a knot before they actually work with real patients and surgeons.

This benefit of simulators builds on an understanding of medical practice as being made up of constellations of discrete skills that can be learned separately and out of context, and then put together in the examination or operating room to create a complete medical procedure. For a number of different reasons, simulators are assumed to be good tools for teaching these separate skills (Risucci et al., 2001; Seymour et al., 2002), the most obvious being that a simulation can be designed to allow a specific skill to be rehearsed repeatedly and out of context. A student can first practise making a stitch without having to also tie a knot. Once that is mastered, the student can practise tying knots without having to also make an incision and remove an object. The training can be broken up into small components and these can be repeated without having to wait for patients to present the appropriate pathologies.

The ability to produce a report on what the student is actually feeling or doing is another benefit of simulator training in medical education; simulators provide a way to measure performance and standardize the learning situation (Hoffman & Vu, 1997; Marescaux et al., 1998). Aspects such as speed, efficiency of movement and collisions with internal organs can be measured and displayed for the student and instructor in an objective score at the end of the simulation, and these scores can be compared between students. At the same time, computer simulators can provide a way for instructors to view what the students are doing inside the simulated body. Gynaecological simulators with pressure-sensitive sensors, for example, can test if students are actually feeling the various parts of the internal

anatomy during the gynecological examination, and if the students are feeling with the correct amounts of pressure. Without the simulator, it is difficult for an instructing doctor to know just what the student is actually feeling inside the patient's body. With the simulator, it is easier for the instructor to monitor what the simulator says the student is feeling (Pugh et al., 2001). And, with a little 'suspension of disbelief', the instructor can assert that this is the same thing as knowing what the student is feeling.

'Suspension of disbelief', however, is one of the issues often discussed in simulator training, usually in connection with the terms validity, high fidelity and realism; terms used almost interchangeably in much of the literature to indicate how closely the simulator mimics the real anatomy (Felländer-Tsai et al., 2001; Torkington et al., 2001; Maran & Glavin, 2003; van Meurs et al., 2003). Within the medical simulator community there is an undercurrent of activity that strives to make the computer models complex and 'realistic' enough, while still being easy to use, and above all, to make the models true to the real body and real procedures so the students learn how to conduct medical procedures correctly.⁵

Perhaps because of the concerns about their validity, and because of the types of benefits simulators are seen to have (economical savings, skill acquisition and teaching standardization), many studies about simulators either focus on what the simulator is (how it is made technically, how realistic it looks or feels, how valid the represented anatomy is, and so on) or on what the results of its use will be (McCloy & Stone, 2001; Issenberg et al., 2003; Schuwirth & van der Vleuten, 2003; Wright et al., 2004). Explicit and individual aspects of knowledge occupy a central position in much of this work on simulators. For example, the simulator used for this analysis has been designed to teach isolated skills thought to be important to the practice of MIS. It attempts to isolate aspects of surgery such as the manipulation of minimally invasive surgical tools (the endoscope and the probe), and to teach these skills outside of the operating room. It has been designed to provide the opportunity for students to learn the skills of manoeuvring these tools inside the three different anatomical volumes that can be represented. I am not going to take issue with this way of thinking about skill and explicit medical knowledge (see Resnick [1989] and Attewell [1990] for discussions on skill as context independent). However, with this paper I will show that a significant amount of work is required to transform the learning of these isolated skills into medical practices. As I will discuss, my approach examines how the simulations and the skills they are built to teach are situated in medical training. This approach encourages an analysis of the relationships among participants. Rather than focusing on skill acquisition, I examine how medical simulators are actually being used.

I have chosen this perspective because medical education involves much more than just memorizing theoretical knowledge about anatomy and pathology. Medical education is about learning how to be a doctor, something that is absorbed through the apprenticeship of clinical training. Apprenticeship is not only a method of teaching skills, it is also a way of regulating who may practice a skill (Attewell, 1990: 435). It also is a form of

labour (Goody, 1989) and a way of conferring legitimacy to newcomers (Lave & Wenger, 1991). Medical training, with its medical schools, work with patients in residency programmes and regulating licensing boards, combines the more formalized educational aspects of apprenticeship with the actual work of medicine (Starr, 1982; Haas, 1989; Jülich, 2002). I observed both these aspects in the research for the larger study, as the students alternated between being on the wards, at times as the only doctor on the night shifts, and attending theoretical lectures with class cohorts. Students experienced the practice of being a doctor at the same time as they created an identity for themselves within the medical profession. How soon and how often in the medical education students come in contact with patients can vary from hospital to hospital and from country to country, but working with practising doctors on patients is an essential part of the apprenticeship (Becker et al., 1961; Haas et al., 1987; Hughes, 1988; Sinclair, 1997). Surgery, including MIS, has also relied on this practice of apprenticeship, as expressed in a saying surgeons use for their own learning process: when learning a new technique, they 'see one, do one, teach one'.

To understand how simulators can be integrated into medical training, I have turned to the concept of situated learning, which provides the tools for a detailed examination of context (Attewell, 1990). Importantly, situated learning shies away from the term 'skills', with its overtones of possessed and transferable elements, and instead speaks of knowledge as constructed through social practices, and treats learning as a way of becoming a member of a community of practice (Wenger, 1998). In this view, learning is active as a verb, and knowledge also is active: as expressed by the verb *knowing* – an event or phenomenon in construction (Barad, 1996; Mol, 2002). Contexts, relations and activity become material for study, rather than isolated tasks and performance criteria.

Theories of situated learning, as expressed by the concept of legitimate peripheral participation (Lave & Wenger, 1991), together with methods of observation, interviews, and conversation and interaction analysis, provide my tools for understanding practices at the simulator centre. These tools helped to show how knowledge can be constructed as *medical* knowledge, and how the knowledge from the simulator centre is related to the rest of the students' medical education (Rystedt, 2002). Practices within and beyond the simulator centre were part of the process of constructing identity as a medical student, a legitimate peripheral participant in the medical practice of the hospital, rather than a mere user interacting with a simulator interface.

Legitimate peripheral participation is a theoretical term that refers to the relationships between participants in communities of practice. It denotes how individuals gradually take on more central identities in the community of practice, and how 'newcomers become oldtimers through a social process of increasingly centripetal participation' (Lave, 1991: 68). The concept is an analytical tool for examining how an individual becomes a full participant over time. The process of becoming a full participant through legitimate peripheral participation includes the learning of knowledge skills. However, the term also denotes a process much broader than

the practice of learning a particular 'skill'. The learner actually participates in a community of practice, gradually changing position within it, while remaining a member of it, through a progression of less peripheral degrees. Analysis using this term emphasizes the shifting position of members within a community of practice, compared with a traditional conception of learning through internalizing an increment of knowledge.

When the term 'skill' is used, the situated learning approach employs an understanding of the word, not as something that can be isolated and lifted out of context while still maintaining its original essence, but as constructed in social practice (Brown & Duguid, 1991). This understanding implies that skills change when the setting for practice changes, which has led to critiques of attempts to apply the concept of situated learning to traditional didactical teaching contexts (Tripp, 1996). When a skill is not a stable, discrete element of a practice, it is more difficult to conceive of as an object that can be programmed into a simulator and transferred to the student, as the surgical simulators try to do, for example, with tool manipulation. When skill is no longer a 'thing' that can be possessed by the individual, research about skill extends beyond the focus on the individual to an exploration of the context, the situatedness, of the social practice in which it is embedded. Accordingly, it is no longer appropriate to study the individual learner alone; methods for observing group interaction, institutions and contexts need to be employed. The fact that learning depends on the situation in which it occurs means that it is not sufficient to look only at the interaction between simulators and users. The researcher is forced to step back and look at the broader context of the simulation, at what happened in the simulator centre and the teaching hospital. Doing so in the present case showed that the routines of the hospital frequently 'interrupted' simulation exercises: the instructors were paged on the intercom system and discussed actual surgeries in front of the students; instructors name-dropped about other famous surgeons and boasted about the skiing conditions at the recent orthopaedic convention; visiting doctors were allowed to watch simulations and simultaneously provided the chance to talk about medicine with the students; other members of staff would appear dressed in hospital clothing and students observed how their instructors interacted with nurses and technicians; and students also would respond to or ignore the pages they received. The simulations became part of the medical apprenticeship, as they were not actually separate from the rest of the hospital, despite the isolated tasks of the machine and the purpose-built offices in the simulator centre. I explicate this further in other work (Johnson, 2004, forthcoming). Likewise, when the patient body and surgeon body were reconstituted in the simulation, elements of the apprenticeship were also reconstituted. Even when the instructors and students were entirely focused on the simulations, when the paging system was quiet and there were no other visitors in the room, medical practices from the larger hospital setting were still brought to their attention. The instructors thus created a medical practice out of the computer-based simulations. The remainder of this paper details how this was done.

Practice: Reification and Participation

Wenger's theory about learning in communities of practice, which grew out of situated learning work done with Lave, explores among other things what practice is. There are many different ways to conceptualize practice (for examples, see Bourdieu, 1977; Lave, 1988; Chaiklin & Lave, 1993; Lindenbaum & Lock, 1993; Suchman et al., 1999; Säljö, 2000; Schatzki et al., 2001), but I choose to use Wenger's definition because it is particularly broad (Wenger, 1998: 47), yet applicable to studies of people interacting with things. He uses practice as an overarching term to cover an analysis of the duality of participation and reification, a duality of active performance by participants on the one side, and materialized (and materializing) practice embodied in things, on the other.

One of the benefits of Wenger's terminology is that, while addressing learning and meaning making, the concepts of participation and reification move beyond the tacit/explicit knowledge distinction. When used as Wenger suggests, participation and reification are more fluid and fuller than other binary classifications of knowledge and learning. Participation is not uniquely tacit or informal because it can also include practices that follow a codified rule system, and reification is more than explicit knowledge materialized, because it also includes the process of negotiating meaning in practice (Wenger, 1998: 69). Reification refers to the process and products of turning practice into objects, and the re-negotiation of meaning from those objects. Wenger's analysis extends beyond the idea that technology acts on people, to include how people reinterpret, or even misinterpret, an artefact's prescriptive qualities. Wenger uses the concept of participation in much the same way as it is used colloquially, to mean doing in the world, the 'profoundly social character of our experience of life' (Wenger, 1998: 57). Because Wenger is not more specific than this about participation, I have chosen to articulate and examine one type of simulator participation, which I call 'reconstituting'.

Previous studies of material bodies modelled in simulators also focus on the reification of medical practice. The research on which they are based tends to suggest a move toward more and more technically complex and realistic simulators (Dawson & Kaufman, 1998; Maran & Glavin, 2003; Al-khalifah & Roberts, 2004). The reification that has occurred in their construction is, like a directive in a memo, consciously created to direct future practices. The simulator's engineers, usually in conjunction with medical doctors, claim to be able to reproduce a model of the body and create a platform for medical practices enacted on it. An example of how this happens can be found in Prentice (2005), whose work on the development of a MIS simulator shows how different actors collaborate to calibrate the haptic motors of a simulator. In this collaborative process, the creation of the simulator becomes an intentional reification of the idealized form of a set of medical practices. Such practices are built into the physical shape of the simulator.

When confronted with user difficulties or misunderstandings, simulator designers commonly bring a simulator back to the drawing board and

rework its algorithms, its instruction book, design or user interface. But in Wenger's terms, in the interaction between reification and participation each element adjusts for the other to create a successful practice. Wenger's concept of the duality suggests that participation complementing the reified practice in the simulator is equally essential to its functioning as a meaningful object, and thereby encourages an analysis of simulations as practice rather than as artefacts alone.

The physical shape of the MIS simulator, with the instrument panel at patient level and the monitor displaying the 2-D view akin to what a surgeon would see during a real MIS operation, reflects one understanding of how surgery is done. The ways the instrument handles and the haptic feedback simulates what it feels like to touch a liver or a stomach also involve reified knowledge from specialist surgeons who work with the engineers to develop the simulator. However, according to Wenger's theory on reification, the materialization of these aspects of surgery becomes only part of the simulation. When these physical instruments are combined with participation by the instructors and students, understandings of surgery and the patient body are activated and materialized. A reification becomes meaningful within a practice when it is activated through participation. An idea of how a liver feels can be reified with a simulator, but it must be approached and understood by participants, by the students and instructors, for meaningful medical practices to occur.

The usefulness of the reification-participation duality can be demonstrated with some observations I made of students' confusion with positioning the patient body in relation to the simulated organs. At one point during my fieldwork, I commented to an instructor that it seemed to help when he would gesture at one side of the simulator and say, 'the head is here', and then point to the other side and say, 'and the feet are at this end'. The instructor responded by suggesting that it might be useful to attach a mannequin to the simulator so that students could see immediately which way the body was oriented. I had to agree with him to an extent. The suggestion would perhaps make reading the simulator more obvious for students, but it would also be more unwieldy and probably more expensive. At the same time, my observations suggested that it was unnecessary to attach a mannequin to the simulator, since the gesture allowed it to work as it was. In terms of Wenger's duality of participation and reification, it is clear that the instructor's gestures toward the head and the feet are an example of how participation successfully and meaningfully complements the reified practice in the simulator. In a successful interaction between reification and participation, each element adjusts for the other to create meaningful practice. This is why the simulator can work even though there is no 'real' patient body.

The participation that re-negotiates the meaning of the simulators can take many forms: gleefully approaching the practice as a fun chance to 'play surgeon'; running through the simulation as quickly as possible as if trying to win a computer game; critically denying the simulator's ability to reproduce a valid human anatomy, and so on. In the following examples, I will show a specific type of participation that the instructors and students used

to construct medical practices out of simulator training sessions. Instead of working with a very advanced computer game, medical practitioners used the simulations to work on medical patients. This highlights a type of participation that Wenger's theory does not specify: participation that creates a different context (different actors and different techniques) when using simulators. The term 'participation' denotes the practice of incorporating the material results of practice, but it is not specific enough to speak about the particularities of using simulators. For that I have chosen to use the term 'reconstitution'. Reconstituting is done by the participants, both the instructors who are trained as practising surgeons and the students who together with the instructors jointly produce the simulation. They all represent surgical practice and the practice of learning surgery, as participants reconstitute their ideas and understandings about medicine while working with the reified object, the simulator.

Features of the Simulation

Medical techniques feature in the simulations. Three such techniques are interpreting a 2-D image as a 3-D volume, functioning with the visual coordinate system, and the fulcrum effect caused by inserting the surgical instrument through a small incision in the body. These basic MIS techniques tend to be problematic for beginners in both real and simulated surgery.

2-D to 3-D Translation

The simulated patient body is a 3-D volume, but it is represented by a 2-D image presented on the screen. Real MIS surgery is still usually done with a 2-D video image,⁶ so one of the important practices to learn in real surgery is how to translate the 2-D image into the 3-D body on the operating table. This problem also can present difficulties for students in simulation exercises. To address it on one occasion, the instructor spoke as though an actual patient body was present in his instruction, referring to the probe's movement through space in both anatomical terms and in relation to an operating environment: 'Move the point down toward the table, [the sphere] is deeper in the abdominal cavity ... deeper in the abdominal cavity, move the point toward the operating table, toward the spine.'⁷ Constructing the simulator as a patient and using the patient body as a map for the movements helped the students understand the 2D-3D translation.

Aside from being a useful way to assist the students to navigate through the 3-D anatomy, referring to the simulated objects in terms of the human anatomy attuned their focus to the medical aspects of the task at hand. It directed them to think about how the instruments were moving throughout the anatomical volume, rather than focusing on the instruments as handles on a simulator. This was particularly useful when dealing with difficulties in aligning the image produced by the camera with the simulated anatomy, and working with the fulcrum effect on the instruments, both of which are detailed below.

The Visual Coordinate System

The endoscope of the surgical simulator, like many real MIS endoscopes, is made up of a camera set at a 30° angle from the shaft. Therefore, the image on the screen represents the anatomy positioned at a 30° angle from the straight handle that the student is manipulating. It is constructed this way to enable viewing around organs and into tight areas. In addition, the optic can rotate 360° and present any number of horizons of view, producing one coordinate system for the image on the screen and another for the movements inside the body. A practical implication of this is that the image on the screen does not necessarily match the physical position of either the camera or the surgical instrument in the student's hand. When the student tries to move his/her probe in one direction according to the image she/he sees on the screen, it actually moves in a different direction in the patient's body. Consequently, manoeuvring the camera and optic so that the image on the screen is intelligible to the user is one aspect of the simulation that almost always required the instructor's help. Many students commented on such difficulties during interviews following such sessions, saying that only after the instructor pointed out the correlation between the image on the screen and the angle of the camera, and in some cases even adjusted the camera for the students, did they understand how the optic worked and where their instruments were in relation to the anatomical volume.

The instructors often mentioned the displacement of the image at the beginning of a simulation exercise, physically helping the students to adjust the camera and optic correctly, while discussing what they were doing both in terms of surgery and in terms of the simulation. When doing so, they tended to use the body metaphor: speaking about the patient body as the site of the artificial blue sphere that the simulator created for the student to find. 'Sometimes you can be too far in', the instructor said at one point, referring to the shoulder joint, 'so that you are blocking the blue sphere from view, and you can't see what is closest to you.' After stating this, the instructor reached over and adjusted the camera for the student.

During a simulation, when helping the student physically to adjust the camera, the instructor would sometimes explain what he was doing in reference to the instrument handle. The instructor would say 'raise the camera up a little' – actually talking about the handle on the outside of the simulator – an action which would *lower* the camera on the inside of the patient. This was intelligible to the student when the instructor's talk about the instrument handle was accompanied by placing his hand on the student's hand and moving the optic handle that way. At such times, the discursive shifting between the instrument inside the (virtual) patient body, the instrument handle outside the simulator and the image on the screen was not a problem. But when the instructor switched reference frames without making it clear with gestures which frame he was speaking in, the students had difficulties following what he meant. By physically helping the student adjust the camera, the instructor was able to head off potential misunderstandings.

Fulcrum Effect

In real surgery, the instrument the students used to prod the blue spheres and move about in the virtual anatomy is inserted through a small incision in the body. This results in a fulcrum effect; moving the handle of the probe to the left moves the tip of the probe to the right. It is a fairly straightforward phenomenon, but one that tends to cause confusion for beginners. In addition, the disorientation caused by this effect is exaggerated by the fact that the view of what is happening with the body on the screen is not always matched with the coordinate system of the instrument panel. As noted above, during the simulations this could cause confusion because the visualized tip of the instrument did not respond to the students' hand motions in the way they expected, something they found frustrating and difficult to adjust for.

To address this problem, the instructor would sometimes reconstitute the patient body for the student. The instructor would do so by using anatomical way-points and by referring specifically to the student's hands and physical structures outside of the simulation, such as the desk the simulator rested on and the imaginary operating table the patient would be lying on. Explaining to the students how the body of a patient underneath the surgical cloth was positioned helped them understand what they were doing with the instrument. When they knew where the head was and where the feet were, they could better interpret the image on the screen and the movements of their tools. This was sometimes done verbally, by saying for example, 'The probe is on the patient's right side.' Sometimes it was done by pointing to the blue sphere on the screen and then gesturing to where it would be underneath the surgical blanket, while mentioning parts of the anatomy. It was also done by asking the student to identify anatomical structures during the simulation. Students responded to such questions by identifying objects in the anatomy and moving the probe through the anatomical volume, claiming that they recognized where 'they' (themselves as MIS surgeons) were located in the body. The importance of reconstituting the body appeared when it became clear that students became confused when instructors gave directions that were divorced from the metaphor of a real body, as in the following example:

It [the blue sphere] is deeper down when you see that. If you see the tip of the probe in front of the blue sphere, then you just swing it towards the sphere ... instead of pulling it back and trying to push it in. See what I mean? ... And now you can just swing it down, down, down back, yeah, that's it.

During this monologue the instructor was gesturing with his hands in the direction he wanted the student to move the instrument, but the student initially was confused, unsure as to whether the instructor's gestures were indicating how she should move her hands at the instrument panel or how she should move the tip of the instrument inside the abdomen. After trying to explain verbally again, the instructor finally returned to why the student should manipulate the instruments in a specific way, drawing the focus of attention completely

away from the simulator and deploying his own body while explaining the theory behind the movement in a surgical context. He physically demonstrated the fulcrum effect by pivoting his hand back and forth at the wrist.

Difficulties with MIS, such as the fulcrum effect, mismatched coordinate systems and the 2-D image on the screen, have been built into the simulator because they are difficulties encountered in surgical practice. They have been reified into the physical specifications of the simulator so that they are encountered in simulation exercises that are meant to mimic surgery. During such simulations, the instructors reconstitute these difficulties, so that the students will master surgical techniques associated with MIS, and not techniques specific to the simulator. By acknowledging that the problems the students were having were *surgical* difficulties, not merely tricky bugs in the simulator, their solutions become surgical practices instead of ways to manoeuvre in the simulator. This construction became apparent when one of the students complained that the handles were difficult to hold onto, and the instructor replied, 'You should see them in the operating theatre. They're not that easy, there, either.' By directly linking the problematic handles of the simulator with those encountered in the operating theatre, the instructor was helping the student understand the practice of manipulating the 'difficult' handles as MIS practice. To show this in more detail, I will now recount two examples of how the instructors reconstituted the medical patient and therewith medical practice.

Reconstituting the Patient Body

As noted earlier, the MIS simulator has a virtual body, but no physical patient body for the students to relate to. To use the patient body as a tool for explaining MIS techniques, then, the patient body must first be reconstituted. As can be seen in the following examples, the instructor showed the students how the patient's body was related to the simulator's by mapping his own body onto the simulator body. Using the instructor's body in this way thus constructed an actor – the patient – in MIS, and did so in a way that approached the interplay between the physical patient body and the normative anatomical body, as discussed by Hirschauer (1991). Throughout the simulation, the instructor referred to the image on the screen and the instrument panel as a patient body. Before and during the exercise the instructor gestured to the empty space around the instrument panel as he described the anatomy, presenting an imaginary body lying beneath the surgical cloth and instrument panel. Through speaking about the body and pointing with his hands, the instructor located where the head and feet of the patient would be, and explained in detail where the probe and camera enter the body, using medical terms and pointing to his own body. The following is an excerpt from this exchange between the instructor and a student about how the patient body is positioned for MIS in the shoulder (see Figure 2). The excerpts included here are the author's translation of dialogue that occurred in Swedish.⁸

- (Instructor gazes at the imaginary patient)

1. Instructor: *The patient is lying on the side*
 2. Student: *uhmmmm*
Instructor gestures to the patient's head
↓
(Instructor looks at student)

 3. Instructor: *Head towards you*
 4. Student: *OK*
(Instructor stares into space, mimicking patient)
xxxxxxxxxxxxxxxxxxxx
 5. Instructor: *The shoulder raised so*
↑
Instructor moves shoulder into patient position
↑
Instructor extends his arm upwards

(Instructor looks at student)
 6. Instructor: *xxx_____*
You look inside the shoulder
↑
Instructor points to the front of his own shoulder
(Instructor stares into space) (at student)
 7. Instructor: *xxxxxxxxx _____*
You look in from behind
↑
Instructor points to the back of his own shoulder
(Instructor looks at machine) (at student) (at machine)
.....
 8. Instructor : *And that there Comes from the outside, right?*
↑
Instructor gestures to the instrument
↑
Instructor wiggles the instrument panel's probe handle

FIGURE 2
Instructor pointing to his own shoulder to indicate the patient's shoulder



As Figure 2 shows, the instructor pointed to his own body to explain which shoulder was being operated on, how the probes were entering the body, and how the patient was positioned on the operating table.⁹ This is an example of how the patient's shoulder is reconstituted, providing the participation necessary to compensate for elements of the medical practice that were missing in the simulator. By pointing to his own physical body and using it to represent the simulated patient's body, the surgeon's participation complemented the simulator's reified practice. Specifically, he did so by using gesture to direct his own and the student's visual orientation, thereby creating mutual orientation, as Goodwin (1986) has explored. But these gestures do more than merely direct gaze. They also serve to reconstitute the patient body by creating a gloss or mock-up of a surgical field. This mock up, this reconstituted body, functions as a stand-in for the actual patient body, and is accompanied by the participants' willingness to overlook missing or incorrect elements (the missing physical body under the surgical blanket, the existence of blue spheres in the virtual anatomy) while using the simulator (Garfinkel & Sacks, 1970: 363).

Reconstituting the body can also rely on verbal cues as well as the instructor's own physical body. At one point during a simulation exercise in the abdominal cavity, a student was experiencing difficulties reaching the blue sphere with the probe and kept moving the probe in the wrong direction. The surgeon had previously conducted post-simulation surveys with students, which indicated that they found it difficult to know where the probe was in the anatomical body in relation to the blue sphere. He interrupted the exercise and said to the student, 'Now it is in front of the point of entrance. And if you are in front of the entrance, you are in front of the gall bladder and the liver.' Presenting the 'patient' and the surgical procedure in this way allowed the student to imagine how the anatomy of the patient should be laid out. By so doing, it enabled the student to map the images seen on the computer screen with the imaginary body the instructor had described. Thus, the reconstituted patient's body also created a natural reference point from which the instructor could base simple instructions, as in the following: 'It [the blue sphere] is lying somewhere toward the stomach ... toward the foot side. Where were the feet?' The student understood immediately, and moved the probe toward the foot end of the imaginary patient. However, referring to the simulator in patient terms was helpful for the students because both they and the instructor had prior medical knowledge of human anatomy. Using anatomical terms such as bladder and liver only helped the student navigate and act on these organs because of a pre-existing understanding of where the organs should be in the body.

Reconstituting the Surgeon Body

Reconstituting the patient body as described above also serves to construct the student as a medical participant, as can be seen in the following example, taken from an exchange between the instructor and a student about how the simulator is representing MIS in the left knee (see Figure 3).

Instructor points to his knee with his right hand before speaking
↓
(Instructor is looking at his knee)

1. Instructor: *The optic enters there*

Instructor points to his knee with his left hand
↓
(Instructor looks at student)
.....

2. Instructor: *The probe enters there (Figure 3)*

Student, who has been looking at Instructor's knee, glances up at Instructor briefly
↓

3. Student: *yeah*
↑
And then looks back at the knee

Instructor gestures around the front of his knee with his right hand while speaking
(Instructor is looking at his knee)

4. Instructor: *And the majority of the balls*

Instructor lifts his hand above his knee and holds it there
(Instructor looks at Student, who briefly makes eye contact before returning gaze to knee)
.....
(Instructor looks back at his knee)

5. Instructor: *I can tell you right away, they are lying*

Instructor drops hand to knee, points to lateral region, and then moves hand around in a circle while talking.

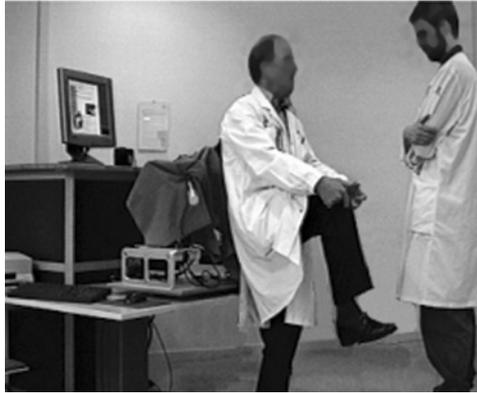
(Instructor still looking at knee)

6. Instructor: *in the lateral part [of the knee]*
The student keeps looking at the knee

7. Student: *yeah*

After the instructor had pointed to the area of entry for both the camera and the instrument, he turned around to the simulator's instrument panel and again reconstituted the patient's knee, this time gesturing toward it with his hands as if it lay under the green surgical cloth that was hiding the simulator's mechanical parts.

FIGURE 3
Reconstituting the patient's knee



During this interaction, the student gazed primarily toward the surgeon's knee (or reconstituted patient's knee, as the case may be), but following verbal cues in the instructor's monologue and in response to attempts on the part of the instructor to secure the student's gaze, the student briefly glanced at the instructor's face (lines 3 and 5), before returning to look at the field of surgical action and the hand gestures being made by the instructor. Gaze direction tends to be an emergent interactional accomplishment, as Goodwin (1980) points out, but the student, the reconstituted patient, the instructor's knee and the simulator-as-artefact are also enrolled into the work of achieving mutual orientation through the instructor's use of demonstrative reference. And while doing so, they re-establish the meaning of the simulator as a surgical field (Hindmarsh & Heath, 2000).

Once the patient's body was laid out on the imaginary operating table in front of the student, the student was forced to approach the instruments and patient with his own physical body, thus broadening the simulation beyond the images on the screen and the haptic feedback provided by the instrument handles. By telling the student that he was standing on the patient's left-hand side, the instructor helped to embody the surgical practices. This encouraged the student to see the simulator as a stand-in for surgery and to see his actions as part of surgery, rather than merely a navigation through a virtual environment. Reconstituting the patient's body into the simulation simultaneously served to construct the simulator as a body upon which surgical practices were enacted *and* to create a surgeon's body out of the student. The student becomes a simulated surgeon rather than a computer user.

In the last example, it is interesting to note that while giving directions in the dialogue, the instructor switched back and forth between framing the simulation as a computer exercise with blue spheres and framing it as a surgical procedure employing an optic and probe within the lateral part of the knee, indicating that participation related to the computer simulator itself co-exists along with the reconstituted medical practice. Thus, the work done to reconstitute the medical practice was not the only type of participation at work. And

reconstituting the medical context occurred repeatedly, continuing after the simulation exercise, when the evaluation of the student's performance was also discussed in terms of how it would be related to a real surgical procedure: 'You conducted that very calmly and carefully, and the most important thing is not to collide with anything. Because, I mean, if you poke an endoscope like this straight into the gall bladder, then you are going to cause damage.' But in the 'reality' of the simulator, poking the endoscope into the gall bladder would only produce a lower score. The instructor contributes to the simulation here by speaking about the score as though it had implications for the patient. 'Damaging the gall bladder' allows the activity to be constructed as surgical activity, and is associated to a discussion of patient safety, a topic for a lecture the students had sat through earlier in the semester.

Conclusions

Apprenticeship implies training in the workplace, as well as following and participating in real practice. The research discussed in this paper examined how skill-training sessions can be constructed and integrated into such learning practices. Analysis of the ethnographic material has shown that, during what is generally considered training for very specific skills, elements of the wider apprenticeship come into play and are integrated with simulations. These elements serve to reconstitute a context that is different from what is physically presented for students during isolated skill training. By examining the participation of those involved in the training, I have shown how the actors and techniques of skill training on a simulator are reconstituted as actors and techniques of medical practice. This creates meaning for the simulator sessions that extends beyond the learning of simulator skills.

This study has shown how simulator practice can be turned into medical practice, using Wenger's understanding of practice as a duality of participation and reification. According to this analysis, objects are incorporated into meaningful practice through participation. Simulators, reifications of medical understandings and practices, become objects around which varied practices can be enacted through participation, including surgery and the use of computers. When using simulators, a specific type of participation – reconstitution – is used to create medical practice out of simulator practice. How to approach the simulator as a surgeon and how to use it as a stand-in for a patient's body were not self-evident for students. Simulations are defined as medical practices, and users as practitioners, when reconstituting the patient body and the surgeon body.

When simulation becomes surgery, the simulator is reconstituted as a *patient body* and the student as a *medical professional* and *apprentice*, rather than merely as simulators and users. To do this, the instructors verbally refer to the anatomy in human terms and used their own bodies to demonstrate the patient body. Because the surgical simulator described in this paper did not have any 3-D physical representation of the body visible to the students, except for the visual image on the computer screen, the

instructors reconstituted the patient body for the students by referring rhetorically and gesturally to the simulator as a body. Once the patient body was constructed and the student approached the simulator, the student's body became a simulated surgeon's body, though of course still within the context of a simulated surgical exercise.

The details of how instructors and students achieved such reconstitution are important to consider when thinking about teaching methods with simulators. They underline the importance of having a legitimate instructor speaking about what is happening in surgical terms. Hearing from a practising surgeon that a lower score is due to an actual/virtual accident that threatens patient safety, grounds the simulation in medical practice in a way that may be difficult to mirror with written instructions for moving the probe. A similar process happens when instructors and students refer to images on the screen, handles of the simulator, and experiences during the simulation in medical terms. By verbally discussing the simulation through their medical understanding, the participants constructed the simulation as medical, rather than as merely technical or pedagogical, thus reconstituting medical practice. But it is also noteworthy that this reconstitution relied on prior knowledge of human anatomy and MIS that the students brought with them to the simulator centre, as well as an instructor who could legitimately explain what was happening. In these ways, both the actors and practices of surgery were reconstituted in the participation of the simulation, and the simulator practice became medical practice.

Reconstituting the patient body creates an object around which mutual orientation is established, both in dialogue in front of the simulation and when repairing instructions during an exercise. This is particularly relevant when using the MIS simulator, as its built-in flexibility allows it to be used for several different types of surgery. The aim of this paper has been to show how the patient body is reconstituted in the details of practice that emerge through analysis of actual simulations. While the technical finesse of a simulator and the thought that goes into creating exercises to teach specific skills are important considerations for simulator development, when a simulator is used there is also a significant amount of work required on the part of participants to coordinate and direct interaction. Such work serves to reconstitute medical practice. By articulating this specific type of participation, I hope to enhance our understanding of such work and encourage reflection over the details of how, and by whom, simulators are used. The benefits of simulator practice lie not only in learning discrete skills, but also in situating knowledge in clinical practice.

Notes

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1. MIS is a general term that describes surgical procedures done inside the body without making a large incision to expose the internal anatomy. Typically this involves using a camera (endoscope) that is inserted into the body through a small incision and feeds images of the surgical field to a video monitor in the operating room. Using the images generated by the endoscope, the surgeon operates inside the body using other instruments also inserted through small incisions. For an STS analysis of this type of surgery, see Zetka (2003).
2. The eighth semester is in the fourth year of medical school in Sweden. At the teaching hospital where the research was conducted, the eighth semester involved a number of specialty courses, such as surgery and anaesthesiology, which combined work on the wards with more traditional lectures. Students interact with and treat patients much earlier in Sweden than students in many other European countries, something that attracts foreign students to Swedish medical schools.
3. The endoscope is a camera and fibre-optic instrument inserted through an incision in the body. Images from the endoscope are displayed on a video screen in the operating room or on the computer screen in the simulation.
4. The probe is simply a long pointed tool that can be used to prod objects in the anatomy. In the simulation it is used to prod the blue spheres that appear throughout the anatomy.
5. One can problematize what kind of 'body' the simulators are trying to mimic (Johnson, 2005).
6. Technologies to provide 3-D volume rendering for MIS exist (for example, CBYON SAVANT software) but 2-D imaging through fibre optics is most common in hospital practice.
7. Quotes are the author's translations from Swedish.
8. I am using a transcription style inspired by Charles Goodwin's work (1980, 1986, 2000). With this transcript, I want to give the reader an understanding of the participants' interactions, gaze and gestures, but because the original material is in Swedish, I am not including references to pronunciation, pauses and timing.
9. A detailed analysis of the way participants use gesture as a mechanism for cohesion across turns at talk and to display mutual understanding can be found in Koschmann & LeBaron (2002).

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