Simulating Medical Patients and Practices: Bodies and the Construction of Valid Medical Simulators

Ericka Johnson

Body Society 2008; 14; 105
DOI: 10.1177/1357034X08093574

Simulating Medical Patients and Practices: Bodies and the Construction of Valid Medical Simulators

ERICKA JOHNSON

Why and how can a gynaecological simulator that has been 'validated' in one context, that is, accepted by experts as a functional and realistic model of the body on which to teach gynaecological exams, not be considered functional when it changes contexts and is used in another country?[1] To think through this problem, which grew out of reflections upon the ontological basis of the simulator's different functionality within the US and Swedish contexts, I examine the use of the terms 'reality' and 'validity' in medical simulator literature, and then apply Karen Barad's concepts of agential reality and intra-action to the gynaecological simulator's development. This provides a new way of thinking about how knowledge can be created in and from a simulator.

Barad asserts that we need to think about what and how we know as phenomena instead of as knowing subjects and known objects. She proposes two terms which are of particular use for my analysis of bodies in medical simulators. The first term is *intra-action*, which is used to indicate that 'a phenomenon is a specific intra-action of an "object" and the "measuring device"; the object and the measuring agencies emerge from rather than precede, the intra-action that produces

Body & Society © 2008 SAGE Publications (Los Angeles, London, New Delhi and Singapore), Vol. 14(3): 105–128
DOI: 10.1177/1357034X08093574

them' (Barad, 2007: 128). Intra-action can help to articulate how the female reproductive organs are produced through gynaecological practices before they are (re)produced in the simulator. Intra-action works within the theoretical framework of *agential reality*, the second term I will be using, which examines how discursive practices are related to material phenomena, and addresses 'the material nature of practices and how they come to matter' (Barad, 2007: 45).

The idea that discursive practices and materiality are interrelated is not new. Barad draws much of her inspiration from feminist work on materiality (esp. Butler) and the field of feminist science studies (esp. Haraway). That social relations and politics are embedded in the materiality of technological artefacts is a founding concept within the field of Science and Technology Studies (STS), from which Barad also pulls ideas. Here, the politics of objects are often taught through the story of Winner's (actually, Moses') bridges in intro-STS courses (and problematized by Woolgar and Cooper [1999], though this does not seem to be taught as often). STS, and in particular Actor-Network Theory (ANT), provide a vocabulary for speaking about the politics of the material world, considering artefacts and humans as actants. As Latour points out, the use of the term 'inhuman' to describe technologies is a misnomer, and one that hides the translation, delegation and prescription mechanisms embedded in the construction of technologies for very human purposes and by very human engineers (Latour, 1988: 303). He clarifies these concepts through his well-known exploration of the 'hole-wall' and 'door closer'. Technologies are seen as delegates of social relations, and prescribe back to the users the values and structures they were built to enforce (Latour, 1988: 310).

ANT terminology puts words to the way technologies can be created and used to reproduce social relations. Later ANT-inspired analysis is helpful to talk about how 'existing' objects are not so stable and defined as we might be inclined to think. ANT-and-after ideas have offered alternative, more flexible understandings of objects and what they do as actors (see Law and Singleton, 2005: 347). Playing on the ANT term *immutable mobile*, later work has also shown how objects do not necessarily remain the same as they move across contexts and through time; rather, objects can be very *mutable* mobiles (Laet and Mol, 2000). Likewise, the definition of an object can resist closure completely, oscillating between various understandings and definitions even within the same context and at the same time (Dugdale, 2000).

Thinking about the gynaecological simulator I have been working with in terms of delegation and prescription, one could posit that it is used to prescribe a specific way of examining the patient. The simulator delegates what an instructor would say to a student: 'Press this hard, right here, to feel the cervix', the simulator seems to communicate through its computer screen. And one could make the argument that teaching the bimanual exam on a simulator, with standardized responses to pressure, on a standardized female anatomy, on a machine that is movable across contexts, countries and practices, is a textbook example of an immutable mobile. But one could also, after watching the simulator being used in practice, make the argument that this simulator is actually quite mutable. For example, rather than just using it as a teaching tool for doctors in training, the gynaecologists I worked with in Sweden brought the simulator into their examination rooms, removed the abdominal skin, and used the simulator to explain upcoming bimanual exams to their patients, even letting the patients give an exam on the simulator, both to explain what they were going to experience and as a way of educating the patient about her own anatomy. This 'misuse' of the simulator as a teaching tool for a completely different audience shows how the artefact is flexible, even within the context of one hospital. That it changes in how it is understood (from student training tool to patient educator), by whom and when attests to the oscillations of meanings that it moves through.

These are all interesting observations. But how does one interrogate the validity of the knowledge of the body found in the simulator? How can we express (and understand) the way knowledge about the world (and social relations) is initially generated to then be replicated in technological artefacts? To address these questions, I have turned to Karen Barad's agential reality and the concept of intra-action as a useful way to think about our relationship with medical simulators and the 'valid' models of the medical body that they provide for users. Within the theoretical framework of agential reality, intra-action articulates how the circumstances of experiencing an object are what define the object. This is very relevant to understanding how the patient body is known in medical practice and how the phenomenon of knowing the patient body in specific practices is then used to create valid models of it in simulators. As I will explain below, as designers work to create models of the human body, they are thinking about how their models are experienced by the users, and – though to a less articulated degree – how the patient bodies they are simulating are experienced by medical practitioners. Barad's theoretical work, which understands reality as things-in-phenomena, as our participation within nature (Barad, 1996: 176), is therefore a useful tool for examining simulator practice and debates about validity because it shifts an analysis away from discussions of things and users, subjects and objects, to the phenomenon of knowing as the basic unity of existence (Barad, 2003: 815).

Thus, in this article, I will use the concepts of agential reality and intra-action to show that the gynaecological simulator refracts phenomena of knowing the female reproductive organs through the bimanual pelvic exam as performed in very specific ways. By expounding upon this example I hope to show the analytical usefulness of these terms for more general simulator studies, and for understanding how the body is produced as relational phenomena. Importantly, as I will discuss at the end of this article, by interrogating the bodies reified in medical simulators, the concept of agential reality directs analysis to the practices of knowing the patient body that are then materialized, reconstructed and taught in the simulators. Recognizing the primacy of practice in the discussions about simulators and their use is important, as it highlights that it is often very context-specific practices that are being standardized in the physical artefacts used to teach them. It also opens up a discussion of the question of *whose* experiences of medical practice are articulated by the simulators.

Valid Patient Simulators?

Although a large variety of medical simulators exist, their introduction to medical education invariably tends to bring up a standard discussion of validity (or 'fidelity', 'realism' and 'authenticity', the terms are used loosely and slightly interchangeably in the medical literature).[2] The typical concern is whether or not simulators actually represent the 'real' body and if they are really teaching medical procedures correctly; no one wants medical students to spend their time training on a false model of the body or practising an incorrect procedure and then damaging patients when they transfer their knowledge and skills onto a living patient.

Medical debates about simulator validity have tended to focus around how well the body is modelled, with the understood subtext being how realistic the representation of the human anatomy is. In common usage, the term 'simulation' generally refers to imitations or representations of a separate, distinct, 'real', although Baudrillard (1994) has problematized this category with his work on simulacra. As it is often conceived, the referent being simulated can be a system or process, or it can be an object. Or, as in medical simulators, it can be both – an operation upon a body, for example. The use of the term 'simulation', rather than 'reproduction', also carries with it the concept of distilling and representing essential characteristics rather than the entire object; creating a model of the essence rather than the whole.

Medical simulator developers tend to use visual representations and tangible examples of the anatomy to source and support their models of the body, everything from traditional, dissection-generated anatomies to advanced imaging technologies like MRI and CT scans. Which technology is used to visualize the anatomy is very relevant to what is seen and then reproduced. As Thacker notes, technologies of visualization interact with institutional structures and economies of bodies to produce 'particular, performative spectacularizations of the anatomico-medical body' (1999: 320), though I would argue that these epistemological aspects are not always sufficiently considered when such visualizations are used in the design of simulators. For example, virtual reality simulators sometimes use data from the Visible Human Project to construct organs and internal volumes which claim to mimic an actual body, but which bodies are mimicked, how they are known, and what they say about our understandings of the human subject and pathologies are questions generally left to the humanities and social sciences (see Cartwright, 1998; Waldby, 1999, 2000). Likewise, there seems to be little reflection within the simulator community over the way these various methods of gathering information about the patient body influence, or to use Barad's ideas, intra-act, with the body to create the phenomenon of knowing it that is then called an anatomy.

When developing medical simulators, information and communication technologies are also being integrated into models to then send signals and responses back to the users. Likewise, many medical simulators combine both visual and tactile stimuli. Visual images are often created on a computer monitor, representing the interior of the body or giving performance feedback through graphs and numbers. The tactile elements of a medical simulator can take the form of a mannequin or artificial body part. The tactile can also, however, be created virtually through the use of haptic feedback computer programs that allow a user to 'feel' a virtual object with a surgical tool or other medical instrument.[3]

However, and of relevance to the theoretical discussion here, one of the primary considerations used to evaluate medical simulators, whatever form they take or technologies they use, is how well the simulation recreates the *experience* of medical practice. When calibrating and evaluating a simulator, medical experts are often asked to test how the simulator mimics the 'real thing', where the real thing is the practice of a medical procedure. Thus the simulator community relies on 'objective' representations of the physical body (i.e. information gathered about an ontologically separate body that is not bothered by epistemological considerations) as a foundation for the validity of their simulators, but their evaluation criteria often draw on knowledge about and clinical experiences of medical practice. The implications of this two-pronged approach are what will be explored here.

At the heart of this dual approach is a conflict between what a simulator is and what it represents, a conflict that is really a discussion of ontology and epistemology, of what is known and how it is known, something often discussed and debated in the fields of science, technology, medicine and society and feminist science studies (as elsewhere). This debate raises questions about how knowledge is created in situated practice, whether knowledge can be considered a phenomenon rather than a representation of an ontologically separate truth, and if it is best analysed through how the world is experienced, including a respect for the way technologies can shape the phenomena we know (see Barad, 2007; Haraway, 1998; Mol, 2002; Suchman, 2007). It also points to the importance of considering who does the knowing (Harding, 1991) and what the objects of knowledge are, as illustrated by debates about medical testing and the gendered body (Oudshoorn, 1994, 2003; Shaw et al., 2004) and the patient's experience of and participation in medical practice (Cussins, 1998). Applying these critiques of knowledge production to the development of medical simulators highlights questions about how evidence of the body is created, maintained and taught to new practitioners.

Simulators as Examination Tools

When looking at articles about the use of simulators in medical education,[4] the issue of validity seems to address two related but different aspects of simulator use. The first and perhaps most common area of usage is the question of how a simulator can test or examine a user's knowledge of a medical procedure, and how 'valid' a representation test results are of the actual knowledge acquisition or demonstration. The discussion about validity in these cases tends to focus on the question of whether or not one can make a valid assessment of a student's or doctor's skill by testing it on a simulator (Dawson and Kaufman, 1998: 481). This use of the term *validity*, and use of the simulators, also touches on a much older debate within medical education about how exams, certification and credentialling can guarantee that the professionals being licensed to practise medicine actually know what they are doing.[5]

To address the use of simulators as assessment tools, many medical studies try to justify simulator use against other, more traditional, methods of examination. One approach is to demonstrate through case studies that exam results produced from a simulator actually match those the same students receive when being examined in more traditional ways, like paper-based tests (see Pugh and Youngblood, 2002). Another method of validating simulator test results is to compare the test results of experts with those of residents, and extrapolate that better results by experts say something about what skills the simulator was actually measuring (Tsai et al., 2003: 74). Perhaps the most rhetorically convincing argument for using simulators as valid testing tools comes from the field of surgical simulators, where simulators provide a place for students to engage in the traditional method of learning, and to demonstrate their knowledge in practice, but without actually endangering real patients (Schuwirth and van der Vleuten, 2003). This argument tends to connect back to the medical aphorism, particularly common within surgery, that a medical student should 'see one, do one, teach one' as they learn medicine, and points out that the last thing a patient wants to be is a medical student's 'do one' guinea pig (Dawson and Kaufman, 1998).

Simulators as Patient Models

The other area in which validity becomes an issue is the question of which model of the patient is being simulated. It is in these discussions that *validity* is often interchangeable with the terms *realism* and *fidelity*. Concern is expressed over how well the simulator actually mimics the patient body, with directives for future development addressing very technical aspects like, 'The color of tissues must be realistic, and the surface texture maps must accurately reflect the simulated organ' (Dawson and Kaufman, 1998: 481). In this use of the term, a valid simulator recreates the body realistically. Barad's concept of agential reality, addressing 'the material nature of practices and how they come to matter' (2007: 45), is useful here to demonstrate what phenomena of knowing produce the 'realistic body' being recreated.

I posit this because closer examination of this use of the term validity indicates that the issues being discussed are not how well the simulator mimics the body, but how well the simulated medical practices recreate those medical practices carried out by experts. As with some of the attempts to validate simulators in testing situations, references to the use of experts appear in this literature. For example, in the development of a haptic urological simulator, in which both tactile and visual stimuli are reproduced, engineers working on the simulator mentioned in their report of the technical development that 'Observations of actual operations on humans and animals showed that a urological operation can be divided into two phases, i.e. the insertion phase and the main operation' (Papadopoulos et al., 2002: 2), indicating that during their development process they used actual practice as a model for the simulator, rather than solely relying on anatomical representations of the body. Their statement also reveals elements of time and narrative in their practice. The 'realism' that they were trying to incorporate into the simulator was not merely referring to the urological anatomy, but was describing specific participation with the patient body by medical experts through time. As a result, the simulator mimics practice not anatomy, and simulates participation with the body. It simulates specific practices carried out through time, not ontologically pre-existing bodies independent of experience, because the urological body being simulated is that of the intra-action between the patient's urological system (and all of the technological, cultural and economic structures that contribute to its very situated presentation; see Barad, 1998) and the medical practices of the surgery.

The same group of technicians mention that, after initial development of the simulator, they sent the machine out to 'potential users' for testing and evaluation. Involving experts in both the design and testing stages is very common practice, as Prentice (2005) delineates, and other articles in the selected material also mention the use of experts to judge whether the simulators were valid (Dawson and Kaufman, 1998: 481; Tsai et al., 2003: 76), which means the simulators are evaluated against the knowledge of medical practice that experts have.

In many medical practices, however, knowledge about the patient body is generated through mediating technology; not in direct intra-actions only between a physician and a patient, but with the help of technological instruments – often measurement apparatuses. Simulators are, therefore, also being built to recreate technological representations of medical knowledge. In writing about the development of a natal distress simulator, for example, the developers acknowledge that they were trying to build a simulator that replicated the baseline signals (primarily read through anaesthesiology monitoring equipment) sent by a baby and the mother during birth and in response to the therapeutic interventions given to the patients. They tried to recreate these by, 'comparing model responses to animal or human data presented in the literature' (van Meurs et al., 2003: 31), i.e. by replicating the way that medical knowledge is recorded, reported and read by others in the community. In this way, the simulator can send technologically mediated signals of its response to the medical interventions of users just as a patient would. The same development goal exists for other simulators, in particular the ones which are used in anaesthesiology training to teach individuals and teams how to deal with patient reactions to pharmaceutical practices in the operating room (Good, 2003: 16; Johnson, 2004). This type of simulator, which can take the form of a full patient mannequin that sends responses through monitoring equipment just as a human would, is sometimes called a high-fidelity simulator, in which 'fidelity is the extent to which the appearance and behaviour of the simulator/simulation match the appearance and behaviour of the simulated system' (Maran and Glavin, 2003: 24). The fidelity comes from how the simulator can relay these signals to users in a way that mimics those physical and technological responses given by patients through monitoring and mediating technology during anaesthesiology. Significantly, although not articulated as such in the medical literature, the concept of simulator fidelity is based on intra-action (see Barad, 1996, 2007), that is, how we read signals to know about the patient, not re-creation of the patient, and can be compared to Barad's discussion of Bohr's philosophy-physics and the way in which the apparatus of measurement 'enacts a cut delineating the object from the agencies of observation' (Barad, 2007: 114).

The definition of fidelity above comes from an article in which Maran and Glavin make a distinction between engineering fidelity – replication of the physical characteristics of the real task – and psychological or functional fidelity, which they define as, 'the degree to which the skill or skills in the real task are captured in the simulated task' (Maran and Glavin, 2003: 24). But, while they do not specifically comment on this, it is worth noting that in both of these examples of fidelity, it is a *task* that is being simulated, not merely a body part or a medical environment. Practice, phenomena and action are simulated, not the body as an unchanging anatomy.

Thus, it would seem as if the medical and technical professionals working with simulators are realizing, though not necessarily reflecting upon, the fact that they are simulating practice (Al-khalifah and Roberts, 2004; Dawson and Kaufman, 1998; McCloy and Stone, 2001; Wright et al., 2004), a realization which also appears in an article about the testing of the gynaecological simulator. In it, the simulator's inventor states:

> Some researchers have focused on recording the hand and arm movements the surgeon makes in reference to an instrument, whereas others focus on the 'operative outcome' or end result, such as the quality of an anastomosis. The research reported here suggests it is equally or more important to capture data representing how the user interacts directly with the tissues – either by direct contact (hand to tissue) or by instrument contact with the tissues (instrument to tissue). By placing sensors on the tissues being manipulated, *the data that are captured are more specific to the procedure being performed* than to the physical attributes of the user or how a user interacts with an instrument. (Pugh and Youngblood, 2002: 458f, emphasis added)

A concern to capture the data '*specific to the procedure being performed*' indicates that the way simulators are being designed takes into account the concept of knowledge as a phenomenon involving practice, though without actually using those terms. To demonstrate this further, I will now turn to an analysis of the interview material gathered while speaking with both the gynaecological simulator's inventor in the US and the woman in the UK who modelled the physical pelvic mannequin which the simulator uses. Through examples from the design and usage practices of this gynaecological simulator, I will show how Barad's theoretical approach to knowledge and materiality can be useful in understanding the complexity of medical simulators. In doing so, I also present a theoretical discussion of why a validated simulator can work in one context, yet be problematic in another.

Simulating the Bimanual Pelvic Exam

As described above, validity is a general concern for those working with medical simulators (Maran and Glavin, 2003). It became a specific concern for me when

I started to study the use of an imported gynaecological simulator in Sweden. The simulator had been designed to help teach students how to conduct the bimanual pelvic exam. It simulates a female pelvis, with the uterus, ovaries and vagina sitting inside a pelvic cavity and covered by a synthetic skin. The internal organs are fitted with special pressure sensors that can display on the attached computer whether the student is 'feeling' in the right place and how hard they are pushing on the internal organs.

At the beginning of this research project, I had travelled to the US to observe a training session using the simulator at a university hospital. The medical students using the simulator had arrived at the session having previously examined a live patient in their obstetrics and gynaecology course. They were now going to conduct a pelvic examination on the simulator, with the help of an instructor. Their work on the simulator began after the instructor first went through some of the pathologies that can present during a gynaecological exam. She then described to the students how they would conduct a speculum exam and a bimanual exam on the simulator.

The speculum exam entailed gradually inserting a Pederson speculum into the simulator's vaginal cavity and slowly opening it up to observe the cervix. After this was done, the speculum was removed and the bimanual exam was conducted, which consisted of three distinct phases. First the students were to enter the simulated vagina with one hand and feel the cervix. Then, with their other hand pressing downward from on top of the simulated patient's abdomen, the students were to lift the uterus upward with their first hand and feel the presence and size of the uterus (see Figure 1). The students were to note when they touched the fundus[6] of the uterus. Finally the students were to try to feel both ovaries between their internal and external hands.

As the students found and touched each of these organs, the pressure they put on them was measured by the simulator and graphically displayed on the computer screen of the laptop attached to it. At one point, towards the end of the simulation, the instructor mentioned in passing that she would not be able to really know if they were touching the organs if it were not for the pressure displays on the screen. For her work as an instructor, being presented with visual proof of what the students did was helpful. For the students, the visuals were also a way of knowing if they had really touched what they were 'looking for' with their fingers. The simulator not only gave them a model to work on, it gave them feedback about what they were doing.

After the session, the students and instructor all seemed pleased with their simulator training and talked about how the experience related to what they would encounter with patients. This satisfaction with the simulator was not shared by

Figure 1 The pelvic simulator

the gynaecologists I was working with back in Sweden. What has triggered my reflections in this article is that it became apparent that the validated simulator which worked in the US (Pugh and Youngblood, 2002) was not meeting the demands my Swedish research partners were making of it. They were dissatisfied with the small size of the simulated pelvic bone, the cervix, which they thought was too short, and the firmness of the abdominal wall. And, perhaps most telling, they were dismayed that they could not use the simulator to conduct the pelvic exam that they teach their students; the very same bimanual pelvic exam I had observed in the US, in which a student feels the cervix, feels the fundus and tries to feel the ovaries.

I began to wonder about the source of the negative reaction from the gynaecologists in my research group, and why the simulator could be used to teach a bimanual pelvic exam in one context but not in another. And, since the simulator in question had been validated by experts, how a discussion about its performance in two different contexts could be related to validity. These thoughts led to reflection on what the simulator is simulating. Surely the whole reason to make valid and realistic simulators is so that they simulate an objective patient body. Medical simulators are designed to simulate patient bodies,[7] and the female body is not that different in the USA, where the simulator was invented, than in

Sweden. Unless, perhaps, medical simulators are not actually simulating bodies. Perhaps simulators are simulating something else. But first, a little background about the simulator's history.

When developing the gynaecological simulator, its American inventor worked with a number of different rubber and plastic models of the body already in existence before settling on the model now used. The current model had been on the market, without pressure sensors, for 15 years before it was adapted to the simulator. When I was talking with the inventor about this process and how she conceptualized the simulator, an interesting view on the material construction of the artefact came up. Because she had used several different models of the female anatomy in the process of designing her simulator, she had opinions about how the various anatomies they represented were modelled. She felt that some had specific mistakes in the anatomical construction that made their use problematic, and others had been designed for alternative procedures which made their use for the pelvic exam difficult. For example, one of the models she initially tried using had been designed to train students in laparoscopic surgery for tubal ligation, and therefore the plastic that the vagina was made out of was too solid to work when students were attempting a bimanual vaginal examination. The inventor tried to convince the designer and producer of that model to make the vagina out of a softer latex by photographing the red and chafed hands of people who examined it, i.e. reintegrating the results of (simulator) practice back into the simulator's design.

During an interview about the design process, her conceptualization of the ideal model indicated a concern with (correct) practice. She said:

> I was thinking abstractly that it didn't have to be a mannequin, it could be some glob. . . . You put your hand in a black hole and it . . . reshapes itself into either a spleen or a pelvis or whatever, and the bigger element of it was the visual feedback that you got *so you had an understanding of what you did compared to what the quote unquote experts do*. (emphasis added)

For the simulator's inventor, the important aspect was not how realistically the mannequin mimicked the human body. Instead, when conceptualizing the simulator she was focused on the way the simulator represented a practice – the expert examining the pelvis – and how information about that could be relayed to the person using the simulator. This focus on the practice of using the simulator in relation to the practice of experts giving a pelvic exam, rather than the artefact mimicking the anatomy, also appeared when talking about how the pressure sensors in the pelvic cavity were calibrated. As the sensors register the pressure a person puts on various parts of the internal anatomy, there has to be a way of determining if the touch is purposeful or accidental. To determine this, the inventor conducted a study which registered the average pressure generated when trained and practising gynaecologists examined the simulator. This was then coded into the simulator and used as a benchmark for further exams.

In addition to inserting digital sensors that register touch and pressure to parts of the anatomy, the inventor also changed a few elements of the pelvic model that she finally chose to use. She had a harder plastic inserted in the ovaries, for example, to make them easier to feel and easier to attach sensors to. She also moulded the stubs of legs, which the model originally did not have, to make the simulator look more like a female body from the outside. After making these changes, the UK-based designer of the model sent the altered simulator out to a series of medical experts – practising gynaecologists – for their responses and reactions, to see if it was still a 'valid' representation of the female anatomy. The comments that came back from this prototype test, which discussed the way the uterus moved and how solid the ovaries felt during the exam, also speak of the phenomenon of knowing the female body during an exam. The model was judged based on these gynaecologists' reactions to the simulator and comparisons of it with their experiences of live patients' bodies during the pelvic exam, not, as could have been done, on dissections of female cadavers or images or scans of the female body.

One of the more interesting things the inventor had changed about the model was that she demanded the manufacturer package the simulator with an insertable 'fat pad' that could be placed underneath the skin of the abdomen to allow students to practise examining obese women. The fat pad, which is now shipped with each pelvic simulator, is a thin, silicon insert much like a slightly oversized mouse pad. The skin of the abdomen is removed from the pelvic simulator, the fat pad is inserted above the uterus and ovaries in the simulator, and then the skin is put back in place. The reason for having the fat pad is because a significant amount of the bimanual pelvic exam involves pressing upward with the hand that has been inserted into the woman's vagina while simultaneously pressing downwards with the other hand from on top of the abdomen, and then trying to feel parts of the anatomy between the hands, locating and feeling, for example, both of the ovaries. Finding the ovaries during the pelvic exam is difficult to master; the ovaries are relatively small and soft, and it can be difficult to feel them between the hands. In addition, as they are located off to the sides of the uterus, the examiner has to manoeuvre their hand inside the vagina into a position where the ovary can be caught between the internal and external hand. It is even more difficult to feel the ovaries between one's hands if the patient being examined is significantly overweight, and obese patients are becoming more and more common, both in the US and in many other Western nations.

Thus, inclusion of the fat pad is a relevant consideration for teaching exams with the pelvic simulator. However, I was surprised by the fact that the simulator's pad was made of a relatively thin layer of silicon. I brought this up with the model's designer, who explained to me that fat in the body is, of course, at body temperature, and when it is that warm it is not very solid. It is bound in small capsules of sorts, but these have a tendency to move around almost (but not quite) like a liquid in parts of the body. Thus, when a patient is lying down on her back during the pelvic exam, the fat in her abdomen tends to slide downwards, off the peak of the stomach. When examining an obese patient's pelvic region, as the hands press up from inside and down from on top of the abdomen, the fat in that area is gently pushed out of the way. Not all of it, of course, but quite a bit of it. Therefore, the 'thin' fat pad gives the feeling that a doctor would have when examining a much larger patient. As the designer told me:

> When you're going in, and someone's got that much fat, it will displace quite a lot. . . . Whereas even though that silicon is very soft, it doesn't displace the same way. . . . It's a matter of judging what is simulated, or how the simulation will equate with the real life.[8]

Significantly, what she is saying is that the fat pad is simulating not the actual body of the patient, since it is not made of a gelatinous, almost liquid substance that moves out of the way and changes its behaviour depending on temperature and position. In the most literal sense of the word, the fat pad is not a valid representation of the body because it does not recreate the physical characteristics of fat. What the fat pad is simulating is the phenomenon of examining an obese patient lying on her back. The simulator then becomes a valid representation of a specific practice, of a specific phenomenon of knowing patient obesity experienced by a doctor during a pelvic exam.

The designer's description of how she thinks of patient fat and simulator fat resonates with Barad's conception of knowledge as constructed in practice. The designer did not use the terms *intra-action* or *phenomena*, but her design took into consideration how the simulator would be able to reflect the *phenomenon* of examining an obese patient, rather than simply creating an obese simulator. Just as Barad, when writing about how ways of knowing and reality are mutually constituting during scientific experiments, states that '*observations do not refer to objects of an independent reality*' (1996: 170, italics in the original), the designer seems to recognize that it is the way a doctor observes the obese patient's body, the practice of observing and creating knowledge, which should be simulated, not the body as an object independent of epistemology. When knowledge about the body that has been gleaned through practice is reified into a simulator, that specific phenomenon of knowing the body is simulated, not the ontologically independent body as such.

Barad uses the term agential reality to explain the practices of phenomena that create our knowledge about the world. She draws her original inspiration for this theory from the work on quantum physics by Nils Bohr. Using his explanation of light, a point of contention within the physics community at the beginning of the 20th century, Barad explains how Bohr asserted that light can be both a particle and a wave, depending on the apparatus of measurement used to examine light. What light *is* becomes dependent on the way it is measured or observed. From this example, Barad posits that *concepts are defined by the circumstances required for their measurements* (1996: 169). Light, and everything else, cannot be separated from the way it is experienced. The phenomenon of knowing something is what determines what is known. As she states, '*Phenomena are constitutive of reality*. Reality is not composed of things-in-themselves or things-behind-phenomena, but things-in-phenomena. . . . What is being described is our participation *within* nature' (Barad, 1996: 176). She calls this participation within nature agential reality. Fundamental to an agential realist analysis is that phenomena become the basic unit of existence, not subjects and objects. 'That is, phenomena are ontologically primitive relations – relations without pre-existing relata' (Barad, 2003: 815).

The concept of intra-action is used in the theory of agential reality to explain the details and actors in the practice of knowledge phenomena. By using the neologism *intra-action*, Barad makes the point that, within the theoretical framework of agential reality, the distinction between subjects and objects as separate entities, a dichotomy of knower and known, is erased. The term dissolves the boundary between objects and 'agencies of observation'. Intra-action signifies that the object of knowledge cannot be separated from the way, the practice or phenomenon that makes it known. It is in contrast to the more common term *interaction*, which reinscribes the separateness of the object and the method of observation (Barad, 1998: 96). Intra-action reflects Barad's dismissal of representationalism, of the 'belief in the ontological distinction between representations and that which they purport to represent' (2003: 804). The referent and the object of observation (and by extension the person doing the observing) become intra-acting sub-units of a phenomenon, all of which are necessary components for the phenomenon to be observed. And what is described by the observations is not nature, but the intra-active participation of all the sub-units (Barad, 1998: 105). Analytically, the term intra-action becomes useful because it articulates the local, specific practices involved in making what Barad calls agential cuts. It provides a way of analysing the details in knowledge practices. It can show, for example, how a fat pad and an examiner's hand can intra-act in a way that simulates examining an obese patient even though the fat pad does not change consistency with temperature changes or move loosely throughout a cavity like human fatty tissue.

As mentioned earlier, Barad's work draws inspiration from Judith Butler's theories about gender and performativity (Butler, 1990) when she asserts that technoscientific practices are also performed, and it is in the performance that knowledge is created (Barad, 1998: 105). She also acknowledges the inspiration of Haraway's (1998) examination of situated knowledge for the development of her theory (Barad, 1996: 166). But agential reality expands on situated knowledge by creating a way to activate the concept of situated knowledges in analysis of scientific practice through observations of practice and phenomena of knowing. In addition, and of particular interest, agential reality and intra-action expand the work of Butler and Haraway to include artefacts. By making phenomena the base unit of analysis, the concept of intra-action becomes a particularly useful tool for thinking about how we relate to the world and to technology, and, as Suchman (2000) notes, for considering what happens in the relations between humans and non-humans (see also Suchman, 2007). Relying heavily on Barad's concept of intra-action in an article that considers agency for persons and artefacts, Suchman points out that 'it matters when things travel across the human–artefact boundary, when objects are subjectified (e.g. machines made not actants but actors) and subjects objectified (e.g. practices made methods, knowledges made commodities)' (Suchman, 2000: 7). Using the concept of agential reality, one can begin to pay attention to 'travel across the human–artefact boundary'.

Agential reality differs from (some) Actor-Network Theory (ANT) (see Latour, 1999; Law, 1987) in that it does not merely include artefacts through the concept of symmetry and actant; it also lifts the unit of analysis from actants and networks to the phenomena that create both artefacts and actors. It also places agency in the relationships between people and material artefacts, rather than with people and/or material artefacts. 'According to agential realism, agency is a matter of intra-acting; it is an enactment, not something someone or something has. Agency cannot be designated as an attribute of "subjects" or "objects" (as they do not preexist as such)' (Barad, 2001: 236; see also Suchman, 2000). One of the criticisms of ANT has been that it is possible to interpret the term *actant* in such a way that agency is attributed to things and thereby can appear to make humans and non-humans equal through the concept of symmetry, which hides issues of power in our relationships with the world (see Star, 1991). And while ANT actually has only proposed that things and people be treated symmetrically in analysis, which is slightly different, and later ANT analyses have tended to look at enacted relationships as well, the concept of symmetry disguises the fact that 'people and artefacts do not appear to constitute each other in the same way' (Suchman, 2000: 6). Through the emphasis on phenomena as the unit of analysis, Barad's concept of intra-action is able to explain how non-human objects can be implicated in the question of agency, since agency must be seen as relational in the intra-active practices of knowledge phenomena.[9] Analysing the pelvic simulator with the concept of intra-action can explain not only that it works in one context and not in another, but why. It is easy to look at a medical simulator and assume it is a representation of the body. However, a simulator is really a representation of specific phenomena of knowing the body, which makes simulators representations of practices, practices that can vary from one context to the next.

Looking again at the bimanual pelvic exam, small, contextual differences appear between the US and Sweden.[10] Some of the differences involve interactions with the patient, and are a result of issues specific to the public/private display of the body.[11] For example, the Swedish and US exams can vary in the way eye contact with the patient is made or avoided, and how/if the patient's body is covered during an exam. But some of the differences are found in the actual medical practices of the exam. These have become reflected in the way the simulator is built and refracted by the change in context. So, for example, the simulator allows for the fundus of the uterus to be pressed up against the top of the abdominal wall and felt from above, from outside of the patient's abdomen. Feeling the fundus in this way, according to interviews with the inventor and the pelvic exam guidebook that is shipped with the simulator, is typical procedure for a (US) pelvic exam. However, the Swedish gynaecologists I worked with have a different method of examining the uterus. Their exam, which they currently teach using professional patients rather than a simulator, involves pressing the uterus up against the abdominal wall and then tilting it forward, so that the examiner's hand outside of the abdomen is able to feel firmly down through the abdomen and examine the back side of the uterus, checking for possible growths on this otherwise unobserved area of the body.

A human body is flexible enough to allow for the uterus to be tilted forward during an examination. The simulator, however, is not. In the simulator the uterus is firmly connected to the plastic encasing that represents the pelvic bone and cavity, and it is not possible to flip the uterus up and backwards to examine the back side of the organ. Thus the simulator facilitates the less invasive US examination of the uterus, but not the Swedish method.[12]

The difference between examination practices and the way the anatomical representation works in one context but not in another beg the question of how we can understand and determine validity in the case of simulated human bodies. I suggest that Barad's concept of intra-action is a useful way of approaching this issue. To understand it, one must shy away from simple representationalism and think of phenomena as the basic units of knowing. The first step towards doing so, when working with medical simulators, is to acknowledge that practice is the ontological basis upon which they are constructed, not an objective, epistemologically independent human anatomy.

Discussion

When it comes to thinking about how simulators are conceived of and constructed, how the valid medical body is replicated, agential reality demands that we include practice in our understanding of the object (Barad, 1996: 182).[13] In Barad's theory of agential reality, it is phenomena that create reality, so it is the phenomenon of knowing the body which is built into simulators. I conclude this article by suggesting that it is important to recognize phenomena as the basis of attempts to mimic the human patient in medical simulators for both theoretical and practical reasons.

During the course of my research, I saw that the pelvic simulator actually simulated the pelvic anatomy as known in a US pelvic exam. It did not really simulate a Swedish pelvic exam anatomy. There are differences between the two countries in how a bimanual pelvic exam is conducted, and these differences in practice become apparent when a material object is constructed to facilitate that practice. More interestingly, these differences highlight the fact that the gynaecological simulator is only an anatomy for a pelvic exam, which is not the same thing as a reproduction of the female pelvic anatomy.

Simulators do provide models of the patient body, but the body being modelled in the simulator is actually the *experienced* body. The importance of the *experienced* body is why, for example, during the development and testing phases, simulators are built in conjunction with experts who can demonstrate and evaluate the way medical knowledge is experienced as a phenomenon.

Concern with model validity appeared in my fieldwork with the gynaecological simulator. The inventor and the designer of the pelvic simulator both expressed concern that the simulator provide feedback on a phenomenon – a medical practice – and that the represented body be a realistic recreation of the experienced body. The inventor's concept of an 'amorphous glob' whose primary task is to provide feedback on practice in comparison to the experts showed a concern for practice and methods of evaluating practice, rather than ways to simulate the body. The modeller's design of the fat pad also demonstrated an appreciation for the intra-action between the doctor and the patient body in creating medical knowledge of the obese body. The fat pad represents the practice of knowing the obese body rather than the reproduction of fatty tissue. This specific phenomenon of knowing obesity, primarily through the tactile, was then integrated into a simulator which also relies on the tactile, using a physically constructed model.

Aside from the obvious implications for simulator design, the observation of how the obese body is known during a gynaecological exam also contributes to a sociological understanding of how knowledge about the body is created through social phenomena.

One implication this has is for our theoretical understandings of simulators. For medical practitioners and simulator developers, acknowledging the fundamental place of phenomena in their work can emphasize the value of considering which experts are appropriate to use and what those specific expertises say about the standardizing of medical practice, in much the same way that analysis of anatomies has shown how these images standardized and legitimated certain culturally and historically specific ways to see and conceptualize the body (see Jordanova, 1999; Laqueur, 1990; Schiebinger, 1993). The body built into the simulator has a history, as models and understandings of a body do. But my analysis of the simulator shows that the history of the simulated body is a history of knowing the body in practice, and in very context-specific medical practices. Because these practices are context specific, there is a political implication to constructing simulators that recreate and represent certain practices as medical norms. Feminist critiques have shown how medical practices (re)produce the female body (Cussins, 1998; Diedrich, 2007; Fausto-Sterling, 2000; Jordanova, 1999; Maines, 1999; Martin, 1992; Oudshoorn, 1994) and these critiques are just as salient in an analysis of the simulators that reify those practices. Understanding that simulators are representing practice means that we must start to think about which practices are being recreated and taught to new medical practitioners, and start to ask how and why these practices are being standardized, rather than assuming that the simulator apolitically and objectively mimics an ontologically 'true' patient body.

Realizing that it is phenomena of knowledge that are being simulated, and not the body, also holds specific, practical, implications for those tasked with evaluating the simulators. Focusing on the measurements of the body and the standards it reproduces may not actually say that much about the validity of the simulator. Instead, considering the simulator as a representation of practice will demand the development of tools that can analyse and evaluate practice, both in the clinic and the classroom. Using experts to do this is a step in the right direction, but it should be reflective practice.

Another result of viewing simulators as reifications of practice is that their design process then demands methods to gather information about practice, rather than only relying on measurements or images of the body. Acknowledging that practice is simulated by the simulator explains why the 'anatomically correct' uterus works in one context but not in another. But there is more political capital involved in this argument than that. Acknowledging the fundamental aspects of practice in simulator development creates the discursive space to ask *whose* practice is being simulated: Experts? Which experts? Which medical professionals are being made invisible? And what about patients? I ask this last question because, in the work constellations of developers, designers, and medical experts who cooperate in the tasks of simulator design and testing, the *patient's* experience of a medical practice is not merely silenced or made invisible, it is never even considered. But it could be otherwise. One could imagine a simulator which integrates how patients understand certain medical procedures, which integrates patient-specific phenomena of knowing medical practices.

Returning to the pelvic simulator and the practices of gynaecology, it is worth reflecting on the specific ways the body parts of the simulator are laden with meaning, and how these meanings are manifested or silenced in the simulator. Again, here one can examine the practices of the gynaecological examination for answers. Interviews with professional patients (women who allow students to practise the pelvic exam on their bodies while also instructing the students in bedside manners) suggest that professional patients experience the gynaecological exam in ways that are not measured by the pressure sensitive sensors of the pelvic simulator. These women are concerned with how students approach them before the exam, the eye contact that is made during the examination, and the discretion with which certain topics are broached and discussed. Other, physical, aspects of the exam are experienced by the patients, too, besides just the pressure used to find internal organs. For example, the temperature of the examination equipment can be a significant aspect of the patient's experience, but is not recorded at all during the simulation. One could ask how incorporating these issues would change the simulator. Emphasizing that medical knowledge of the body is created through phenomena opens the discursive space in simulator design necessary to think about how, and by whom, medical procedures are experienced. This space can also let us think about the value of including patient experiences of medical practice in simulator design.

Notes

1. The research on which this article is based is an examination of the development and implementation of a digital mannequin that represents the female pelvic anatomy. As part of this project I have interviewed actors involved in the invention, development and marketing of the simulator. Thanks are extended to Nina Lykke, Corinna Kruse, and the anonymous reviewers for helpful comments, and to those I interviewed. Support for this research came from the Swedish Research Council grant 'New Visualization and Simulator Technologies: Their Meaning for Learning and Knowledge Production in Gynaecology' and the Institute for Advanced Studies on Science, Technology and Society, Graz, Austria.

2. See, for example, the articles in the 2003 special edition of *Medical Education* 37(supplement 1) dealing with simulators (Good, 2003; Maran and Glavin, 2003; Schuwirth and van der Vleuten, 2003; Tsai et al., 2003; Van Meurs et al., 2003).

3. See www.mentice.com for examples of this.

4. To examine how this concept and the terms around validity are used, I have chosen to analyse it in the special supplement of *Medical Education* on the use of simulators (autumn 2003) and other articles about simulators which bridge the questions of simulator use and development between engineering and medical actors.

5. For a review of this in the history of American medicine, see Starr (1982).

6. The fundus is the base of a hollow organ, farthest from its opening, in this case the far tip of the uterus.

7. For an analysis of the gendered body in simulators, see Johnson (2005).

8. Interview with model designer of the simulator, January 2005.

9. See also Mol and Law (2004) for a discussion of the body as subject and object.

10. The US and Sweden are very large categories. I use them here for the purpose of argument, but I am aware that local practices can also vary between examination rooms within the US and within Sweden.

11. See Heath (1986) and Pilnick and Hindmarsh (1999) for a discussion of this in other fields of medicine.

12. This difference is something to consider when teaching with the simulator, but it is not necessarily a fatal flaw, even for teaching the Swedish exam. At one level, this physical construction of the simulator can dictate what methods of examination it is used to teach. At another, however, it cannot. The fact that the uterus does not move like a 'human' uterus and cannot be examined in the same way as a woman is usually examined by the gynaecologists I work with offers a discussion point for the contrasts between a simulator and a human, and between the different methods of examination during a teaching session. It allows for Swedish medical practices to be reconstituted verbally, despite the physical difficulties involved in feeling the back side of the uterus.

13. 'Agential realism includes practice within theory – theory is epistemologically and ontologically reflexive of context' (Barad, 1996: 182).

References

Al-khalifah, A. and D.J. Roberts (2004) 'Survey of Modelling Approaches for Medical Simulators', pp. 321–9 in ICDVRAT (ed.) *Proceedings of the 5th International Conference on Disability, Virtual Reality and Associate Technologies*. Oxford: University of Reading Press.

Barad, K. (1996) 'Meeting the Universe Halfway: Realism and Social Constructivism without Contradiction', pp. 161–94 in L.H. Nelson and J. Nelson (eds) *Feminism, Science, and the Philosophy of Science*. London: Kluwer Academic Publishers.

Barad, K. (1998) 'Getting Real: Technoscientific Practices and the Materialization of Reality', *Differences: A Journal of Feminist Cultural Studies* 10(2): 87–128.

Barad, K. (2001) 'Scientific Literacy _ Agential Literacy = (Learning? Doing) Science Responsibly', pp. 226–46 in M. Mayberry, B. Subramaniam and L. Weasel (eds) *Feminist Science Studies*. London: Routledge.

Barad, K. (2003) 'Posthumanist Performativity: Toward an Understanding of How Matter Comes to Matter', *Signs: Journal of Women in Culture and Society* 28(3): 801–31.

Barad, K. (2007) *Meeting the Universe Half-way*. Durham, NC: Duke University Press

Baudrillard, J. (1994) *Simulacra and Simulation*, trans. S.F. Glaser. Ann Arbor, MI: University of Michigan. (First published in French by Editions Galilee, 1981.)

Butler, J. (1990) *Gender Trouble: Feminism and the Subversion of Identity*. London: Routledge.

Cartwright, L. (1998) 'A Cultural Anatomy of the Visible Human Project', pp. 21–43 in P. Treichler, L. Cartwright and C. Penley (eds) *The Visible Woman: Imaging Technologies, Gender, and Science*. New York: New York University Press.

Cussins, C. (1998) 'Ontological Choreography: Agency for Women Patients in an Infertility Clinic', pp. 166–201 in M. Berg and A. Mol (eds) *Differences in Medicine*. Durham, NC: Duke University Press.

Dawson, S. and J. Kaufman (1998) 'The Imperative for Medical Simulation', *Proceedings of the IEEE* 86(3): 479–83.

Diedrich, L. (2007) *Treatments: Language, Politics and the Culture of Illness* Minneapolis, MN: University of Minnesota Press.

Dugdale, A. (2000) 'Materiality: Juggling Sameness and Difference', pp. 113–35 in J. Law and J. Hassard (eds) *Actor Network Theory and After*. Oxford: Blackwell.

Fausto-Sterling, A. (2000) *Sexing the Body: Gender Politics and the Construction of Sexuality*. New York: Basic Books.

Good, M.L. (2003) 'Patient Simulation for Training Basic and Advanced Clinical Skills', *Medical Education* 37(suppl. 1): 14–21.

Haraway, D. (1998) 'Situated Knowledges: The Science Question in Feminism as a Site of Discourse on the Privilege of Partial Perspective', *Feminist Studies* 14(3): 575–99.

Harding, S. (1991) *Whose Science? Whose Knowledge?* Ithaca, NY: Cornell University Press.

Heath, C. (1986) *Body Movement and Speech in Medical Interaction*. Cambridge: Cambridge University Press.

Johnson, E. (2004) *Situating Simulators: The Integration of Simulations in Medical Practice*. Lund: Arkiv.

Johnson, E. (2005) 'The Ghost of Anatomies Past: Simulating the One-sex Body in Modern Medical Training', *Feminist Theory* 6(2): 141–59.

Jordanova, L. (1999) *Nature Displayed: Gender, Science and Medicine 1760–1820*. London: Longman.

Laet, M. de and A. Mol (2000) 'The Zimbabwe Bush Pump: Mechanics of a Fluid Technology', *Social Studies of Science* 30(2): 225–63.

Laqueur, T. (1990) *Making Sex: Body and Gender from the Greeks to Freud*. London: Harvard University Press.

Latour, B. (1988) 'Mixing Humans and Nonhumans Together: The Sociology of a Door-closer', *Social Problems* 35(3): 298–310.

Latour, B. (1999) *Pandora's Hope: Essays on the Reality of Science Studies*. London: Harvard University Press.

Law, J. (1987) 'Technology and Heterogeneous Engineering: The Case of Portuguese Expansion', pp. 111–34 in W.E. Bijker, T.P. Hughes and T. Pinch (eds) *The Social Construction of Technological Systems*. Cambridge, MA: MIT Press.

Law, J. and V. Singleton (2005) 'Object Lessons', *Organization* 12(3): 331–55.

McCloy, R. and R. Stone (2001) 'Virtual Reality in Surgery', *British Medical Journal* 323: 912–15.

Maines, R. (1999) *The Technology of Orgasm*. Baltimore, MD: Johns Hopkins University Press.

Maran, N.J. and R.J. Glavin (2003) 'Low- to High-fidelity Simulation – A Continuum of Medical Education?', *Medical Education* 37(suppl. 1): 22–8.

Martin, E. (1992) *The Woman in the Body: A Cultural Analysis of Reproduction*. Boston, MA: Beacon Press.

Mol, A. (2002) *The Body Multiple: Ontology in Medical Practice*. Durham, NC: Duke University Press.

Mol, A. and J. Law (2004) 'Embodied Action, Enacted Bodies: The Example of Hypoglycaemia', *Body & Society* 10(2): 43–62.

Oudshoorn, N. (1994) *Beyond the Natural Body: An Archeology of Sex Hormones*. London: Routledge.

Oudshoorn, N. (2003) *The Male Pill: A Biography of a Technology in the Making*. Durham, NC: Duke University Press.
Papadopoulos, E., K. Viachos and D. Mitropoulos (2002) 'On the Design of a Low-force 5 DOF Force – Feedback Haptic Mechanism', Proceedings of the DETC – Design Engineering Technical Conferences and Computers and Information in Engineering Conferences, Montreal, Canada, 29 September–2 October.
Pilnick, A. and J. Hindmarsh (1999) '"When You Wake Up It'll All Be Over": Communication in the Anaesthetic Room', *Symbolic Interaction* 22(4): 345–60.
Prentice, R. (2005) 'The Anatomy of Surgical Simulation: The Mutual Articulation of Bodies in and through the Machine', *Social Studies of Science* 35(6): 837–66.
Pugh, C. and P. Youngblood (2002) 'Development and Validation of Assessment Measures for a Newly Developed Physical Examination Simulator', *Journal of the American Medical Informatics Association* 9(5): 448–60.
Schiebinger, L. (1993) *Nature's Body: Gender in the Making of Modern Science*. Boston, MA: Beacon Press.
Schuwirth, L.W.T. and C.P.M. van der Vleuten (2003) 'The Use of Clinical Simulations in Assessment', *Medical Education* 37(suppl. 1): 65–71.
Shaw, M., R. Maxwell, K. Rees, D. Ho, S. Oliver, Y. Ben-Shlomo et al. (2004) 'Gender and Age Inequity in the Provision of Coronary Revascularisation in England in the 1990s: Is it Getting Better?', *Social Science and Medicine* 59: 2499–507.
Star, S.L. (1991) 'Power, Technology, and the Phenomenology of Conventions: On Being Allergic to Onions', pp. 22–56 in J. Law (ed.) *A Sociology of Monsters: Essays on Power, Technology and Domination*. London: Routledge.
Starr, P. (1982) *The Social Transformation of American Medicine*. New York: Basic Books.
Suchman, L. (2000) 'Human/Machine Reconsidered', Centre for Science Studies, Lancaster University, UK, URL (consulted May 2004): http://www.comp.lancs.ac.uk/sociology/papers/suchman-human-machine-reconsidered.pdf (see also 1998 *Cognitive Studies* 5: 1 pp. 5–13).
Suchman, L. (2007) *Human–Machine Reconfigurations: Plans and Situated Actions*, 2nd edn. Cambridge: Cambridge University Press.
Thacker, E. (1999) 'Performing the Technoscientific Body: Real Video Surgery and the Anatomy Theater', *Body & Society* 5(2–3): 317–36.
Tsai, T.-C., P.H. Harasym, C. Nijssen-Jordan, P. Jennett and G. Powell (2003) 'The Quality of a Simulation Examination Using a High-fidelity Child Manikin', *Medical Education* 37(suppl. 1): 72–8.
Van Meurs, W.L., P.M. Sá Couto, C.D. Sá Couto, J.F. Bernardes and D. Ayres-de-Campos (2003) 'Development of Foetal and Neonatal Simulators at the University of Porto', *Medical Education* 37(suppl. 1): 29–33.
Waldby, C. (1999) 'IatroGenesis: The Visible Human Project and the Reproduction of Life', *Australian Feminist Studies* 14(29): 77–90.
Waldby, C. (2000) *The Visible Human Project: Informatic Bodies and Posthuman Medicine*. London: Routledge.
Winner, L. (1980) 'Do Artifacts Have Politics?', *Daedalus* 109: 121–36.
Woolgar, S. and G. Cooper (1999) 'Do Artefacts Have Ambivalence? Moses' Bridges, Winner's Bridges and Other Urban Legends in S&TS', *Social Studies of Science* 29(3): 433–49.
Wright, M.C., J.M. Taekman and M.R. Endsley (2004) 'Objective Measures of Situation Awareness in a Simulated Medical Environment', *Quality & Safety in Health Care* 13: 65–71.

Ericka Johnson is a researcher at the Section for Science and Technology Studies, University of Gothenburg. She is the author of *Situating Simulators: The Integration of Simulations in Medical*

Practice (Arkiv, 2004) and *Dreaming of a Mail-order Husband: Russian–American Internet Romance* (Duke University Press, 2007). Her PhD work examined the use of simulators in medical education and she has since focused on the reification of medical practice in the bodies that simulators present. Her current research examines Viagra and the biomedicalization of Swedish masculinities.