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Learning in Technology-Enhanced Medical Simulation: Locations and Knowings

Abstract: This qualitative study focuses on how knowings and learning take place in full-scale simulation training of medical and nursing students, by drawing upon actor-network theory (ANT). ANT situates materiality as a part of the social practices. Knowing and learning, according to ANT, are not simply cognitive or social phenomena, but are seen as emerging as effects of the relation between material assemblages and human actors being performed into being in particular locations. Data consists of observations of simulations performed by ten groups of students. The analysis focuses on the emerging knowings in the socio-material—arrangements of three locations involved in the simulation—the simulation room, the observation room and the reflection room. The findings indicate that *medical knowing, affective knowing and communicative knowing* are produced in different ways in the different locations and material arrangements of the simulation cycle.

Keywords: simulation, locations, knowings, actor-network theory, collaborate learning, multiprofessional learning.

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Globally, medical education is in a need of renewal. The changing society means that professionals in healthcare sector are facing new challenges, such as ageing population and declining financial resources (WHO, 2010). Conditions relating to cooperation, learning and communication between different groups of professionals in health care have during the last decade been emphasised as significant (Barr et al., 2005; Higgs, Richardson & Abrandt Dahlgren, 2004), not least in the context of patient safety issues linked to communication between professional groups (Bleakley et al., 2006). Interprofessional collaboration has also been emphasised in the ongoing debate as important for improving quality and safety of the everyday work of health care professionals (Kohn et al., 2000). Several aspects of teamwork have been identified as potential causes to unsuccessful outcome (Manser, 2009). In spite of extensive investments and efforts the estimated number of patients harmed does not seem to change (Landrigan et al., 2010). The number of adverse events in healthcare is still unacceptable and it is stated that up to 60% of these events are the result of some sort of communication failure (Joint Commission, 2007). In trying to address these challenges, the use of simulators has become a common teaching strategy in medical education (Cook et al., 2013; Motola, Devine, Chung, Sullivan, & Issenberg, 2013). This type of training is seen as offering opportunities to practice realistic medical cases in safe, pedagogically pre-designed

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environments and for the students from different disciplines to work together as they will do in their future professional lives (Fritz et al., 2008; McGaghie et al., 2010).

While there is a large body of quantitative effect studies supporting the use of technology-enhanced simulations in medical training (Cook et al., 2011; Issenberg et al., 2005; McGaghie, Issenberg, Petrusa, & Scalese, 2010), and qualitative studies examining for example how realism and authenticity are achieved during a simulation exercise and how this might affect the learning outcomes (e.g. Dieckmann, Manser, Wehner, & Rall, 2007; Rystedt & Sjöblom, 2012), there is a lack of rigorous, theory-based, qualitative studies to clarify *how* and *when* to effectively use simulations to train health care professionals. We have adopted an actor-network theory approach to investigate simulation-based cross-professional training situations, where medical and nursing students practice handling acute emergency situations in health care. The study focuses on performance, material arrangements and how these contribute to the emergence of knowing/learning during a full cycle of simulation. We are interested in studying what types of knowing and learning emerge in the different locations involved in the simulation, and how the varying socio-material arrangements might affect these. The study is based on observations of the full cycle of simulation using SimMan3G^{tm} , a computer operated total body simulator as patient, including briefing, simulation, observation and debriefing sessions.

Approach and data

A socio-material approach: Actor-Network Theory

Theoretically and methodologically the present study draws upon actor-network theory (ANT), a socio-material approach that focuses on *associations* between human and nonhuman actors, and on how these produce our day-to-day practices. ANT does not follow the traditional distinction between the natural and the social "worlds," but sees these instead as mutually emergent and entwined, situating materiality as part of social practices. ANT is regarded a useful approach for studying human-technology relations as it provides theoretical tools for analyzing socio-materiality that produces practices and their effects (e.g. Law 2004; Latour 2005; Fenwick & Edwards, 2010). For example, ANT understands "participants" involved in action more broadly than the more traditional scientific approaches do (cf. Sørensen, 2009)—even objects, like the SimMan3G^{tm}, can "act." However, rather than being taken to act "intentionally" like humans, objects act *by influencing states of affairs* through being entangled in networks or assemblages with other actors (Callon, 1986; Latour, 2005). Seen in this way, for example, the SimMan3G^{tm} acts—influences the states of affairs—as part of the socio-material entanglement of actors that come together to produce the simulation exercise.

Key to our paper is the concept of "knowing" (how you come to "know" something), which (similarly to learning) in ANT terms is not simply a cognitive or a social phenomenon (e.g. Sørensen, 2009). Instead, knowing, or coming to know something, is regarded as something that emerges as an *effect* of the socio-material arrangements that gather together and are performed into being through the continual transactions—doings, which are a part of, or may form, practices—engaged by the human or non-human participants (e.g. Sørensen, 2009; Law, 2004; Law, 2009; Rimpiläinen, 2011). In order to study the emergence of knowing from the socio-material assemblage, our analytical attention has been upon the SimMan3G^{tm}, an object, as a focal actor (cf. Latour, 2005). Focusing analytically on an object instead of the human participants brings forth both the *doing* that the focal actor is entangled in, on *who and what participates* in the doing being observed, and what the *effects* of these assemblages and doings are (Mol, 2002; Rimpiläinen, 2012). (For a more detailed discussion on knowledge and knowing, see Rimpiläinen, 2011). In this study we set out to observe how the human and non-human participants (cf. Sørensen, 2009) acted together to produce the simulation exercise and the patient Sofia, and discovered in the process how the varying socio-material arrangements available in the three locations involved in the exercise gave rise to different kinds of knowing and learning, which we will discuss in more detail later on.

The empirical study

The data for this study consists of ethnographic observations carried out by a team of four researchers at a clinical skills training and simulation center at a university hospital in southern Sweden. The research team attended three training days in winter 2012-13 to observe full-scale simulations of acute trauma handling by five mixed groups of 6-8 nursing and medical students per training day (15 groups in total). Each group attended the training only once. The student groups were too large for everyone to take part in the simulation, as only two doctors were needed with two or three nurses. Therefore each group was divided into two, group I and II. Group I performed the simulation while group II observed it from the control room. The research team also split into two groups taking turns in observing in the training days. During the simulation, one member would sit in the simulation room, the other in the control room, and both would join to observe the debriefing in reflection room together. In addition to observation notes, five of the simulation sessions were also video recorded. These data were used for writing more detailed notes on the simulation events, with part transcription of the dialogue. Repeated observations of the same simulation station, with repeated runs of the structured simulation exercise, have allowed the research team to identify a pattern or a "usual" sequence of events to emerge in the simulation act. This has enabled us to compare the different types of effects that have arisen as a result of the changing assemblages of the human and non-human in the three locations that simulation session encompasses.

Setting the scene

The simulation exercises were spread out over three sites as demonstrated in Table 1 below.

Table 1.
Observed locations for emerging knowings and learning in simulation.

Simulation room	Fully equipped emergency room as the physical location for the simulator (SimMan3G^{tm}) and execution of the simulated acute trauma scenario by student group I. Nurse B partici-pates as a technical assistant in the room during the scenar-io.
Control room, adjacent to the Simulation room	Location for remote computerized control of the simulator, and observation of the simulation by student group II through a one-way window. Teacher A and Operator C operate of the simula-tor and communicate with the simulation room via a telephone or via a microphone when enact-ing the "patient."
Reflection room	Separate room for debriefing with comfortable chairs placed in an open circle. All students and all instructors participate in the debriefing ses-sion.

The scenario being simulated involves a young female car accident victim, 17-year old Sofia. She has been found unconscious at the scene of the accident, but has grunted a little during the transport to the hospital. She has no visible injuries except for some bleeding on the left side of her head. The ambulance staff has given her some oxygen and a neck-collar to protect her neck. This is all the information the students are given at the beginning of the exercise. During the simulation Sofia's condition will deteriorate, (altered pupil size indicating herniation) and the students are expected to call for help engaging different colleagues from round the hospital. Calling for an anesthetist plays one of the most important parts in the scenario.

Students' activities around the patient in the simulation room are expected to be structured according to the Advanced Trauma Life Support procedure (ATLS) (Bouillion et al., 2004). Each simulation session began with briefing session about the exercise, in which the teaching staff introduced the students to the locations, the simulator SimMan3G^{tm} and the available equipment in each location. Medical actions enabled by this version of the SimMan3G^{tm} include measuring a pulse, taking temperature, giving oxygen, inserting a catheter or inserting a drip on a patient's vein. The SimMan3G^{tm} is immobile, but can be lifted and moved around. As it cannot respond to touch, the students receive the necessary information, for example on the patient's reactions to stimuli, via a loud speaker from the control room where the simulator is being operated. Additionally, the SimMan3G^{tm}'s pupils can be changed manually, so that these alter in size.

Findings and discussion

In the following sections we will present and discuss the types of knowing and learning we saw emerging from the different socio-material arrangements in the three locations involved in the simulation scenario. The table below summarizes the findings.

Table 2
Different locations and knowings

	Simulation room	**Control room**	**Reflection room**
Action	”Doing”	Observing	Reflecting
Medical knowing	Performance related to materiality of the Emergency room: Treating SimMan3G^{tm} as Sofia (acting “as if” was “as is”)	Discursive: simulation as material for discussion, observing and checking their medical knowledge Teacher- student relation	Discursive and reflective: All events and experiences material for discussion: What happened? Why? What could we have done differently? What have we learned?
Affective knowing	Physically and emotionally experienced: Dealing with stress and the emotional side of treating a patient in emergency work	Discursive: Treating others’ emotions as theatre	Discursive and reflective: Describing emotions and sharing the experiences with others
Communi -cation	Inter-professional between the nurses and the doctors and the senior doctor and the team	Teacher- student, or among students; Spontaneous and critical; Observation of the inter-professional communication “on-stage” and “back- stage”	Among students as colleagues; moderated by teachers; Professional, reflecting, constructive and controlled

Simulation room

From the second the trauma coordinator leaves the simulation room the students are expected to work as doctors and nurses, and treat the situation as if it was “real.” This means, for example, that the teams start preparing for the arrival of the patient by putting on plastic aprons and gloves, and preparing medical equipment. When the SimMan3G^{tm} is wheeled in on the stretcher by the “ambulance crew”—the Teacher A and Nurse B—the teams need to relate to it as “Sofia,” the 17-year old female car accident victim. One specific way to enact the SimMan3G^{tm} as Sofia is to touch her arm and to call her by name: “Sofia, you are now at the hospital, you have been in a car accident. I am your doctor and will take care of you. Can you hear me?” Most teams talk to “Sofia,” but others may miss this important step.

These first actions carried out by students illustrate how medical knowing emerges in the simulation site: through the team’s performance related to the materiality of the simulation room, and through "suspending disbelief" (cf. Essington, 2010) and treating the "as if" of the exercise as "as is." How well the students are able to do this is manifested in how precisely they follow the actual medical procedures during the simulation, even when in actual fact there is no need for them to do certain things. The students should relate to the SimMan3G^{tm} as if it was a real patient, use the available equipment in an appropriate way, as and when necessary. An example would be a doctor changing their "dirty" gloves after carrying out a rectal examination during checking Sofia's spine, while with the SimMan3G^{tm} the gloves are not soiled.

The teams are expected to follow the ATLS-procedure: to check up Airways (Stage A), Breathing (Stage B), Circulation (Stage C), Do a neurological check-up (Stage D) and Exposure and environmental control (Stage E). Each stage should be re-evaluated should new symptoms signal a change in the patient's condition. A moment that highlights medical knowing and tests the team's communication and control skills is when the patient "vomits" and has to be turned over in order to prevent her from choking in her own vomit. This event often happens after the team has carried out stage B in the scenario. When the patient is being turned over, her head should be taken care of. For the SimMan3G^{tm} it makes no difference whether anyone takes care of its head, but for Sofia, this is different. This simple procedure demonstrates how well the team organize themselves in this stressful situation, how the lead doctor takes charge over the procedure and how the team members communicate with one another. Medical knowing is not just about demonstrating that the team members know that they should turn the patient over, but also about how they orchestrate this simple action and engage with the available socio-material set up when carrying it out.

As the condition of the patient deteriorates, an important clue to be picked up by the emergency team would be a unilaterally dilated pupil in the patient's eye. The change in pupil size usually occurs after the team has carried out stage D in the scenario—Do the neurological check-up. This entails looking into the eyes of the unconscious patient, examining the pupillary size, equality and response to light. If the team follows the procedure and re-evaluate the ABCDE stages again, they will discover the dilated pupil, which in this context indicates raised intracranial pressure and uncal herniation. Noticing the dilated pupil and understanding its implications for the patient is usually the most stressful moment of the simulation—the teams realize that they really have an emergency in their hands. This moment changes the team's working atmosphere and induces not only the performance of medical knowing but also the emergence of a particular form of *affective knowing*. The emotional aspect of working at an emergency situation brought forth by the simulation is an important experience according to students who perform the simulation. While many teams are able to handle the situation calmly, the students report unexpected feelings: high stress, high anxiety, uncertainty, sometimes even shame as well as pride. These affective reactions may also manifest themselves physically as sweating, sweaty and shaky hands, stomach pain, dry mouth, blushing etc. We have also been able to observe these reactions as changes in the tones of voice or the way the doctors and nurses speak to each other. Experiencing the bodily and emotional reactions induced by the flow actions and the stress related to working with patient whose life is at stake is something that cannot be gained from reading a text. The *affective knowing* in terms of bodily experience of emotions is an important part of learning in this site.

A third form of knowing that emerged in the simulation room was *communication.* Learning to communicate effectively between different professions in a busy team where various actors are engaged in doing different things at the same time is one of the main goals of the training. Clarity and effectiveness of communication is not at stake only between the team members (between doctors and nurses) but also between the staff at the Emergency room and the other professions at the hospital.

During the scenario the teams are expected to call for assistance, for example an anesthetist, a standby duty, or for an X-ray team. Calling for an anesthetist is one of the most important parts of the scenario in terms of effective communication, a need that emerges when the team has discovered the unilaterally dilated pupil. We will discuss this more in the next section.

As a pedagogical space, the simulation room is a location for learning by doing. The affordances of the SimMan3G[tm], what it can and cannot do, are important for the simulation and its pedagogical purposes. The fact that the SimMan3G[tm] is unable to display bodily reactions by moving its body parts necessitates the doctors examining Sofia to state clearly what they are doing at any given moment in order to receive any medical information from the operator. The operator in the control room gives the necessary information in a monotone robotic voice via a loudspeaker. In this way, the SimMan3G[tm] enforces clear communication between the emergency team members and the staff in control room.

Medical knowing, affective knowing and communication in the simulation room emerge from the students' ability to suspend disbelief and act as if the situation was real. Authenticity of a simulation is mentioned as an important part for learning (Cook et al., 2011; Issenberg, McGagie, Petrusa, Gordon, & Scalese, 2005; McGaghie et al., 2010; cf. Johnson, 2008). Students often mention how "realistic" the simulated situation had felt, while it is easy to point out at the same time how unreal, unauthentic it is. At the beginning of the exercise the students have been instructed to take whatever action they deem necessary in order to take care of the patient. The SimMan3G[tm] affords for many different types of actions to be carried out in a safe environment, where the students cannot accidentally hurt a real patient. At the same time the students need to be aware of which actions are *medically appropriate* for the type of injury and patient in question. It is also important to point out that even though the equipment is the same as in an authentic emergency, the students cannot use it in the same way as they would with a human patient. For example, when taking the patient's temperature, the nurse would place the thermometer against SimMan3G[tm]'s forehead. In order to get the temperature reading, the nurse declares "I am taking the patient's temperature," after which a reading is given over the loudspeaker. While the simulation does not allow for exactly the same actions to be taken as in a real emergency room, it creates a space for carrying out actions that are medically appropriate. The key to successful simulation training is not only based on how much medical knowledge the students "have" or what they can do with the mannequin (its affordances) but how they *engage* with SimMan3G[tm] in order to enact (cf. Mol, 2002) and treat it as the patient Sofia.

The emotional reactions, like stress and its physical manifestations, emerge from relating to the SimMan3G[tm] as if it was a real patient whose life is in the emergency team's hands. Going through emotional reactions and learning how to handle these under pressure cannot be learned from books, these have to be experienced. If the students are unable to suspend disbelief the simulation falls apart. The experienced "authenticity," including the emotional reactions, involve students' ability to relate to SimMan3G[tm] as a real medical professional would relate to a real patient.

Control room and observation-site

The students who do not participate in the simulation scenario stay in the Control room to observe the exercise. This small room has a desk with a computer and three monitors, one displaying a silhouette of the SimMan3G[tm] showing its bodily functions. The SimMan3G[tm] functions through being connected to a computer run by an operator in the control/observation room. The other two monitors display a video film of the simulation room from different angles. There is a row of stools for the observers to occupy at the back of the room, giving a good view of the simulation room through the one-way window and through the monitor displays. Those in the control room can hear what is going on in the simulation room, but not vice-versa.

During the briefing, the medical teacher A emphasizes that observation is not a waste of the students' time—it is simply different type of learning. Observing is a pedagogically structured, planned and driven action. In order to understand what they are observing, the students have to be aware of what the educational practice concerns (Latour, 1987). During the first few minutes of the simulation the medical teacher already guides the students' attention to what is going on in the simulation room. She asks them to pay attention to how the team is preparing for the patient, and gives instructions as to what they should be focusing on, such as the different medical actions the other students are doing, their communication and the structure of their medical actions in the simulation (the ABCDE-procedure).

While in the simulation room the medical knowing comes forth from enacting the SimMan3G[tm] as Sofia within the entanglement of other actors, materials and knowings, in the control room the medical knowing emerges from a more "school-like" setting, where the simulation exercise is viewed like a piece of theatre unfolding before the students eyes. Teacher A gives a running commentary on what the team on the other side of the window is doing, and on how they are doing. She involves the students with question such as "ok, which tests have they done now?" or she may demonstrate what the information she has given to the emergency team through the microphone means, and explain what Sofia's reactions imply medically. The students, who sit next to the Medical Teacher A and the Operator C do not hesitate to ask questions about what is happening in the simulation at any given moment. They may query the dosage of the medicine the team is giving to the patient or the instruments they are using.

While the team in the simulation room is in a very stressful situation, the students in the control room are in a "safe" place. They do not get to experience first-hand the affective side of being a medical professional taking care of a trauma patient whose condition deteriorates, like the team in the simulation room do. What they experience is what they observe: they can see how their peers (colleagues) react in the stressful situation and how they handle it. The team's simulation becomes material for their discussions, questions and reflections.

The observers can also see the different medical practices being enacted into being in the wider "hospital," which the emergency room has access to via a telephone. When the team discovers the dilated pupil and realizes they have an emergency, they call for support. The phone calls are answered in the control room by the Operator C (male) or the Teacher A (female). Usually the doctor in the simulation room looks for an anesthetist, but it is always a midwife they get hold of instead. The midwife (played by the Operator) does not want the anesthetist (the Teacher A) to leave for the emergency room before she has finished treating his patient. Often the midwife offers to deliver a message for the anesthetist and in summarizing the message he deliberately misses out some information. After this communication, the operator explains to the observers what is going on: usually people do not let the specialist go if it is not clearly an emergency—for the midwife his patient is the most important case there is, and he wants the anesthetist to finish treating her. The doctors doing the simulation should also notice that the midwife does not repeat their message correctly. He, the Operator-as-midwife, would remark to the observing students: "I do this because they did not give me clear enough information."

As a pedagogical site the control/observation room can be described as a unique combination of classroom, panopticon, backstage and the extension of the SimMan3G[tm] as mind and bodily reactions of Sofia. The medical and affective knowing in this location emerge as discursive rather than experiential learning, as the observed simulation becomes material for discussion. Both the medical and affective knowings are performed sitting side-by-side in a classroom-like situation, supported and guided by a teacher. Communication here is spontaneous, sometimes quite critical noting which mistakes the team may have made. Also the teachers' answers and comments are more informal and spontaneous.

The debriefing - reflection site

After the simulation is over, Teacher A asks all the students to move to a common space for debriefing. The reflection room is physically removed from the simulation and observation sites. Sofia's life has been rescued and she continues her life somewhere out-there. Only the technology-enhanced simulator SimMan3G^{tm} is left behind on the stretcher, being prepared by Nurse B for the next group of students. In the reflection room, students sit on conference chairs, facing each other. The main activity in this site is to reflect upon the simulation: the students engaged in the simulation talk about their experiences of it and what they have done, why and how they felt it all went. The observer-students comment on their performance and discuss medical decision made and actions taken.

Teacher A assumes the role of a moderator for the discussions, refraining from the teacher role she had in the control room. The medical knowing in the reflection room is practiced in a discursive and reflective way. Rather than asking questions or checking up on the students' medical knowledge, Teacher A will often wait for someone in the group to mention certain medical decisions. Should the students miss an important aspect of the simulation or omit discussion of an important issue further, the teacher will interrupt and point it out. For example, a doctor had ordered a nurse to manually hyperventilate Sofia. When the nurse remarks how quickly the patient's stomach grew big as he hyperventilated her, and the group are about to discuss the next topic, the medical teacher steps in saying "can we focus on the medical aspect here, you do hyperventilation when you take over the patient's breathing. It is exactly as you say, there is a risk that one blows up the patient's stomach instead." While she gives clear and direct medical feedback on what happens in the simulation to the students in the observation room as a teacher, here she rather waits for the observers as peers to give that feedback to the others.

The affective aspect of simulation is one of the main discussion themes. Here the emergency team members share their experiences; they may tell how they noticed their physical reactions to stress, such as shaking hands, raised voices or feeling of not being able to think clearly. The observers contribute to discussion with their observations and how they have understood the team handled the situation and in which way they might do better the next time. Here the discussion does not just focus on what happened in the simulation room but also on how they would prepare for the next stressful situation, and how to cope, what kind of resources to use in such a situation. The teaching staff often offers advice from their own experiences, such as the importance of ABCDE structure, or a notebook one could use.

Communication in the reflection room is characterized by a collegium, where the students talk to each other as peers, colleagues. The most striking change in communication style is by the observer-students. While in the control room their reactions to the events taking place in the simulation room had been spontaneous and often critical, now they formulate their remarks more formally and politely. Students often phrase their comments in terms of respect for the others' experience: "It is very easy for me to say these things, because I did not perform." In terms of presence, the SimMan3G^{tm} /Sofia, as a physical object, is not involved in the reflection-site—only the *effect* of Sofia/ SimMan3G^{tm} is. The medical and affective knowings become produced discursively, on reflection, during the debriefing.

Knowing and learning as effects of socio-material arrangements

Questions about what students learn through attending simulation training, or how effective simulation training is for their learning are common in research concerning our topic. Our study has taken a slightly different approach by conceptualising learning and knowing as an activity, as *doing* that takes place and emerges as an *effect* of the varying socio-material arrangements that gather together in different learning locations (cf. Sørensen, 2009; Fenwick & Edwards, 2010; Rimpilainen, 2011). We have thereby sought to contribute to the understanding of how the varying socio-material arrangements made available to students in simulation training may contribute to, or indeed guide, the types of knowing and learning that emerge during the exercise. Originally it was the teachers of the simulation course, who wanted evidence that even the observation of the simulation training might be a pedagogically useful exercise.

Through an ANT-inspired approach to study the material arrangements of the simulation-based medical education it has been possible to show how different locations with different socio-material affordances respectively bring about different conditions for learning, producing different learning outcomes. Hence we have been able to show how even the observation of the simulation training is pedagogically useful activity, while how learning takes place and what is learned diverges from being actually engaged in the simulation. In ANT terms, what an individual does, or can do, is an effect of the assemblage they are entangled in (Sørensen, 2009) and a part of the assemblage. The material arrangements anticipate humans' doings. If the students' actions take place outside of propriety, (for example, laughing at the SimMan3G^{tm}, making fun of the simulation during the training or communicating in an unprofessional manner in the reflection room), the simulation training fails. Neither humans nor materials alone are enough to make particular pedagogies possible. The different material arrangements are not only created with particular pedagogical intention in mind but these can also in turn create boundaries for propriety—for what kinds of actions are possible for those involved in each location.

Our findings hence highlight the importance of considering how the various socio-material arrangements made available for particular kinds of pedagogies in medical education affect the desired learning outcomes. The study points to the significance of purposefully manipulating the socio-material arrangements made available in a given pedagogical situation and indicates how adding or removing elements from a learning situation may impact the desired learning outcomes. For example, giving pre-structured observation protocols for students observing the simulation, or using video-recordings of the simulated session as part of the debriefing (Dieckmann, Reddersen, Zieger, & Rall, 2008; Johansson, Rystedt, Amoroe & Lindvall, 2013) would structure the learning experience in these spaces differently to the one observed in this study. The findings also contribute to more nuanced understandings of practice and knowing-in-practice as well as a pedagogic knowledge related to simulation-based healthcare education.

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