Understanding Simulation-Based Learning

By

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Simulation Based Learning

Introduction

Learning is about how we perceive and understand the world around us. In professional development, we continuously learn to improve the way we handle patient problems with increasing effectiveness. Traditionally in Clinical Medicine, procedural knowledge is acquired through an apprenticeship mode, and frequently in accordance with the paradigm of “see-one, do-one, and teach-one.” Unfortunately, this primal mode of learning comes with a high emotional price to be paid by the learner and a significant risk associated with the patient.

Medical learners are generally proficient in remembering factual information and acquiring practical techniques. As such they adapt well in many unfavourable learning situations. They are also quick to pick up clinical methods and develop cognitive approaches to problem-solving. Hence, despite the anguish of a heavy medical curriculum and stress in the learning environment, medical undergraduates thrive well.

In recent years, the medical profession has become progressively concerned about patient risks and safety. We have acquired better insights into the understanding of the psychology of human errors. In particular, the aviation industry has provided us with much relevant knowledge and many valuable lessons on operational safety. The introduction of the patient simulator for training is a most timely development. With the inception and use of simulation in clinical teaching, learners are now able to confront their anxieties within a far safer environment. Modern computer technology is a blessing. It has made possible for high fidelity patient simulators to be developed and manufactured, to the extent that medical teachers are now able to function within a reproducible and regulated teaching arena.

What is Simulation?
A simulation is a method of training or research that attempts to create a realistic experience in a controlled environment. The earliest practical use of simulation was in the construction of physical models of real objects. The purpose then was to permit the designer to test specific aspects of the object that he wanted to build on the replica. This put him in a better position to avoid making mistakes and reduce wastage in the construction of the real object.

In the use of simulation for teaching and training, the educationist is more concerned with its use in the study of psychological and social processes. Many knowledge disciplines have used simulations in various forms and for different purposes (Table 1).

In Medicine, simulation refers to the manipulation of an operating model. In early medical education simulations typically represent biologic processes (e.g. muscle and respiratory physiology) or clinical experiences. Computer-based clinical simulations have since shifted the focus from text-oriented presentations to multimedia-based systems. Nowadays patient simulators come as mannequins that represent human patients in both appearance and anatomical form and are equipped with computer feedback systems (Fig. 1). In addition, they are able to represent certain aspects of the human physiological response and respond electronically to pharmacological intervention.

**Fig. 1. The Medical Patient Simulator**

(Photo courtesy of Medical Education Technologies, Inc)
## Table 1. Simulation-based Learning

<table>
<thead>
<tr>
<th>Discipline</th>
<th>Example of Simulated Model</th>
<th>Use in Learning</th>
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<tbody>
<tr>
<td>Aviation</td>
<td>Flight simulator</td>
<td>Train pilots to handle problems of mission difficulty and complexity. Used as transition training for new types of aircraft.</td>
</tr>
<tr>
<td>Business</td>
<td>Simulation of market competition</td>
<td>Learn to abstract, organize, and use information from a diffuse environment. Facilitate understanding of the complexity of running a business.</td>
</tr>
<tr>
<td>Economics</td>
<td>Simulation of a demographic model</td>
<td>Understand behaviour of complex models without complicated mathematics</td>
</tr>
<tr>
<td>Human Resource</td>
<td>Simulation of office-based human interaction</td>
<td>Assess executive competence. Identify management talents</td>
</tr>
<tr>
<td>Industrial Engineering</td>
<td>System simulation</td>
<td>Build mathematical models. Aid problem solving. Study complex operating plans</td>
</tr>
<tr>
<td>Medicine</td>
<td>Patient simulator</td>
<td>Train doctors’ response to crisis. Improves patient safety. Teach communication skills &amp; crisis resource management</td>
</tr>
<tr>
<td>Military Strategy</td>
<td>War games</td>
<td>Train combat personnel to perform under stress and life-threatening conditions</td>
</tr>
<tr>
<td>Political Psychology</td>
<td>Simulation of international relations</td>
<td>Develop theory in international relations research</td>
</tr>
<tr>
<td>Traffic Management</td>
<td>Simulation of bus peak hour operations</td>
<td>Determine queuing times and length of passenger waiting lines</td>
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In medical simulation, the term “model” refers to an operating system that functions as a scientific tool. To represent the human physiological system and reproduce biological processes in action, the operating model is capable of continuously providing information about the patient’s changing physiological status in real time, and in addition, the changing dynamics of interaction between various players in the clinical environment. As we use this learning tool more often we will begin to appreciate that developing a good operating model involves the abstracting from reality those pertinent components and relationships which are hypothesized as crucial to those aspects of pathophysiology that are being modeled or represented.

In a simulation exercise, the essential information about the patient’s changing status is presented to the participants in different modes:

(i) acoustically,
(ii) pictorially,
(iii) electronically, and
(iv) experientially

The simplest patient complaints may be generated acoustically by the mannequin itself, whereas rapidly changing physiological
parameters are displayed electronically on the patient monitor. The participants in a simulation will normally request for blood biochemistry. Such ongoing laboratory data can be delivered via a telephone line. ECG and radiographic images on the other hand, can be passed either manually to the participants or conveyed to them via a computer laptop. The preferred mode of operational information delivery is really a function of the level of reality desired by the trainer for the simulation exercise concerned. More often than not, the simulation is enriched with the addition of social information (e.g. a distressed relative) using actors in role play.

**Levels of Reality**

The patient simulator comes as a product spectrum with various levels of reality of representation. Some of the common physical features that are represented with significant reality in the mannequin include:

- Acoustic presence of heart and breath sounds
- Touch reality for rectal and pelvic examinations
- Catheterisable urinary system
- Anatomically accurate airway that can be used for endotracheal intubation.
- Electronically displayable heart rate, respiratory rate, ECG rhythm and oxygen saturation levels
- Life-like surgical anatomy for certain procedures, e.g. peripheral venous cannulation, pericardiocentesis, chest-tube insertion, central venous line insertion, etc.

Likewise there are different levels of sophistication in the representation of physiological responses. These include:

- Constriction and dilation of pupils
- Variable lung compliance and airway resistance
- Recognition and response to administration of drugs, fluids and drug dosages
- Response to needle decompression of pneumothorax, chest tube drainage and pericardiocentesis
- Automatic control of urine output
**Types of Simulation**

While simulations can be conducted entirely on a mechanical model ("pure-machine" simulation), more often than not they are enriched with the additional element of human interaction. Simulations in which human participants act and interact within the simulated system ("man-machine" simulation) are most commonly used by medical educators for training purposes. This type of simulation may be used to train the participants to serve in various capacities e.g. crisis team leader, emergency room physician, ambulance nurse, etc. and to teach medical undergraduates about the physiological disturbances and manipulations in a cardio-pulmonary arrest.

**The Simulation Exercise**

A *simulation exercise* is an activity resembling a clinical situation in which participants, playing the part of medical caregivers, are presented with multiple complex stimuli represented by a set of patient data presented to them sequentially and in different
forms. The *complex stimuli* may come as a combination of the following:

(a) A brief description of a clinical scenario being read out to the participants at the start of the exercise
(b) Complaints uttered by the mannequin as the simulation begins
(c) Relevant history presented by the accompanying “relative”
(d) Physical signs pre-created by moulage on the mannequin
(e) Hard copies of radiographs or ECG scripts delivered to the participants as when requested,
(f) Social information provided role players in the exercise,
(f) Any additional information provided from time to time by an *assessor* in the control room who interacts with the participant throughout the simulation.

During the exercise, expected overt responses from the participants may include making clinical decisions, leading the resuscitation team, communicating problem situations with professional colleagues and patient’s relatives. In the meanwhile, assessors observe the behavior and rate the participant’s effectiveness on one or more performance dimensions. Performance *dimensions* may include in addition to clinical competence, decision-making abilities, willingness to take initiative, teamwork and crisis resource management.

The simulation exercise can sometimes be a very simple one requiring only the participation of the learners within a described patient scenario. At other times the exercise can be an elaborate rule-governed game which demonstrates complex problem-solving. This may come with or without issues of interpersonal relationships to demonstrate how different behaviours generate different psychological reactions. This latter situation often involves the addition of role-play.

To play the role of someone else requires self-reflection. “*How do I do this?*” or “*How does it seem to me that someone else does it?*” are two pertinent questions upon which the skill of role-play is based. The key to generating useful learning opportunities for
the participants is to create a dynamic scenario that supports ongoing reflection that is congruent with the learning objectives. It is the transformation of the content to be learned into a communicative environment of problems and interactive information which the participants must actively engage.

**Advantages of Simulation**

Although the scope of a simulated exercise is small when compared with the real patient system it represents, this method of learning has the advantage of being instrumented at will. The processes can be started and stopped at the will of the assessor. This property of simulation makes the participants’ performance readily observable and the training schedule convenient.

Optional starting is particularly important for learning. A complete study of a participant’s interventional efforts in response to a designed patient problem is facilitated when the assessor is able to vary the initial patient state at will. Complete investigation of the learner’s performance is also facilitated if the assessor is able to reverse the relationship of the clinical variables as when he wants it. This is particularly advantageous where the response to a patient’s situation occurs in a very brief period of time, as in clinical crisis situations.

A crisis is the physical and social manifestation of a chaotic phenomenon. In a crisis situation a familiar and comfortable world suddenly turns unpredictable and threatening. It becomes a high stake situation typified by surprises with insufficient information. A high level of uncertainty suddenly clouds the situation. Time is of essence and there is ongoing pressure to make quick decisions and act. However, the uncertainty makes it more difficult to evaluate the situation and recognize alternative responses.

In a crisis, the participants will feel and experience a lack of control of the situation. They have little time to reflect or
pontificate over a given decision. Often the response has to be given on the spot and this limits opportunities for clinical judgment. The sense of urgency to continually respond to the rapidly changing situation increases the level of stress and fatigue. Relational changes and clinical tensions add further on to the anxiety.

In time a crisis may unearth more problems that are usually kept contained under normal circumstances. Besides this, handling a patient crisis involves a clinical team that is often assembled under ad hoc conditions. As a result of stress and pressure, conflict may occur among team members or develop between individuals internal and those external to the team. The opportunity and option to repeat the simulation of a crisis situation, or certain aspects of it, is therefore of immense value in training.

A second advantage is that the experiences in a simulated exercise are real but there is no lasting effect on the external world. Hence, the simulation can involve making mistakes, and allow the carrying out of therapeutic procedures on a patient without a real disaster. This creates powerful learning opportunities, because in real life a more capable clinician would have to intervene. This also means that good simulation-based training requires a great deal of careful planning and construction. A good simulation can take a long time for the instructional designer to develop, but once developed, it can be used again and again.

A third advantage of the simulation process is its ability to replicate days and weeks of clinical activity in a very short period of time. Participants will be able to see how the results of their decisions and actions unfold within a short period of time. Alternatively the simulation time can be slowed down for detailed study of specific situations. However for most training needs, it is preferable to have the simulation carried out in real time. Real time simulation resembles reality better and are generally more conducive to learning.
Why Learn through Simulation?

Learning is about how we perceive and make meaning of the world around us. It involves mastering abstract principles, understanding rationale, and remembering factual information. It also involves recognizing patterns and phenomena, acquiring techniques, debating ideas and developing reasoning appropriate to specific situations. The final common pathway for all these processes is towards transformation of the individual, both intellectually and behaviorally.

The real world of patient care poses certain natural disadvantages to the educationist in terms of training. Certain clinical conditions of great theoretical and practical interest occur rarely, while other conditions of little theoretical interest occur profusely. Certain physiological effects of great theoretical significance are often obscured by other more powerful effects that are of little interest. Through simulation, many disease processes can be simplified, measured and manipulated so that rare conditions and physiological effects may be created as reasonably exact replicas for learning.

In simulation there exists the advantage of the ability to eliminate certain extraneous disturbances while allowing the disease process to be observed comprehensively and precisely at the will of the learner. An example of an uncommon state is a clinical condition that arises when there is a lag in the effect of the disease agent on the patient, but the outcome is, in natural settings, usually found in an advanced stage of progress (e.g. organophosphate poisoning). The difficulty in recognizing the disease condition in its earlier stages makes the condition both rare and clinically important for learning.

For this reason, the less commonly encountered medical emergencies tend to offer the widest scope for the application of simulation training. Where relatively unique situations are being studied, or where very few of them exist, (e.g. infectious epidemic, natural disaster) it is useful to simulate them so that many more
exact replicates may be made available for learning. Mass casualties are another example. With only one Emergency Medicine Dept in a hospital, its few functional components though complex can usually be made to vary freely in a crisis situation. A simulation exercise with the use of triage scenarios in the Emergency Medicine Department with different levels of resources and staff strengths is one convenient and effective way of learning.

However the application of simulation-based learning to crisis conditions also offers one of the biggest challenges. This is simply because three levels of complexity need to be addressed:

(i) the crisis itself and its associated chaos,
(ii) the complexity of the human response to crisis and of the interpersonal relationships under stress conditions
(iii) the learning behaviour, which varies from person to person.

How Individuals Learn

It is widely held that people actively and constantly construct their knowledge base. This concept of constructivism is based on the idea that we continuously build and amend previous cognitive structures and schemata as we assimilate new experiences and knowledge. In other words, we learn by fitting new understanding and knowledge into old understanding and knowledge. In fact, any learning of a higher order happens only when the underlying schemata are themselves changed or rearranged to incorporate new insights. Such changes are fundamental and valuable. They will themselves facilitate our retention of factual knowledge for the longer term.

In simulation training, we reconstruct our knowledge by doing and gathering new experience. Experiential learning is based on the premise that understanding is not an unchangeable element of thought but is formed and reformed through experience.
Transformational learning, which can occur either gradually or from a sudden powerful experience can change the way we see ourselves and the world.

Experience gained through whatever form, be it at work, in life or during formal educational processes will play a central role in our learning. Acquiring experience through simulation has long been an established part of nursing training and midwifery education, especially through the use of role play. Traditional practical rooms have been used to simulate the nursing environment that enables psychomotor skills to be practiced, and at the same time facilitates experiential learning through discussion and reflection.

However, the real world is intricate, entangled, and continuously varying. Much as we like, it is virtually impossible to predict certain patient situations and manage all the changing variables at once. All clinical emergencies and patient crises belong to this category. In these situations it is generally not possible to study a subset of the patient’s variables because they are continuously altered by the effects of the larger set. A patient who sustained an acute subdural haematoma from a road traffic accident may be expected to exhibit a rising blood pressure and a bounding radial pulse of raised intracranial pressure as described by the Cushing reflex. However, a concomitant haemoperitoneum from an undiagnosed ruptured spleen would mask the sign and make the patient present to the emergency clinician in less than predictable ways.

**Complexity as a Challenge to Learning**

All experiences offer lessons for our learning. When experiencing a process or a phenomenon we perceive it through our senses and associate with it thoughts and feelings in order to make sense of it. We either connect it with other events and experience from the past or project it onto our future plans. As a result experiential learning cannot be dissociated from our thoughts, feelings and emotions.
The human dynamics behind the coordination of our senses in experiential learning comes in different forms in different people. It is commonly egocentric, and in which case the individual’s satisfaction from learning comes from pursuing his own interests and self-advancement. However, learning and growth can be carried to a higher level if the human dynamics are focused instead on one’s urge for enlightenment. This type of dynamics is behind the most precious human knowledge – knowledge of ourselves. Wisdom, intelligence, modesty, humility and freedom from egotism are some of the qualities that will evolve with the dynamics of enlightenment.

Kolb’s Learning Cycle and Professional Competence

Experiential learning is a continuous, cyclical process. Being an experience-based phenomenon, it is understood that we frequently bring our own ideas and beliefs at different levels of elaboration to our learning situations.

Fig. 4  Kolb’s Learning Cycle
Kolb teaches that for this type of learning to be successful, the cyclical model requires four kinds of abilities:

1. Concrete experience (CE)
2. Reflective observation (RO)
3. Abstract conceptualization (AC)
4. Active experimentation (AE)

Firstly, the learner gets freely involved in new experiences (CE). The crisis simulation exercise directly provides this opportunity for him. Then time and space is made for him to reflect on his experience from different perspectives (RO). This is usually done as a debrief session immediately following the conclusion of the simulation activity. It is this reflective element in the learner's cycle that will be strongly influenced by feedback from his peers or assessors, making the debrief session so valuable for learning.

Next, the learner will be able to construct and reconstruct his ideas and process them into sound logical theories for future learning (AC). This moves him towards the last part of the cycle (AE) in which he now use what he has understood to make clinical decisions and solve future crisis problems. By testing out implications in new situations, he will generate new learning content for the starting point of the next cycle, the *concrete experience* again.

All four stages of the process are necessary for effective learning to be achieved. In simulation-based learning, the instructional designer needs to be able to use the operational model to create in the training programme learning opportunities that are sensitive to all these different stages of the cycle of learning.

Reflective learning lies at the heart of the relationship between professional knowledge and professional competence. We are all familiar with the fact that recognized experts in their own field always exhibit distinct artistry in their professional skills. We are also aware that this artistry cannot be learned through conventional teaching models. This is because it requires self-observation and reflective practice.
Table 2: Kolb’s Learning Styles

<table>
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<th>Learning style</th>
<th>Strengths</th>
<th>Dominant Learning ability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convergent</td>
<td>Apply practical ideas</td>
<td>AC and AE</td>
</tr>
<tr>
<td>Divergent</td>
<td>Imagine and generate ideas</td>
<td>CE and RO</td>
</tr>
<tr>
<td>Assimilation</td>
<td>Create conceptual models and make sense of disparate observations</td>
<td>AC and RO</td>
</tr>
<tr>
<td>Accommodative</td>
<td>Carry out plans and tasks that involve themselves in new experiences</td>
<td>CE and AE</td>
</tr>
</tbody>
</table>

We learn through observing competent professionals who are experienced in carrying out all the tasks of his job and who reflect insightfully upon his own practice. Such reflective practice generally follows Kolb’s pattern of cyclical conceptualization and re-conceptualization as part of a continuous transformative process. In developing habitual reflection as part of one’s learning, the individual has most likely embarked on his journey in lifelong learning.

More Advantages of Simulation

Advantages in learning abound in simulation. We have earlier noted how simulated practice environments are useful for reflection upon experience in clinical areas because it draws out learning points, develops clinical reasoning and integrates theory with practice. Mistakes may be made and learning can occur without risk to patients. Practical skills can be developed in a systematic supported manner. Furthermore, discussion of theoretical and ethical matters which are normally inappropriate in the presence of a patient can occur in parallel with the developing of practical skills.

One significant advantage of simulation is that it permits both the trainer and the learner to study patient treatment processes in
ways that nature prohibits. The simulation can be run many times with the values of the parameters being modified between runs and the changes in outputs observed.

In today’s medical education, we increasingly appreciate that it is somewhat artificial to separate the teaching of communication skills from the clinical activities in which they are embedded. After all, there simply isn’t any aspect of clinical practice that does not contain communication as a key element. The use of simulation and role play therefore enjoys a significant advantage as a teaching strategy for communication skills.

With sophistication, actors are increasingly engaged to simulate patient’s relatives or professional colleagues. They then subsequently come out of their role to provide feedback to the learners. With both the physical and psychological safety of this setting, learners can express themselves more freely while investigating the relative’s or the colleague’s perspective through the eyes of the actor.

**Value of Video Recording**

Video recording of “real life” interactions is an extremely valuable tool for learning. It enables later self-analysis and reflection and peer feedback. Feedback allows relevant points to be highlighted. It also encourages the learner’s performance to be adjusted or corrected in comparison to a standard. Although the context in role play is simulated, the feelings of the people within the simulation are real. The effectiveness of feedback is increased when a participant views his own behaviour when dynamically performing a motor action or making a social decision. The learning may sometimes be enhanced when the video play back is delayed after a preliminary verbal evaluative feedback.

**Know the Mannequin First**

A central problem that is inherent in any simulation processes is adequacy of the level of reproduction of the real system.
Obviously if the simulator does not validly model the necessary attributes of the real system the results found in solving problems in the simulated environment cannot adequately indicate the behaviour of the real system. This means that the trainer must know a great deal about the real system before he can presume to simulate it. It also means that the learner must know a great deal about the operating system used for simulation before he can maximize his learning from the simulation exercise.

It follows therefore that a participant should familiarize himself with what the mannequin simulator can or cannot do, prior to the commencement of the simulation exercise. Owing to technological constraints, some patient parameters such as skin temperature cannot be simulated. However, this should not prevent the participant from asking for the relevant clinical data, if it is pertinent to the simulated scenario.

**The Ultimate in Simulation**

Exercises in simulation must remain a challenge to learners. If at the end of a successful simulation, the participants do not want to stop and instead remain keen to continue to test the system, it is a sign that their learning has become automatic. When their full attention has been captured as an urge to push their own limits and improve their performance, I believe, learning has started to become a joy for them.
Bibliography


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