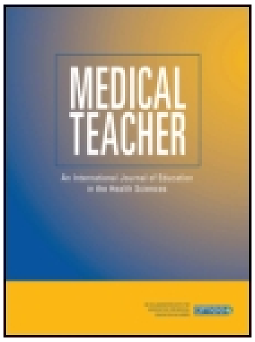

Medical Teacher

ISSN: 0142-159X (Print) 1466-187X (Online) Journal homepage: http://www.tandfonline.com/loi/imte20

A typology of educationally focused medical simulation tools

Guillaume Alinier

2007; 29: e243–e250 MEDICAL TEACHER

WEB PAPER

A typology of educationally focused medical simulation tools

GUILLAUME ALINIER
University of Hertfordshire, UK

Abstract

Background: The concept of simulation as an educational tool in healthcare is not a new idea but its use has really blossomed over the last few years. This enthusiasm is partly driven by an attempt to increase patient safety and also because the technology is becoming more affordable and advanced.

Aims: Simulation is becoming more commonly used for initial training purposes as well as for continuing professional development, but people often have very different perceptions of the definition of the term simulation, especially in an educational context. This highlights the need for a clear classification of the technology available but also about the method and teaching approach employed. The aims of this paper are to discuss the current range of simulation approaches and propose a clear typology of simulation teaching aids.

Method: Commonly used simulation techniques have been identified and discussed in order to create a classification that reports simulation techniques, their usual mode of delivery, the skills they can address, the facilities required, their typical use, and their pros and cons.

Results: This paper presents a clear classification scheme of educational simulation tools and techniques with six different technological levels. They are respectively: written simulations, three-dimensional models, screen-based simulators, standardized patients, intermediate fidelity patient simulators, and interactive patient simulators. This typology allows the accurate description of the simulation technology and the teaching methods applied. Thus valid comparison of educational tools can be made as to their potential effectiveness and verisimilitude at different training stages.

Conclusions: The proposed typology of simulation methodologies available for educational purposes provides a helpful guide for educators and participants which should help them to realise the potential learning outcomes at different technological simulation levels in relation to the training approach employed. It should also be a useful resource for simulation users who are trying to improve their educational practice.

Introduction

The word *simulation* in itself seems well understood but causes problems when a precise educational definition is sought for its implementation. Shannon (1975) defined this term as "*the process of designing a model of a real system and conducting experiments with this model for purpose either of understanding the behaviour of the system or of evaluating various strategies for the operation of the system*". This explanation shows that simulation can be applied to a broad range of applications, but in our case the "system" would ultimately be the "trainees treating a patient" (actor, simulator, or computer animation) or a "healthcare team". A simpler definition found in the online Oxford English Dictionary (1989) describes it as a "*technique of imitating the behaviour of some situation or process (whether economic, military, mechanical…) by means of suitably analogous situation or apparatus, especially for the purpose of study or personnel training*". This definition is more readily applicable to the use of simulation in healthcare education, however it still allows people to have very different perceptions of what should be called "simulation" or how it should be conducted.

Practice points

- Technology has evolved, so should our teaching approach.
- People have different perceptions about simulation training which can cause ambiguity.
- The proposed typology should be used as a guide to reflect on what we are currently offering to our students.
- What is defined as realistic scenario-based simulation training should be student-led.

Simulation, in its different aspects, is increasingly gaining in popularity and the literature supports its use in healthcare education (Issenberg et al. 1999; Alinier et al. 2006; DH 2006). It presents a number of advantages over more traditional methods of teaching and learning that will be discussed. To gauge whether or not simulation practice time should count toward practice hours for nursing students, the UK Nursing and Midwifery Council recently commissioned a number of institutions to carry out individual research projects. It appeared at the briefing gathering of selected institutions that

Correspondence: Guillaume Alinier, Hertfordshire Intensive Care & Emergency Simulation Centre, University of Hertfordshire, College Lane, Hatfield, Herts, Al10 9AB, United Kingdom. Tel: 01707286395; fax: 01707284199; email: G.Alinier@herts.ac.uk

ISSN 0142–159X print/ISSN 1466–187X online/07/080243–8 © 2007 Informa UK Ltd.
DOI: 10.1080/01421590701551185

people's perception of simulation was very divergent and ranged from the very basic exercise not requiring any special equipment to placing students in a realistic simulated clinical environment with patient-like interactive robots, referred to as patient simulators. Even if two institutions reported their intention to use the same simulation technology in their project, they were adopting very different teaching approaches.

The training approach whereby healthcare trainees are immersed in a realistic simulated environment to take charge of a scenario has grown to the point that several national and international societies with this focus have been formed. They include for example the Society for Simulation in Healthcare (http://www.ssih.org), the Society in Europe for Simulation Applied to Medicine (http://www.sesam.ws), the UK National Association of Medical Simulators (http://www.namsonline.com), but also the recent inauguration of the journal Simulation in Healthcare (http://www.editorialmanager.com/sih/).

Common misconceptions about simulation

It may seem that many people use the word *simulation* in too broad contexts or inappropriately (Beaubien and Baker 2004). Considering the uninformed use of an interactive full-size patient simulator, some would consider that teaching trainees passively at its bedside to demonstrate some practical skills or observe its ECG on a monitor forms a simulation session since it uses simulation technology. A more appropriate approach would either be to use a classroom with the required teaching aids such as a computer-based ECG simulator, or to actually run realistic scenarios. This might imply repeating the activity several times but ensures that all trainees are given a chance to actively participate, use the equipment, and critically think about what they are observing and doing. Many experts would argue that at a higher level there is more to simulation than human-like mannequins; the setting, atmosphere, and trainees' active participation are key parameters of the simulation learning process. A simulated environment is more realistic if no one else is directly observing the trainees from the same room and if they are briefed with a patient history realistically engaging them in the scenario. A common characteristic of many widely accepted educational definitions of healthcare simulation is that trainees are required to be actively involved in trying to solve the problem presented to them by interacting and communicating with their peers, the environment/equipment, and the patient (Spannaus 1978; Miller 1984).

The expression "*written simulation*" (Abrahamson & Wallace 1980; Feinstein et al. 1983; Miller 1987), which typically includes essay-type clinical problems or written patient management problems is another widespread misleading use of the word *simulation* as it should have been called *written case*. It is inaccurate in the way that all parameters cannot be described adequately in the scenario, which leaves a non-negligible part of it up to the mind of the individual doing the exercise. This is not to criticise or denigrate this method often used to reinforce skills acquired by other means, but it is an inaccurate and confusing appellation because it has little correlation with the definition of *simulation*. This teaching method cannot be realistic and requires trainees to rely as much on their imagination as on their knowledge. It requires them to think and recreate mentally the environment in which the action would take place. Observing facts concerning patients is different from reading them. In real-life trainees will not solely be concentrating on written information but will also be assessing and listening to their patients. When answering written problems, trainees frequently forget to describe or address things they would have done in a real setting where non-verbal cues prompt their actions. Similarly, written indications or cues that may have remained unnoticed by trainees in real-life are made completely explicit in the written setting of the scenario. Written simulation leads to two types of errors, firstly, it is by definition incomplete and so there are errors of omission, secondly, the need to provide information to trainees leads to the provision of cues which in the real case trainees would have to learn to pick out. The use of such cues in the clinical case is therefore not learnt, which means that important aspects of learning about the clinical situation are therefore ignored. Simulation should allow trainees to concentrate on the clinical problem as it would be presented in reality, without relying on their imaginative sense. A solution would be to define written simulation at the lowest technological level (Level 0, Table 1) among a classification of simulation methods. A more realistic approach which would also broaden the learning outcomes addressed could be an "hybrid standardised patient and written simulation" requiring trainees to interact with a standardised patient (Collins & Harden 1998) from whom they could take the chief complaint while being video recorded for marking and debriefing, or the use of a simulation software that allows trainees to find information about a patient after investigation and administer treatment (Schwid 2001).

Simulation for skill mastery: Consequences of misuse

Misuse of terminology can give false impressions to trainees, making them believe that they are fully prepared to confront reality. A possible reason for the false impression might be that trainees will compare the session they have attended and so-called "simulation", with the type of simulation training that airline pilots have to attend and reputably prepares them well for real crisis situations. They could become overconfident then faced with reality where they may perform badly. This frequently results in loss of motivation, ambition, and self-confidence, and a consequent lack of trust in their own expertise and in their tutors. Similarly, when using two-dimensional media or other methods like software or screen-based simulation, trainees should be warned that their behaviour in "providing" or "suggesting" care to a computer animation would often be very different to the one they would have in a real context. For example, trainees' response to interactive training videotapes showing trauma wounds would certainly be very different to them treating real wounds. Providing care involves more than just intellectual processes. Emotional effects of acute real-life encounters can affect our thinking abilities and skills. Things can be much more bearable

Table 1. Proposed typology of simulation methodologies split in 6 levels and with there respective characteristic. Each can either be student or trainer-led.

Technological simulation levels	Level 0	Level 1	Level 2	Level 3	Level 4	Level 5
Simulation technique	Written simulations includes pen and paper simulations or "Patient Management Problems" and latent images	3-D models which can be a basic mannequin, low fidelity simulation models, or part-task simulators	Screen-based simulators Computer simulation, Simulation software, videos, DVDs, or Virtual Reality (VR) and surgical simulators	Standardized patients Real or simulated patients (trained actors), Role play	Intermediate fidelity patient simulators Computer controlled, programmable full body size patient simulators not fully interactive	Interactive patient simulators or Computer controlled model driven patient simulators, also known as high-fidelity simulation platforms
Mode of delivery	Usually student led	Student or trainer led	Student or trainer led	Student or trainer led	Preferably trainer led	Preferably student led
Type	Passive		Interactive		Partly interactive	Interactive
Skills addressed	Cognitive	Psychomotor	Cognitive	Psychomotor, cognitive, and interpersonal	Psychomotor, cognitive, and interpersonal	Psychomotor, cognitive, and interpersonal
Facility required	Classroom	Clinical skills room or classroom	Multimedia/Computer laboratory or classroom	Depends on the scenario requirements	Clinical skills room or simulation centre realistic setting (simulated theatre, ICU, A&E or ward)	Simulation centre with realistic setting (simulated theatre, ICU, A&E or ward) usually set up with audio and video recording equipment
Typical use	Patient management problems Diagnosis Mainly for assessment	Demonstration and practice of skills	Cognitive skills Clinical management Sometimes interpersonal skills (software allowing for a team to interact over networked computers)	Same as Level 2 plus patient physical assessment, diagnostic, or management problems Interpersonal skills	Same as Level 3 plus procedural skills Full-scale simulation training Sometimes used for demonstrations	Same as Level 4
Disadvantages	Unrealistic Feedback cannot be given instantaneously after the exercise	Limited range of training functions No or little interactivity	Unrealistic setting Students and trainers have to be familiar with the software/ equipment Software has to be kept up to date with the relevant medical regulations/procedures VR sometimes requires very high computational power	For small groups of students only Patients have to be trained and briefed Inconvenient if the exercise has to be repeated many times Not valid for any invasive practice unless used in conjunction with a part-task trainer	May require programming of scenarios Several trainers required for a relatively small group of students Trainers have to be familiar with the equipment Requires an emulated patient monitor for most parameters	Cost (mannequin and facility) Several trainers required for a relatively small group of students Trainers have to be familiar with the equipment Not very portable
Advantages	Low cost (no special equipment required in most cases) One academic may be sufficient for a large number of students	Equipment relatively mobile and always available One academic may be sufficient for a class of students working on the same skill Spares patient discomfort	Relatively low cost, except for VR One academic may be sufficient for a large number of students Students can use it on their own (self learning) Software often provides feedback on performance	Can be very realistic A must for communication skills and patient history taking Allows for truly multiprofesional training	Provides a fairly realistic experience Can be used to apply a broad range of skills Students' performance sometimes recorded Allows for truly multiprofesional training Usually portable	Provides a realistic experience Can be used to apply a broad range of skills Students' performance recorded for debriefing Allows for truly multiprofesional training Can be used with real clinical monitoring equipment

out of context or in a non-realistic environment than they are in real circumstances, and trainees may not appreciate it. This type of simulation could be referred to as Technological Simulation Level 2 under the proposed typology (Table 1) and described in the following section.

It could be argued that trainees should not be taught using simulation-training tools as such except alongside a wide variety of different delivery methods aimed at teaching a particular skill. Even if transferability of skills from software-based training to full-scale simulation scenarios (Schwid 2001) or from part-task trainers (Level 1, Table 1) to real patients was demonstrated for a number of skills such as airway management (Roberts et al. 1997) and cardiovascular assessment (Woolliscroft et al. 1987), there is a danger that trainees become skilful at dealing with the training technology rather than with actual patients. Trainers have to make sure that the skills assimilated by trainees are not becoming automatic procedures that can only be performed using a given model and under certain circumstances. Primarily those media are employed to get trainees used to procedures which will then have to be performed on real patients. Exercises or scenarios should be varied in difficulty and in the succession of events occurring thus allowing trainees to experience a range of situations and patient behaviour or responses, recognizing that no one is the average patient. This leads us to briefly introduce Technological Simulation Levels 3, 4 and 5 with a student-led approach (Table 1) which ensure we can observe and formatively assess trainees using their skills (Cognitive, psychomotor and interpersonal) as and when it seems appropriate to them. It also relates to the top part of the framework of acquisition of skills presented in Figure 1.

This illustrates the fact that there is a need for a variety of training methods and we should carefully address the succession and the way in which they are used. There is currently no comprehensive guide to help trainers or clinical educators gauge the potential of the different tools and training approaches available. This leads us to introduce the complete and new typology of educationally focused simulation tools in healthcare education partly elucidated in the above paragraphs. It represents a hierarchical list of simulation techniques, each having its place in the learning process of trainees and diagrammatically represented alongside Miller's pyramid (Miller 1990) in Figure 1.

Proposed typology: a classification of "simulation" tools and training approaches

One of the earliest typologies of medical simulation identified five types with clear definitions (Miller 1987). More recently an analytical framework was suggested to identify and characterise critical elements of simulators (Meller 1997) but this could be extended to other types of simulation teaching methods (Ziv et al. 2000; Issenberg et al. 2001; Lane et al. 2001). One of the latest typologies proposed three levels; Case studies/Role play, Part-task trainers, and Full mission simulation (Beaubien & Baker 2004). However simulation tools also need to be ranked according to their functions or to the lifelike experience they can potentially provide to users. The classification proposed should not only consider the physical simulation tool such as a dummy or software, but examine it from a broader perspective. It should take into account whether or not and to what degree the environment and the interactivity have been reproduced, the mode in which trainees are interacting with it, and how much or how little input they receive from the trainer. This would give trainees a better idea of the type of simulation technique they have been trained with. It would give them a measure of how realistic it was, and also enable them to describe it more easily to a third party. This way a standardised definition incorporating the degree of fidelity to reality of each type of simulation could be used. Table 1 presents the hierarchical list of the different recognized simulation techniques with a summary of their types and variations, the teaching mode in which they should ideally be used, whether any special facilities are recommended, their typical use, their advantages and disadvantages. This could be used as a guide for trainers, clinical skills tutors, or simulation facilitators.

The six types of educational simulation tools or levels that have been identified cover a wide range of degrees of authenticity (Table 1). Written simulation has been classified as Technological Simulation Level 0 as it does not require any particular equipment other than the actual written cases and sometimes patient information such as X-rays, blood test results, pictures, or ECG printouts. Three-dimensional models have been classified as Technological Simulation Level 1 and includes all the passive anatomical models used for demonstration and to practise individual patient assessment or psychomotor skills. In order not to create too many categories, Virtual Reality and screen-based simulation (Ziv et al. 2000 Schwid et al. 2001) were grouped together as Technological Simulation Level 2, as was done with standardised and real patients (Collins & Harden 1998) for Level 3. Technological Simulation Level 2, which is screen-based, includes a broad spectrum (computer games, videos, and virtual reality) which

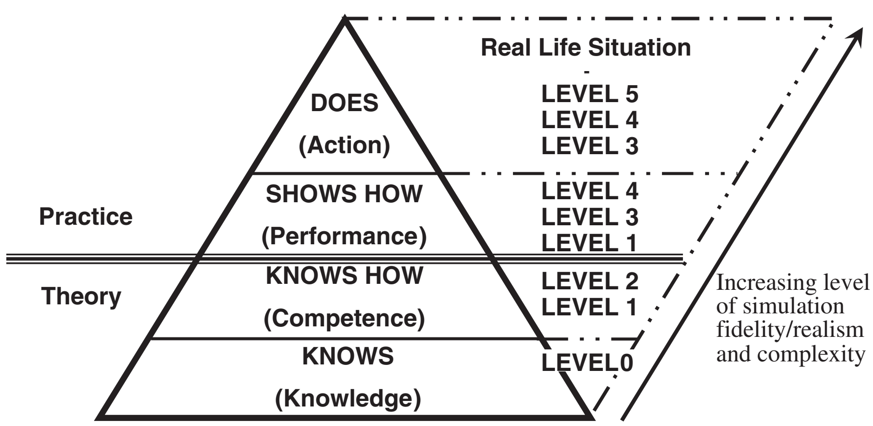

Figure 1. Framework for acquisition of experience and skills through simulation training adapted to the pyramid proposed by Miller (1990) and according to the simulation levels defined in the proposed typology (Table 1). Reproduced with permission from Academic Medicine, Journal of the Association of American Medical Colleges.

sometimes overlaps with other levels as they can be a mixture of physical models connected to computers such as endoscopy or surgical simulators, part task trainers or screen-based simulators with standardised patients (Kneebone et al. 2002, 2004). Some of them fit in the 'SHOWS HOW' part of the pyramid shown in Figure 1. Technological Simulation Level 3 primarily differentiate itself from Levels 4 and 5 because invasive procedures can not be performed on simulated patient and they are limited in the range of conditions they can simulate. Unless real patient are used, even the best actors cannot control their auscultation sounds, temperature or blood pressure. They can however be superior in realism to the most advanced patient simulators for some scenarios for example involving psychotic patients. It is arguable that Levels 4 and 5 could be grouped together if we consider that they both include full body size patient simulators. The major difference resides in the fact that Technological Simulation Level 4 relates to more simplistic programmable mannequins that may not always be used in very realistic settings for full-scale student-led scenario-based simulation training. Level 5 simulation is about the most advanced and expensive type of patient simulators that are driven by physiological models to reproduce all the vital signs that can normally be monitored on a patient. In such case the trainer is expected to simply facilitate the session and leave the trainees fully in charge of the scenarios. Both Levels 4 and 5 are sometimes used at an early stage in the training to develop the understanding of basic medical science of a range of health professionals as they allow the simulation of certain aspects of body functions and drug responses. For such a purpose it is often more economical to use a software (Level 2) as the physical degree of realism of the patient simulator probably offers little added value to the learning outcomes of the demonstration. This corresponds to using a medium to high-fidelity patient simulator for a low fidelity simulation session, which would be equivalent to using a jumbo jet to demonstrate how a plane takes off. Such use might however be justified if it is part of the strategy to familiarize trainees with the technology and environment.

Accordingly to the degree of complexity of the skill being practised or tested and to the trainees' competence, a certain level of fidelity or realism might be more or less suitable. Usually, the higher the degree of fidelity, the more prepared or qualified trainees need to be (Figure 1). To that effect the different types of simulation described can be used in two different modes: demonstration or skill/protocol practice, or scenario-based simulated event. Demonstration or skill/protocol practice will be referred to as the pedagogy making use of simulation tools but not necessarily in a realistic setting. The trainer may interact and give guidance to trainees during the exercise so they can see and understand the effect of a drug or how a procedure is performed for example (Trainer-led approach). It is also the most appropriate way of introducing a new piece of teaching aid to trainees so they can learn about its capabilities. On the other hand, the scenario-based simulated event mode of teaching is meant to give realistic experience to trainees. It relies in a student-centred teaching approach as they should not get any guidance but they are expected to make appropriate decisions by themselves and resolve their conflicts and delegate tasks and responsibilities if they are operating as a team (Student-led approach in that case). It is only after the event or scenario that trainees should be debriefed and receive feedback on their performance. Provision should be made to distinguish those two modes of delivery which can also be described as "trainer-led", because trainees should receive guidance and instructions, and "student-led", because they are the one making the decisions and facing the consequences of their actions without any prompting.

The first approach is applicable to Technological Simulation Levels 1, 2, 3, 4 and 5, and ensures trainers that trainees are not acquiring bad habits in their clinical practice by quickly rectifying their action and guiding them, while the second approach, applicable to Levels 2, 3, 4 and 5, allows the trainers to observe the students' actions, reactions, and interactions in context within a team and with a patient for example. The trainer has to adopt a role of facilitator, providing basic briefing before the scenario while not directing the trainees, but encouraging them to reflect during the debriefing by getting them to bring out the important points of their management of the scenario. Most of those simulation methods are or can be used for both teaching and examination purposes. Ideally a set of nationally recognised standards should be developed for the use of educational simulation techniques at different levels to enable trainers and trainees to compare learning experiences.

The requirements for educational full-scale simulation

It is a pre-requisite that anybody taking part in full-scale or high-fidelity simulation training (Student-led, Level 3, 4 and 5) already possesses the underpinning knowledge and skills that will be required during the scenarios. The trainees' learning journey should ideally include sequentially all the stages of the framework for acquisition of experience and skills (Figure 1). Note that there is a separation in the pyramid dividing purely theory and practice. Within the theory section trainees can demonstrate their knowledge through a written exercise (Technological Simulation Level 0) or their competence by demonstrating they know how to perform a given task using an anatomical model or going through the steps of a procedure on a screen-based simulator (Technological Simulation Levels 1 and 2). The first practice section of the pyramid requires trainees to be more skilful as it requires them to demonstrate their ability to perform something when requested to. This can involve the use of a part-task trainer, a simulated patient, or a patient simulator, respectively, Technological Simulations Levels 1, 3 and 4. The second practice section of the pyramid brings trainees a lot closer to reality and they would be expected to use any of their skills as and when appropriate without being prompted to do so. It includes Technological Simulation Levels 3, 4 and 5 as they allow to run full-scale scenario-based simulation training, but also real life situation, which is just beyond high-fidelity simulation training. This stage should be introduced when trainees have sufficient skills to tackle a range of scenarios. The running cost of simulation sessions is not negligible, which implies that it should be used effectively and at a proper time in the training curriculum to be profitable (Murray & Schneider 1997) as well as effective for the people who are exposed to it. Depending on the degree of fidelity (Miller 1984; Beaubien & Baker 2004) or on the technology used, an important amount of preparation is required to develop and run challenging and realistic scenarios enabling effective learning.

As stated earlier, a simulation is a practical experience that produces a convincing re-creation of a real-life event or set of conditions. Trainees should become focused on the exercise whether it is screen-based or in a simulated environment. For full-scale simulation (Student-led, Levels 3, 4 and 5), the environment in which it takes place plays an important part on how effective the simulation will be, or in other words, how easy it will be for the trainees to react in the way they would in the same situation, but for real. The parameters involved include the atmosphere created in the room (equipment/decoration/noise), the task being undertaken, the distractions, the number of participants, the range of disciplines represented, and the timescale over which the scenario is occurring. All those parameters have to be as realistic as possible to offer the best experience possible towards providing better learning outcomes. It places trainees in a position close to the top of Miller's pyramid (Figure 1). Even if trainees are aware that they are taking part in an exercise, it is essential that it reflects reality to totally engage them and help them suspend disbelief. It is extremely important to help participants experience the same pressure and stress they would have in real-life. In such situation, not having their tutor hovering near them or giving prompts helps trainees forget more rapidly that they are being observed while taking part in a simulated event and encourages them to make decisions by themselves or as part of a team, ideally multiprofessional.

At a lower degree of fidelity, the environment and tutors' input can be different because trainees might primarily be learning or practising a psychomotor skill and require expert guidance. This primarily relates to Technological Simulation Level 1 but can be adopted as an introductory stage with all other levels of simulation. Simulation at any degree of fidelity requires preparation and close supervision to ensure trainees are performing correctly and so their errors can be corrected at an early stage. This supervision should be provided in terms of feedback post scenario-based training to allow trainees to learn from their mistakes (Ziv et al. 2005), whereas it should be provided during training when they are practising individual psychomotor skills.

The current technological trend: full-scale simulation

As the technology progresses in terms of ideas, computational power and software developments, it becomes easier and cheaper to produce realistic interactive patient simulators. Advanced mannequins were introduced in medical education some 40 years ago as is clearly presented on a paper briefly presenting the history of the development of simulators (Cooper & Taqueti 2004). The earliest of its kind was "SimOne", created by engineers and scientists from the University of Southern California, Aerojet General Corporation and the Sierra Engineering Company in 1967 (Abrahamson & Wallace 1980). Until recently highly sophisticated mannequins were an important investment for any training centre. More affordable alternatives to high-fidelity simulation platforms have now been available for about 7 years with Laerdal®, METI®, and Gaumard®, who have respectively commercialised SimMan®, Emergency Care Simulator (ECS®), and Hal®. These are partly interactive computer-controlled mannequins offering a range of features suitable to most healthcare professionals' training needs (Airway features, breathing, voice, auscultation sounds, ECG output, pulses, blood pressure…). Their attractiveness and success as training aids is proven by their popularity: already over 400 units sold in the UK. The arrival of these intermediate fidelity simulators has driven the growth of the number of simulation centres internationally. The adoption of such technology is often accompanied by the installation of specialist Audio/Video systems which enable other trainees to observe the performance of their peers live and remotely, along side the vital signs of the patient. Playback can be used as a good support for debriefing to enhance reflection and illustrate important learning points, whether they relate to communication issues or treatment provided.

Discussion on the benefits and limitations of simulation

Whether it is acquired under simulated condition or in real-life, accumulated and repeated experience often improves performance and confidence (Morgan and Cleave-Hogg 2002). This applies to all professional activities and is particularly important in healthcare where the primary concern is to save lives and ensure patients' well-being. The variety of simulation tools available make that this teaching approach is appropriate for any learning objective whether it involves cognitive, psychomotor, or non-technical skills. Depending on the skills level of teaching that needs to be delivered, the use of certain types of simulation tools is more or less appropriate. Lower levels of learning or understanding of skills, or basic academic knowledge are better taught in classrooms. Some skills should be taught in clinical skills centres as they require the use of part-task trainers. This can be referred to as Technological Simulation Levels 0 to 2 in the typology (Table 1). Once a relevant range of skills has been mastered, the use of simulated patients (Collins & Harden 1998) or of patient simulators may be the most practical way to observe how those skills are applied by trainees. This requires trainees to use higher level cognitive and practical skills, hence reaching Levels 3 through to 5 of the typology (Figure 1, Table 1).

Simulation seems to be an ideal way of learning without causing harm, inconvenience or putting patients at risk (Miller 1987; Ziv et al. 2000) and is also a very convenient method of assessing skills. Identical scenarios can be repeated with different students (Miller 1984) and they can be customized to incrementally augment the difficulty of a case. By varying parameters of scenarios it is possible to expose trainees to a wider range of possible behaviours and outcomes than they could encounter in clinical practice over the same or much longer period of time. As a result of observations drawn from scenarios, weaknesses can be identified and trainees can be encouraged to practise particular skills or address particular issues until they master them. Simulation involves more than trainees practising complex protocols or clinical skills, it integrates the human factor dimension where non-technical skills such as teamwork, communication or leadership are contextually applied (OR, ER, pre-hospital...) during Crisis Resource Management training (Holzman et al. 1995; Gaba et al. 2001; Aggarwal et al. 2004; Beaubien & Baker 2004, Leonard et al. 2004). This is not always recognised by trainers who are used to the lower levels of simulation fidelity, hence focus more on psychomotor skills than human factor issues. It relies on a totally different teaching approach which is about facilitation rather than demonstrating or lecturing. This highlights the fact that to provide the best possible learning experience to trainees or achieve the learning outcomes in the best manner, faculty should receive training in facilitating simulation sessions irrespective of their prior educational expertise or discipline. This requirement, although still difficult to systematically enforce, is supported by many experts in the field and addressed by special training programmes (Issenberg 2006). Provided it is rigorously organized, simulation can be used for assessment as it can recreate realistic situations that place trainees close to the top of Miller's pyramid (Miller 1990) (Figure 1). Alternatively, at a lower degree of fidelity, a range of skills using several simulation modalities can be examined by breaking down the activities in smaller tasks using Objective Structured Clinical Examinations and recently evaluated in nursing education (Alinier 2003).

Several studies have qualitatively explored the potential of simulation training and obtained encouraging responses with primarily cost as the main disadvantage (Gordon et al. 2001). Investment in US$250,000.00 patient simulators has been made by many institutions yet it is recognised that very few robust studies have demonstrated their effectiveness in healthcare education (Beaubien & Baker 2004; Ziv et al. 2000; Gordon et al. 2001; Forrest & Taylor 1998). Recently, the University of Hertfordshire Intensive Care & Emergency Simulation Centre carried out a British Heart Foundation funded quantitative study which evaluated the effectiveness of simulation training with nurses using Laerdal SimMan®. They proved that exposure to student-led Level 4 scenario-based simulation enabled students to significantly improve their skills in comparison to students who did not benefit from the same opportunity (Alinier et al. 2006).

One might think that mass production of skilled professionals goes in tandem with simulation training, however the resources need to be available. Technological Simulation Levels 3, 4 and 5 mostly relies on space, time, physical and human resources, so it has inevitable shortcomings. Setting up and running a simulation centre can be very expensive as it requires clinical, technical, and administrative staffing, a patient simulator or simulated patient in a simulated operational clinical or community area, a control room, a debriefing room, and an integrated Audio/Visual system. Students' numbers, staff availability, and other technological or resource limitations might restrict trainees' simulation exposures. This approach is and should be about providing quality learning and hands-on experience to a few trainees at a time, and at the appropriate time in their curriculum. The current problem in the appropriate adoption and use of high-fidelity simulation lies more in the readiness of institutional mechanisms than the technology itself (Issenberg 2006, Gaba & Raemer 2007).

Conclusion

The use of simulation tools is starting to play an increasingly important role in the education of future healthcare professionals, but also for qualified providers in terms of continuing professional development. Proposing a typology of the current simulation technologies is a starting point toward standardizing their use and prescribing their requirements for training centres. The relevant societies should develop standards for the appropriate use of simulation training tools to encourage best practice. This would benefit trainees and ultimately, enhance patient care. Some educators fail to identify what type of tool is better suited at what stage, for what purpose, and in which mode of delivery. Such failure can adversely affect trainees' acquisition of skills and the selection of the best methods of assessment.

Similarly, the word *simulation* should be used more concisely and in context to prevent confusion. Preceded by a "level" (0 to 5) and the mode of delivery used (trainer or student-led) as advised in the typology presented would ensure people are talking of the same thing and prevent ambiguities. Less rigorous use of the terminology can create false impressions of performance achieved, and trainers and trainees themselves could come to believe that they are more adequately prepared to face real situations than they actually are. To be most beneficial, the appropriate type of simulation tool needs to be used correctly and at the right stage in the educational curriculum. The trend seems to be evolving toward more advanced and sophisticated training tools allowing trainees to learn more autonomously and use a broader range of skills. The broad spectrum of simulation can address cognitive, psychomotor as well as interpersonal skills, especially at the higher technological levels of the typology. It is important for its application principles to be well defined and rigorously applied to get the best benefits from this educational technique. The typology presented in this paper is for developers and users, and rationally defines simulation tools, their applicability for the specific skills or knowledge to be imparted or for their appropriate assessment.

Notes on contributors

GUILLAUME ALINIER is a University and National Teaching Fellow in the Faculty of Health and Human Sciences. He has had a key role in developing and now manages the University's multiprofessional Hertfordshire Intensive Care & Emergency Simulation Centre, UK. He is also module leader on concepts of simulation training in healthcare education with the Bedfordshire & Hertfordshire postgraduate medical school.

Acknowledgement

The author would like to express his gratitude to Professor John Cookson for his encouragements and for providing valuable feedback about the earlier drafts of this paper.

References

Abrahamson S, Wallace P. 1980. Using computer-controlled interactive manikins in medical education. Med Teach 21:25–31.

Aggarwal R, Undre S, Moorthy K, Vincent C, Darzi A. 2004. The simulated operating theatre: comprehensive training for surgical teams. Qual Saf Health Care 13:27–32.

Alinier G. 2003. Nursing students' and lecturers' perspectives of objective structured clinical examination incorporating simulation. Nurs Educ Today 236:419–426.

Alinier G, Hunt WB, Gordon R, Harwood C. 2006. Effectiveness of intermediate-fidelity simulation training technology in undergraduate nursing education. J Adv Nurs 543:359–369.

Beaubien JM, Baker DP. 2004. The use of simulation for training teamwork skills in health care: how low can you go? Qual Saf Health Care 13:51–56, Suppl 1i.

Collins JP, Harden RM. 1998. AMEE Medical Education Guide No. 13: real patients, simulated patients and simulators in clinical examinations. Med Teach 206:508–521.

Cooper JB, Taqueti VR. 2004. A brief history of the development of mannequin simulators for clinical education and training. Qual Saf Health Care 13:11–18.

Department Of Health. 2006. Good doctors, safer patients: proposals to strengthen the system to assure and improve the performance of doctors and to protect the safety of patients. Report By The Chief Medical Officer, London: The Stationery Office.

Feinstein E, Gustavson LP, Levine HG. 1983. Measuring the instructional validity of clinical simulation problems. Eval Health Prof 61:61–76.

Forrest F, Taylor M. 1998. High level simulators in medical education. Hosp Med 598:653–655.

Gaba D, Howard SK, Fish KJ, Smith BE, Sowb Y. 2001. Simulation-based training in anesthesia crisis resource management (Acrm): a decade of experience. Simulat Gaming 322:175–193.

Gaba D, Raemer D. 2007. The tide is turning: organizational structures to embed simulation in the fabric of healthcare. Simulat Healthcare 21:1–3.

Gordon JA, Wilkerson WM, Shaffer DW, Armstrong EG. 2001. "Practicing" medicine without risk: students' and educators' responses to high-fidelity patient simulation. Acad Med 765:469–472.

Holzman RS, Cooper JB, Gaba DM, Philip JH, Small SD, Feinstein D. 1995. Anesthesia crisis resource management: real-life simulation training in operating room crises. J Clin Anaesth 78:675–687.

Issenberg SB, Gordon MS, Gordon DL, Safford RE, Hart IR. 2001. Simulation and new learning technologies. Med Teach 231:16–23.

Issenberg SB, McGaghie WC, Hart IR, Mayer JW, Felner JM, Petrusa ER, Waugh RA, Brown DD, Safford RR, Gessner IH, Gordon DL, Ewy GA. 1999. Simulation technology for health care professional skills training and assessment. J. Am Med Assoc 2829:861–866.

Issenberg SB. 2006. The scope of simulation-based healthcare education. Simulat Healthcare 14:203–208.

Kneebone R, Kidd J, Nestel D, Aswall S, Paraskeva P, Darzi A. 2002. An innovative model for teaching and learning clinical procedures. Med Educ 36:628–634.

Kneebone R, Scott W, Darzi A, Horrocks M. 2004. Simulation and clinical practice: strenghtening the relationship. Med Educ 38:1095–1102.

Lane JL, Slavin S, Ziv A. 2001. Simulation in medical education: a review. Simulat Gaming 323:297–314.

Leonard M, Graham S, Bonacum D. 2004. The human factor: the critical importance of effective teamwork and communication in providing safe care. Qual Saf Health Care 13Suppl 1i:85–90.

Meller G. 1997. A typology of simulators for medical education. J. Digital Imaging. 10:194–196.

Miller GE. 1990. The assessment of clinical skills/competence/performance. Acad Med 65:S63–67.

Miller MD. 1984. The use of simulation in training programs: a review. Educ Technol 24:39–41.

Miller MD. 1987. Simulations in medical education: a review. Med Teach 91:35–41.

Morgan PJ, Cleave-Hogg D. 2002. Comparison between medical students' experience, confidence and competence. Med Educ 366:534–539.

Murray WB, Schneider AJL. 1997. Using simulators for education and training in anaesthesiology. Amer Soc Anesthesiol Newslett 6110:633–638.

Online Oxford English Dictionary 1989. 2nd Ed. Oxford University Press. http://Dictionary.Oed.Com accessed on 8/11/2005.

Roberts I, Allsop P, Dickinson M, Curry P, Eastwick-Field P, Eyre G. 1997. Airway management training using the laryngeal mask airway: a comparison of two different training programmes. Resuscitation 333:211–214.

Schwid HA. 2001. Components of an effective medical simulation software solution. Simulat Gaming 322:240–249.

Schwid HA, Rooke GA, Michalowski P, Ross BK. 2001. Screen-based anesthesia simulation with debriefing improves performance in a mannequin-based anesthesia simulator. Teach Learn Med 132:92–96.

Spannaus TW. 1978. What is simulation? Audiovis Instruct 235:16–17.

Woolliscroft JO, Calhoun JG, Tenhaken JD, Judge RD. 1987. Harvey - the impact of a cardiovascular teaching simulator on student skill acquisition. Med Teach 91:53–57.

Ziv A, Ben-David S, Ziv M. 2005. Simulation based medical education: an opportunity to learn from errors. Med Teach 273:193–199.

Ziv A, Small SD, Wolpe PR. 2000. Patient safety and simulation-based medical education. Med Teach 225:489–495.