THE ROLE OF SIMULATION ENVIRONMENT AND SIMULATORS IN MEDICAL EDUCATION – WHERE DO WE STAND?

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Abstract

Simulation can be defined as "the act of mimicking a real object, event or process by assuming its appearance or outward qualities" (Gorman et al. 1999). In a medical setting, simulation can be seen as the reproduction of a complete clinical encounter consisting, but not being limited to, specific items of equipment ('simulators') (Kneebone (Anon 2010a). Simulation-based medical education (SBME) is increasingly needed in clinical practice due to an onus on patient safety, decreased operative exposure of trainees, the introduction of new operative techniques, as well as the need for clinicians' revalidation. SBME addresses these needs by being learner-centred, being amenable to objective-setting and sustained repeated practice, as well as providing feedback. Furthermore, simulation gives trainees 'permission-to-fail' in an environment where patient safety is not compromised (Kneebone et al. 2006).

Keywords: *Simulation, Simulators, Medical Education*

INTRODUCTION

Different classifications of SBME exist, including low-fidelity vs. high fidelity or physical vs. digital simulation. More recently, a distinction had been made between decontextualised or pre-integrative simulators and those which offer skills training within a clinical context (integrative or contextualised simulators) (Kneebone 2003). This highlights the fact that SBME consists not only of technical-skills acquiring devices ('simulators'), whether mechanical, digital or hybrid, but also includes the simulation environment and individuals participating in the simulation itself. This three-domain concept (Figure 1) must give equal weighting to each individual component in order to create a simulation experience that is realistic, clinically relevant and transformational (Kneebone et al. 2007). The skills acquired through such a balanced simulation experience are not simply technical ones, but include a broader range of behavioural and social competencies such as professionalism, communication, crisis and time management.
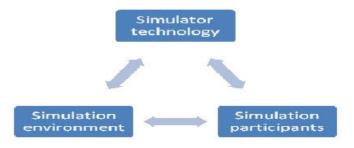

Figure 1. The three components of SBME

The authors questions whether an asymmetrical development has occurred in SBME, where simulator technology has developed at the expense of the simulation environment. To answer this question, it is necessary to analyse current evidence related to the four criteria of successful simulation (Kneebone 2005):

1. Gaining and acquisition of technical proficiency
2. The place of expert assistance in task-based learning
3. Learning within a professional context
4. The affective component of learning

GAINING AND RETAINING OF TECHNICAL PROFICIENCY

SBME is a powerful method of engaging learners in deliberate practice (DP), currently identified as a key method of achieving professional expertise (Kneebone 2009b). Simulations offer many of the key tenets of DP,

including repetitive practice, adjustment of learning objectives to learners' needs and providing focused feedback.

Simulator technology provides a wide range of opportunities for the acquisition of surgical skills using the principles of DP. Simple, traditional simulators, such as cadavers, offer complex cognitive and haptic stimuli to learners, as well as being amenable to a variety of teaching exercises, ranging from simple dissections to complex orthopaedic reconstructions. The value of these simulators with respect to tissue handling ability has been confirmed by their wide use in accrediting doctors in Advanced Trauma Life support and Definitive Surgical Trauma Skills courses. These often provide the only exposure to a procedure prior to its practice on live patients. Physical models have also been widely used to teach novices simple procedures, with bench-top models existing for everything from child delivery to urinary catheterisation, wound suturing and resuscitation. A validated physical model includes that of central venous line insertions, where SBME-trained novices were shown to have a reduced number of procedural complications compared to traditional trained ones (Barsuk et al. 2009;McGaghie et al. 2010). The affordable and safe nature of bench-top simulators allows repetitive, focussed practice to occur according to the principles of DP.

The advent of affordable digital technology has seen a massive rise in computer-based simulation since 1995 (Issenberg et al. 2005), with new simulation technology offering not only high fidelity simulation, but also reproducible qualitative and quantitative feedback, as stipulated by DP theory. The combination of physical and computer simulators to produce hybrids has further enhanced learner-simulator interaction, allowing complex manipulation of physical interfaces to elicit real-time simulated physiological responses. Examples include the MIST-VR® (Chaudhry et al. 1999) and Lap Mentor® (Salkini et al. 2010) laparoscopic simulators which can simulate organ injury and allow tissue handling. These provide a powerful simulator experience to learners and require

financial and intellectual investments that have not yet been matched by developments in simulation environments (Satava 2001). Furthermore a wide variety of VR simulators have been developed to provide training and a potential selection and recertification role in non-invasive gastrointestinal (e.g. MIST-VR®) and orthopaedic surgery, following extensive validation processes (Pedowitz et al. 2002). Once again, similar advances in the development of simulation environments have not been reproduced, both in terms of development or validation.

On the other hand, advances in environmental simulation can provide powerful contextualisation of simulator technology, being essential in transferring and applying simulated skills to clinical practice (Kneebone et al. 2004). Furthermore, they provide learning opportunities in a wider range of behavioural skills. To date, major developments in simulation environments have been constrained to specialist education centres, being limited by development and maintenance costs, staff-training and geographical access of trainees to simulation facilities (Kneebone (2010a). Effective, yet isolated examples include the creation of simulated operating theatres (SOT) (Aggarwal et al. 2004) which allow multidisciplinary teams at all levels of training to gain clinical, leadership, communication and decision-making skills. Furthermore, the development of patient-focused simulation (PFS) training combines the use of physical models with simulated patients (SP) to create an altogether new form of simulation hybrid(Kneebone, Nestel, Wetzel, Black, Jacklin, Aggarwal, Yadollahi, Wolfe, Vincent, & Darzi 2006). Learner interaction with the SP provides a more complex and powerful experience with immediate applications to clinical practice and with potential for teaching a wider variety of skills. One example is the performance of an open carotid endarterectomy (CEA) under local anaesthesia using a simulated operation theatre, an SP as the awake patient, a CEA simulator and a full operating team (Black et al. 2006;Black et al. 2010). The combined education impact of

these complex simulation concepts (PFS, SOT and SP) provide an altogether more effective educational experience than either concept in isolation. Unfortunately these are relatively new simulation concepts which are in the process of development, validation and implementation. These are not, at this point in time, universally accessible to trainees. The development of portable, affordable and high-fidelity immersive simulation environments ('distributed simulation'), such as inflatable operating tents, will no doubt overcome many of the current limitations of existing models and will change the role of simulation environments in the future (Kneebone (2010a).

Evidence does exists to document the validity of simulation environments in recreating complex aspects of surgical practice, such as clinician response to stress (Anon 2010b) or reproduction of crisis scenarios for the purpose of high-stakes examinations in anaesthesia (Berkenstadt et al. 2006a;Berkenstadt et al. 2006b). Nevertheless, the largest volume of validation, research and development work in simulation focuses on simulation technology rather than the simulation environment (Issenberg, McGaghie, Petrusa, Lee, & Scalese 2005).

THE PLACE OF EXPERT ASSISTANCE IN TASK-BASED LEARNING

The current interpretation of Vygotsky's zone of proximal development (ZPD) can be broadly defined as the sum of all resources available to bridge a learner's actual performance to his or hers maximum potential achievement. Simulation and simulation technology can play an important role in this by providing performance feedback and highlighting development areas needed to overcome arrested growth (Kneebone 2005).

Simulator technology provides excellent expert support by generating quantifiable feedback data on learners' performance. Many bench top simulators allow learners and trainers to observe, discuss, reflect and improve performance, according to Kolb's cycle (Kolb DA 1984). An example includes the successful integral removal of a simulated sebaceous cyst under supervision in a basic surgical skills simulator. More complex and objective feedback can be derived from computer or hybrid simulators which provide accurate metrics of learner performance, including economy of movement, instrument handling and tension placed on fragile tissues (Aggarwal et al. 2007;Dosis et al. 2005). Simulator assessment is in itself a novel and complex aspect of SBME, with complex tools such as the Imperial College Surgical Assessment Device (ICSAD) being developed to collect positional data and derive measurements of surgical dexterity (Kneebone 2003).

It has been argued however, that the more detailed and complex SBME technology becomes, more remote it is from clinical practice (Kneebone, Nestel, Wetzel, Black, Jacklin, Aggarwal, Yadollahi, Wolfe, Vincent, & Darzi 2006). Assessment of performance in a wider simulation environment is more difficult to capture and quantify, but provides a more holistic view of an individual's performance, encompassing cognitive, technical and psychological domains of proficiency. In this context, video assessment of PFS allows feedback to be given on learner's response to a number of challenges, including emotional aggression, language barriers and breaking bad news(Kneebone, Nestel, Wetzel, Black, Jacklin, Aggarwal, Yadollahi, Wolfe, Vincent, & Darzi 2006). New tools are currently developed to address team work and surgeon's performance under stress which are likely to open new opportunities in developing environmental simulation (Arora et al. 2009;Arora et al. 2010a;Wetzel et al. 2010). At present, with the exception of specific simulation environments, such as distributed simulation and PFS (Kneebone (2010a), environmental feedback is limited to student performance in objective structures clinical examinations (OSCEs) which are by comparison less sophisticated forms of simulation.

LEARNING WITHIN A PROFESSIONAL CONTEXT

SBME can facilitate a learner's transition from peripheral to full participation in a community of practice by introducing and consolidating the knowledge, skills and attitudes that define mastery in that particular field (Kneebone 2005).

Simulator technology provides training opportunities in high risk procedures for learners that have not gained legitimacy in performing the procedure and who would otherwise endanger patients through the traditional apprentiship model of "learning by doing" (Kneebone 2003). To this extent junior surgeons can practice operations such as laparoscopic cholecystectomies, perform GI endoscopies, carotid endarterectomies and learn interventional 'wire skills' on VR simulators at early stages in their careers, when similar interventional opportunities would be neither available nor appropriate in real clinical practice(Kneebone, Scott, Darzi, & Horrocks 2004). Similarly painful or embarrassing everyday procedures, such as urinary catheterisation or digital rectal examinations are practiced by medical students on bench-top simulators as part of their OSCEs leading up to qualification as doctors. Furthermore, proficiency in demonstrating life-support on mannequins such as Resusci Anie® (Laerdal 2010) provides the principal door-keeping assessment in allowing individuals to provide acute care as doctors, nurses or paramedics. Overall, simulator technology provides an essential educational 'scaffold' (Bruner JS 1967) which allows learners to gain legitimacy, and hence integration in a community of practice. The large number of simulators developed in this field, ranging from plastic models to sophisticated hybrids, as well as their widespread use in medicine, is testaments of the dominance of simulation technology in learning within a professional context.

Immersive simulation environments play an equally important, but less prominent role in integrating learners in communities of practice. The development of distribute simulation and SOTs allows trainee surgeons to occupy a central role in a multidisciplinary team, again with minimal risk to real patients, helping them to develop a variety of technical and behavioural skills. Immersive simulation recreates a community of practice and allows the learner to develop an identity within that community, with a direct impact on the individual's clinical practice. A junior surgeon may thus use the immersive simulation environment to lead an operating team consisting of senior nurses and consultant anaesthetist for the first time, developing leadership and decision-making skills in safe and professionally acceptable circumstances. Nevertheless, current access to multidisciplinary immersive simulations is costly, requires large number of trained staff and is geographically inaccessible to the majority of surgical trainees.

THE AFFECTIVE COMPONENT OF LEARNING

Motivation is an essential requirement for DP. SBME has the potential to recreate a variety of physical and psychological stimuli which can help learners relate to and engage with the educational task at hand more effectively.

Whilst bench-top or physical models have limited potential in getting learners to 'buy-in' the simulated experience, high fidelity, VR endoscopic simulators or film-industry grade 'vascularised' silicone models of bowel can create a powerful effect on surgical trainees. The introduction of timed tasks or 'pass-mark' performance on hybrid simulators with complex feedback potential can introduce elements of stress, competitiveness or anxiety in SBME, similar to the emotional pressure experienced in clinical practice (Arora et al. 2010b). The use of simulators in selection for specialist training or revalidation of specialists can further consolidate the willingness of learners' to fully participate in SBME. Nevertheless, it has been argued that highly complex simulators provide a good technical or haptic experience at the cost of contextual realism and translation to practice (Kneebone 2009a). In this way, once the

simulated task has been mastered, the learner achieves a state of arrested development as development of affective domains encountered in real clinical practice cannot be achieved with further isolated simulator experience. This can have serious implications for simulation centres making significant investments in high-fidelity equipment that teaches a limited range of skills.

The use of simulated patients in conjunction with simulators in the form of patient-focused simulation can give an altogether different SBME experience, by integrating an isolated technical skill in its clinical context. Furthermore, immersive simulation, seen in multidisciplinary SOTs, can involve a number of trainees and simulated patients taking on various seniority roles in different disciplines. These have a great potential in reproducing and improving subtle social phenomena such as hierarchical behaviour or inter-professional discrimination, as well as more traditional domains of team work and communication. The introduction of emotions such as empathy, frustration and fear, as well as the need to make and respond to decisions can a create powerful "anchor to each clinician's actual practice, which in turn taps into a complex web of conscious and unconscious professional responses"(Kneebone, Nestel, Wetzel, Black, Jacklin, Aggarwal, Yadollahi, Wolfe, Vincent, & Darzi 2006). In this way the use of simulation context, consisting of simulation environment and participants can turn a simple technical tasks (e.g. skin suturing) into a multivariate SBME experience. Unfortunately, the opportunities to participate in such SBME exercises are overall rare, costly and resource intensive at present.

DISCUSSION

Currently SBME is predominantly based around the development, validation and application of new simulator technology which is amenable to deliberate practice. Recent exciting developments have been made in the development of simulation environments, such as patient-focussed and distributed simulation, increasing the range of skills that can be taught

through SBME and DP. From an evidence perspective however, the acquisition of technical skills is predominately imbalanced towards the technological aspect of simulation.

It is also possible to see that environmental simulation has great potential for providing expert assistance. Nevertheless, simulator technology benefits from more validation work and better performance assessment tools, creating more reliable and quantifiable feedback data. Important work has nevertheless begun to develop tools for assessing performance in simulated clinical environments. However, these have occurred at a slower pace on account of the complex nature of simulated clinical behaviour.

SBME also provides a bridge between peripheral and full participation in communities of practice. Whilst immersive simulation may be more suitable in integrating learners in communities of practice compared to isolated simulators, its status in SBME is limited by a lack of universal availability counterbalanced by a prolific development of simulator technology.

In terms of accessing the affective component of SBME, simulation technology plays a lesser role compared to the simulation environment and participants. These can elicit a broad spectrum of emotions, providing essential clinical context to SBME and enhancing its translation to clinical practice. Further development of research tools looking at the ability of SBME to access affective domains will increase the profile of simulation environments in SBME.

CONCLUSION

It is possible to argue that historical, financial and commercial factors have created an imbalanced development of simulator technology at the cost of the simulated environment. Nevertheless, this represents a natural evolution of a new and exciting area of medical education that requires tool-development prior to tool application and integration. Current research interest related to the development of simulated environment paradigms, techniques and assessment metrics

represent a natural next-stage development of SBME that will lead to a more balanced form of medical education in the future. Similar to all new educational achievements, simulation based medical education will require more time to reach its full potential. Its current, dynamic and imbalanced form represents a healthy state of continuous development.

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