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Simulation-Based Medical Education: A Boon for Medical Students? - An Integrative Review

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Abstract

Simulation is a synthetic representation of a real-world process with sufficient reliability to facilitate learning through contemplation and practice without the hazard, innate in a real-life experience. Nowadays, simulation is a useful accompaniment to medical education as pre-exposure to necessary clinical skills as exposure in the real clinical setting may be insufficient. Clinical skills and performance are considered core proficiency and are crucial to the professionals. This can enable the students to familiarize themselves with patient examination and hands-on- training by using models before coming across patients directly. Simulators are broadly classified into two broad categories: 1. High-fidelity Simulators and 2. Low-fidelity simulators. The fidelity of a simulator is decided by the extent to which it provides realism through characteristics. Simulation Based Medical Education **(**SBME) provides a safe environment for the students to acquire their psychomotor skill but is not necessarily better than other types of instruction as there is a high degree of variability between studies. SBME has been introduced in the health care field and now it is becoming one of the most popular teaching techniques for improving patient safety and care. It would be advantageous if it is included in medical curricula as it may proof boon for the young medicos.

Keywords: Medical simulation; SBME; Simulators

Background

Simulation is a synthetic representation of a real-world process with sufficient reliability to facilitate learning through contemplation and practice without the hazard, innate in a real-life experience[1]. Simulation is derived from the Latin word 'Simulare' which means to copy[2] Simulation is considered at present a fundamental part of the contemporary medical education system, be it graduation or post-graduation. Nowadays, simulation is a useful accompaniment to medical education as pre-exposure to necessary clinical skills as exposure in the real clinical setting may be insufficient. A medical student is expected to acquire certain basic skills by the end of graduation and thereafter pursue learning skills throughout life even after formal education is completed. A trainee is expected to learn patient-centered and process skills (teamwork, information management, self-directed learning, and patient advocacy) in their undergraduate curriculum. It is often found that in a clinical area, a trainee does not get uniform clinical exposure, thereby it is impossible to learn all the necessary skills (Friedman C, Purcell E, Swanson 1992).

Besides issues like medico-legal issues, patient safety, and patient discomfort pose a serious threat to a trainee to practice and get suitable skills even if he gets a suitable patient to learn from. In the current situation, simulation provides an alternative environment to the real patient and trainees get an opportunity to learn a wide range of skills for mastering and practice with the achievement of specific learning goals and objectives. In such a situation learning can place in a dedicated teaching environment rather than in a patient care environment.[3] Clinical skills and performance are considered core proficiency and are crucial to professionalism in medical practice for successful patient care. This can enable the students to learn themselves with clinical examination and hands-on- training by using models and simulators before examining the patients directly. Simulation-based medical education (SBME) has been introduced in the health care field and now it is becoming one of the popular teaching modalities for refining patient safety and care[4].

The three objectives of SBME are:

A. Executing a clinical skill.

B. Practicing the clinical skill under observation.

C. Performing clinical skills individualistically and self-assuredly.

Maastricht university of Netherlands first opened clinical skill laboratory in the year 1974. Over the last 25 years, the use of SBME and skill laboratories has seen a vast advance in medical education. The principle of "See one, Do one and Teach one" is still followed in certain countries. SBME is an educational interposition that links the gap between the "See one and Do one" in clinical practice to stress on psychomotor domain and to focus on the quality of medical care and the patient's safety.

The introduction of SBME is considered advantageous over the traditional style of medical education as it provides medical students and the" simulated patients", a safe environment to commit errors and to learn the right technical skills. Clinical simulation resembles a clinical scenario. It is one of the different modes in "health care education" that is usually offered to learn the competency and technical skills necessary to treat the patients to bring out a successful outcome.[5]

Implementation of clinical skill course

The different skills that are to be instructed to pupils amid the early stage of their medical learning are recorded and each ability is applied within the skill lab. They are classified as "Diagnostic skills, 'Performing skills", "Resuscitative skills" and "High fidelity skills". The skills are instructed during the training session before the candidate performs it on the patient. The students are made to learn and practice repeatedly so that afterward they are made to perform individually under the professional's guidance and supervision. The trainers instruct and insist on them constantly about the skills, the medical students can acquire the skill and perform them individually. Since the students are given repeated practice of the skills, they can perform on the patients independently with utmost confidence. This enhances the learner to become a proficient health care professional instead of acquiring only theoretical knowledge.[6]

The main benefit is that clinical circumstances and outcomes of medical emergencies can be planned, can be detected and then can be replicated and at the same time understanding can be established. The particular clinical questions can be rehearsed by the students and can be replicated several times until they are satisfied and confident about the procedure. Here for training and understanding purposes, clinical circumstances are made so the practice of new competencies is possible without requiring a real patient role.[7]

Simulators

Simulators are broadly classified into two categories: 1. High-fidelity simulators and 2. Low-fidelity simulators. The fidelity of a simulator is determined by the degree to which it offers realism over characteristics like visual signs, tactile characteristics, feedback abilities, and user interface with the learner.

High-fidelity simulators

These simulators make use of lifelike constituents and apparatus to embody the job that the student should execute. It provides the learner with added real-life signals to engage them in a much more accurate interactive situation. Here learners are questioned to relate the correct intrusion or

operation to perform a surgical technique.

1. (a) Scenario presented on PC (High tech)
   (b) Anesthesiology simulators (High tech)
   (c) Human patient simulators (High tech)
   (d) Plastic manikin computerized sounds and physiology skill assessment
   (e) Anesthesiology training applications
   (f) Minimally invasive surgery trainer (High tech) Surgical Trainers
   (g) **Bronchoscopy Simulator:** Used to demonstrate the art of using a bronchoscope. System contains bronchoscope replica. The device is introduced into a mechanical interface mimicking the patient. Encoders are incorporated on both ends the bronchoscope and mechanical interface to track the user's actions.
   (h) **High fidelity Surgical Suite:** Teaches multiple tasks and advanced problem solving
   (i) **Battlefield trauma using HPS:** Leg amputation from landmine using Human Patient Simulator productively.[8]

Low-fidelity simulators

They utilize tools and apparatus that are inferior simulations compared to a true medical environment. They typically provide to perform isolated techniques such as knot tying, practicing dissection, intravenous line insertion, instrument management and hand-eye coordination in endoscopic instruments.

1. (a) **Low-tech Simple 3-D organ models:** These are simple organ models made of plastic or cotton.
   (b) **Hands-on Suture Simulator (Low tech):** These are static models also known as 'Bench Models'. A wide variety of models includes, 'knot tying trainers, 'Models for dissection and suturing', 'abdominal opening and closure trainers', 'episiotomy repair trainers', 'anal sphincter repair trainers' and 'urethral sling procedure trainer'.
   (c) **IV Trainer to Augment Human Patient Simulator (Low tech):** Augmented with an inexpensive IV trainer for scenarios involving heavy bleeding. These models may be reused for frequent practice of a certain clinical task. This includes 'synthetic skin pads' for suture practice, 'synthetic arms' for practicing IV cannulations, and the 'Upper body torso' for practicing airway skills.

Basic mannequin (Low tech)

1. (a) **Full body mannequin:** Patients are represented physically by mannequins. In advanced mannequins by incorporating electronic devices physiological responses may be generated. They can operate by providing the physical conditions like, heart and lung sounds, pulse rate, Blood pressure, pupil dimension and voice command etc. These can provide training for personal tasks and for team-based learning.
   (b) **Dummy type:** These are used for diagnostic procedures and basic skills. They simulate the physical structure of patients. Various skill training is provided using these models in the earlier days.

Human cadavers simulated

They deliver a realistic prototype for surgical skill exercises without involving the actual patient's role. This is a better simulation model compared to others but evidence of the apprentice's performance using the cadaver model is still not being documented.

Realistic procedural simulators/Video Box Trainer

Simulate various endoscopic surgical skills and techniques using original surgical instruments as well as equipment, with video monitors and cameras. "The Box Trainer" is an excellent mechanism for training eye-hand coordination, camera handling, suturing techniques, grasping mechanisms, point-to-point movements, cutting and clipping, and coordinated movements with small objects. Suturing skills may as well be performed using conventional sutures with needles. An essential feature of the "Box Trainer" is that it provides the trainee with the sensing of the equipment on the surface of the tissue and the pressure to close and open the instrument which is sensory feedback.

Realistic interactive patient simulators

These standardized patients are made to play the role of a real patient. Clinical history can be obtained and a physical examination can be performed.

Virtual reality/Surgical simulators

Virtual reality is the knowledge that permits an operator to act together with a computer-simulated setting, whether it is real or fictional. Recent virtual reality settings are primarily graphical images that are exhibited either on a computer screen or through a specific stereoscopic display. It also incorporates haptic systems that combine tactic information, which is in form of force feedback. Alongside simulators make a recording and save actual data on individual execution on specific tasks time taken to achieve the task, the economy of hand motion, agility, and instrument path span. Example: Lap-Sim system.

Miscellaneous

Hybrid simulators

A hybrid simulator combines a simulated patient with a "subtask trainer" to acquire clinical skills. Model wounds can be demonstrated on standardized patients, allowing participants to simultaneously learn clinical techniques, professional behaviors, and related communication skills Similarly, keeping a stethoscope over a simulated subject could be used to assess clinical signs such as cardiac murmurs and irregular breath sounds.

Designing a Simulation Programme

Firstly, learning objectives are defined followed by feedback from the faculty members and trainees are obtained. Best-suited simulators are identified. The preparatory phase consists of arranging infrastructure, procuring the simulators, maintenance, funding, and manpower.[10]

Preparation of blueprint: This is prepared for the training session by specifying textbooks, international guidelines and checklists. The number of trainers is allocated based on the students' strength and the type of the skill to be taught. The resource persons have to be trained based on the total training hours of the session[11].

Evaluation Phase: The student's performance is evaluated based on their responses using a checklist. At the end of the session the drawbacks and strengths of the session is assessed[12].

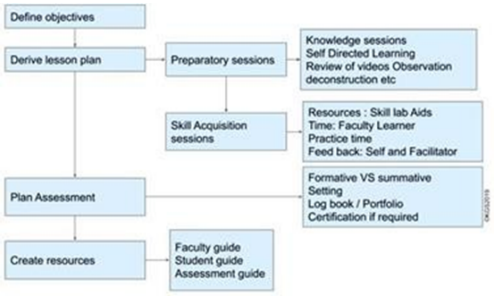

Fig 1. Planning of a Clinical Session [13]

Components of SBME

The following are the essential components for a successful SBME program

A.Training area and Debriefing room: It forms the area where the of the session is conducted from pre-lectures to the demonstration on the models.

B. Simulators and equipment for training

The usage of equipment also varies from simple plastic simulators to high-fidelity simulators with virtually assisted apparatuses. While using live organs and cadavers, a properly well-ventilated space for storage of cadaver is essential.

C. Full-time faculty, instructor, and administrative staff

Resource persons and administrative staffs are essential for a successful simulation program. They have a major role in maintaining equipment, scheduling the clinical sessions selecting and coordinating with learners.

D. Educational content

The content must include the learning objectives, the equipment, manual for using the equipment, the supporting supplies and the evaluation of the session. The content is designed in consultation with the personals in the clinical skill laboratory and the specialist in every department[13].

Benefits & limitations of simulation-based study

Darla Brown once said, "By making this doctor, I have not harmed my patients." It offers a very safe and confident environment for both patients and learners. Medical students' knowledge and confidence are reinforced through clinical skills lab work and simulation training making SBME, a valuable tool during the preclinical phase. The principles of adult active learning are reinforced and learners encounter a variety of clinical cases and rare situations. Simulation-based training integrates clinical and basic medicine. It also improves clinical outcomes, learning and training in appropriate clinical skills for medical students.[14,15]

Merits and Demerits of Medical simulation

Merits

1. Immersive and Experimental learning: The simulated events are believable enough to mentally connect the students, resulting in a unique learning experience. A high-fidelity simulator, can twinkle, inhale, talk, and make movements like an actual patient[16]. A real patient can be simulated by high-fidelity Simulators in today's world. These types of simulated scenarios are strong enough to give pupils a unique learning experience.[17].
2. Better understanding of abstract concepts: The first simulations in medical school can enhance your understanding of fundamental perceptions in medicine such as pharmacology and physiology. These replicated experiences help students appreciate intellectual ideas in basic science that are difficult to distinguish in normal conversation[18].
3. Skill acquisition and maintenance: A significant proportion of students showed better performance and management skills following simulation-based exercises than after PowerPoint lectures[19,20].
4. Student satisfaction and confidence: One of the experiments was teaching medical students how to manage resuscitation during severe shock using simulation. The pupils claimed that it increased their degree of

Table 1. Merits and Demerits of low and high-fidelity Surgical simulators

Simulator	Description	Measurement	Advantages	Disadvantages
		Low fidelity		
Bench models	Static models, such as knot tying and tissue models for practicing dissection and suturing	Direct observation	Less costly Friendly or made easy handiness	No feedback to the trainee from the model Need direct observation for assessment.
Video box trainers	Box with slits on the anterior surface for trocar insertion. make use of true surgical instruments including cameras and video screens.	Direct observation	Use real surgical instruments and equipment. Provide excellent training for laparoscopy because of sensory feedback Moderately expensive	Limited feedback Requires direct observation for a full assessment
		High fidelity		
Virtual reality stimulators	A system that provides a computer- simulated environment to practice surgical skills, consists usually of laparoscopic instruments and a desktop computer.	Performance is measured fairly and data are stored .so the learner can monitor his/her progress. The learner also can set the level of difficulty.	Objective Assessment The learner can practice at his/her own pace.	Primarily visual experience, few provide tactile information. Expensive.
Procedural stimulators	Virtual reality simulators allow the learner to learn the entire procedure.	Direct observation	Helps with basic surgical skill acquisition Enhances knowledge and recognition of anatomy and the temporal sequence of the procedure.	
Animal Models	Live animals	Direct observation	Real practice	Availability High cost Infection concerns Moral and ethical concerns

Source: Hammoud. To the point: role of simulators in surgical training. [9]

Table 2. Skills learnt through clinical skill laboratory

Diagnostic	Per rectal /vaginal exam. Abdominal/obstetrics exam visual acuity testing Documentation and certificate of trauma diagnosis.
Performance	Intramuscular, Intradermal, Intravenous, and subcutaneous injection Blood transfusion and Urinary Catheterization Basic suturing, Basic wound care and bandaging Incision and drainage of superficial abscess Basic fracture and dislocation management Eye irrigation, Instillation of eye medication, and ocular bandaging
Resuscitative	CPR in adults, children, and neonates Early management of trauma and trauma life support.
High fidelity	Advance life support

confidence in handling circumstance after a skill session [21,22].

5. Patient safety: Medical students cannot experiment on human subjects without previous practice skills. Exercise by simulation offers a safe atmosphere for training that does not endanger patients to risk by procedures accomplished by inexperienced trainees. [23].
6. Skill Training:

(a) *Rare event training:* Simulation offers educators the capacity to deliver monitored training conditions under a selection of circumstances including unusual or high-risk circumstances [24].

(b) *Classroom-based training:* Simulation-Based Medical Education is one method that allows students to understand educational uses in a classroom. This can help out them realize the notions better than understanding in crowded

hospital settings

(c) *Planning of training:* Simulator-based medical training can be scheduled with predesigned clinical confronts rather than depend on random case accessibility[25].

(d) *Team training:* Multidisciplinary team teaching and specific behavioral and interaction skills can be explained using simulated environments as it also offers educators a chance to examine participants[26].

(e) *Analysis of training:* Both students and instructors can review the instruction they received. The opportunity to review the training is unique for the organizers through the video and audio recordings of simulation circumstances.[27].

(f) *Training and retraining:* Simulation-based training permits learners to replicate processes as often as required to fix missteps and fine-tune their skills. It also permits for opinion and judgment of the act of individuals at the same level[28].

7. Assessing performance: Simulators have been also suggested as an ideal instrument for the evaluation of learners' clinical skills. This system allows the quantitative size of expertise, as well as replicates the same objective results[29].

Demerits

1. Incomplete mimicking of human system**:** Lots of data is gained from humans, not from instruments. Models and instruments can certainly not match humans entirely.
2. Defective learning: Insufficiently planned re-enactment can empower negative learning. Eg: if physical signs are missing within the re-enactment, understudies may neglect to check for these.
3. Attitude of learners: Individuals will continuously consider a simulator in an unexpected way to actual life. Two common changes in demeanor can happen: (a) hypervigilance which causes over-the-top concern since one knows an occasion is almost to happen (b) careless conduct which happens since it is certain no human life is at stake[30].
4. Cost factor: Simulators especially the high fidelity ones are offered at significant costs; both in terms of original purchase prices as well as maintenance charges. Hence, they are not reasonable for many teaching hospitals.
5. Infrastructure: An educator-to- learner proportion of 1:3–4 is perfect which isn't attainable within the current restorative educational modules where each session comprises a bunch of 10–15 medical undergraduates.
6. Technical difficulties: Some physical findings like skin color cannot be taught in simulators.
7. Programming difficulties: The simulation models have to be controlled by facilitators and simulation engineers in such a way as to reproduce a physiological reaction that may be required under specific conditions.
8. Learner-specific teaching not possible.

[31]

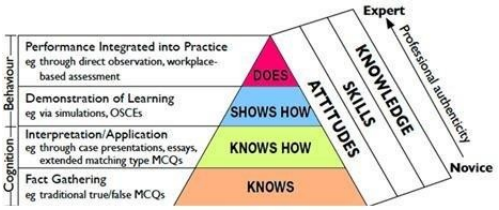

Fig 2. Millers Pyramid: The Effect of Implementing Innovative Education Strategies[31]

Miller's learning pyramid is often mentioned as a guide to explain different stages of learning and skill gain. The first two levels explain reasoning/cognitive aspects and the third fourth level refers to procedural skills. Obtaining knowledge and employing it happens under the first two levels. In the third level, the procedural skills are executed, and the skill lab training takes place on the third level of Miller's Pyramid.

Instructors may wish to present optimally circumstances according to the abilities of different learners (Advanced tasks for proficient students while basic tasks for new or slow learners). This individualized approach is not possible in simulation-based teaching. The acquisition of procedural skills from SBME doesn't carry out the learning sequence of the medical students without learning the first two levels of Millers Pyramid. Self-learning by students without understanding the first two levels can tend to travel the wrong path with incorrect procedures and clinical skills.[32,33]

Simulation vs other intervention : Technology enhanced simulation shows small, statistically significant benefit for knowledge and skills outcomes. Anesthesia review showed moderate effects for satisfaction and skills, large effect for provider behavior, small effect for direct patient benefit compared with non-simulation instruction. Negligible effects are noticed comparing simulation to alternative simulation interventions. Meta- Analysis showed inconsistencies in measurement of non-technical skills[34]. Simulation based education is probably as good as (but is not necessarily better than) other types of instruction. There is a high degree of variability between studies, suggesting that certain simulation interventions may be more effective in certain scenarios.[35,36]

Clinical studies related to skill lab training

Daniel et al., conducted a study with medical students (n 85) from 2nd and 3rd year MBBS curriculum in which

an audiovisual instruction followed by high fidelity mannequins were provided during an Adult and child CPR training session. Pretest and Post-test self-assessment questionnaires were given. Simulation-based training improves the knowledge and skill of medical students[37].

Hermann-Werner et al. (n94). organized a randomized controlled experiment among 4 group of students. One group was trained with TRAD model (Traditional See One, Do One) other group was trained with BPSL (Best Practice model). These groups were monitored every 3 and 6 months. The study found that the BPSL group was advanced to the TRAD groups for several complex skills when examined both immediately and after a follow-up period of three and six months.[38].

Al Suwaidi et al. (n84) described the influence of the simulation in acquiring clinical skills using "Kirkpatrick's Evaluation Framework. First group of students (n= 49) were offered "interactive learning tutorials" and the second group of students (n=35) were given simulation sessions to discuss the clinical vignette. After the session, the second group of students responded effectivity of the simulation session[39].

Swami et al. (n24) divided into two groups of students. One group tested each other's chests and the other group tested with their 'SimMan' model of high fidelity. The two groups then switched places and the groups switched subjects. Three tests were performed (pretest, mid- test, and post test). The study showed that knowledge and ability to perform chest exercises increased significantly, as did students' test performance and confidence levels.[40].

Conclusion

Over the year's models with Simulation machinery evolved along with medical procedures. It has gained rapid advancement in last few years beginning from part assignment trainers to highly advanced computer-guided simulators with innovative technologies. More difficult devices have come into the market and Simulation is refined to a more advanced stage[41]. It has offered its hand in clinical practice and health care deliverance, particularly in the field of patient protection and evaluation[42]. As a part of professional learning, the Skill laboratory is taking place as an integral part of the medical curriculum offering both technical and non-technical skills to medical students[43]. Medical professionals acquire knowledge and many skills such as professionalism, self-evaluation, management, communication, and teamwork through SBME. With proper learning objectives, designing the clinical skill program with efficient teaching faculty and equipment, the SBME is a boon to medical students[44].

Abbreviations

SBME: Simulation-Based Medical Education

Authors' contribution

Author 1 has reviewed the literature and prepared the manuscript. 2 gave significant contributions to revise the text and bibliography, 3, 4 & 5 significantly contributed for revising the article.

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