Narrative Review

Digitalisation of the simulation landscape - Novel solutions for simulation in low-resource settings

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ABSTRACT

Simulation-based training is an acceptable method in medical sciences. The available simulators and the conduct of simulation require both simulators and infrastructural requirements. This narrative review highlights the potential of digital tools for team-based simulation exercises in low-resource settings. This review presents a comprehensive list of affordable digital tools for scenario planning, scenario design, and assessment. It covers various applications and platforms, providing detailed insights into their features, types, and accessibility. Different low-cost digital tools are available, from generative artificial intelligence for scenario planning to online repositories of simulation cases, browser-based assessment designers, and simulation games. These digital tools can make simulation accessible, transforming it into an immersive learning experience to enhance understanding and skill acquisition.

Key words: Digital simulation, low-cost simulation, low resource settings, simulation

INTRODUCTION

Since its release in 1999, the "To Err is Human" report has steered the healthcare landscape towards a greater emphasis on patient safety.[1,2] Simulation has proven effective in enhancing and sustaining individual and team performances, thus mitigating errors. Whether honing a specific skill set for an individual practitioner or introducing an entirely new skill to a department, simulation is a valuable tool for improvement.[3] However, "simulation" is often misconceived and alluded to expensive mannikins.[4]

This narrative review aims to provide the conduct of simulation in the context of low resources.

INITIATION TO COMPETENCY

The anticipated outcome of a 3-year post-graduate training programme is the emergence of a "Competent Physician". However, the concept of competency can be further mapped to distinct facets of an individual and, by extension, even the organisation. Competencies are the knowledge, skills, and attitudes that contribute to individual and organisational performance, the three essential learning domains.[5]

- Cognitive domain – Knowledge (K): Medical, clinical, and scientific knowledge and application of evidence-based practice
- Psychomotor domain – Skills (S): Clinical, communication, critical thinking, and technical skills.

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- Affective domain – Attitudes (A): Professionalism, cultural competence, and adaptability.

While unique, these three components of competency are seldom distinct. An ideal curriculum should balance out not only teaching these competencies but also assessing them. We, however, propose an extension of these competencies to the higher-order thinking skills [Figure 1]:

- Interprofessional Team Dynamics: Collaboration, Conflict Resolution, Shared Decision-making
- Empathy: Compassion, Patient-Centred Care, Cultural Competence
- Crisis Resource Management: Situational Awareness, Adaptability, Resource Allocation, Shared Mental Model

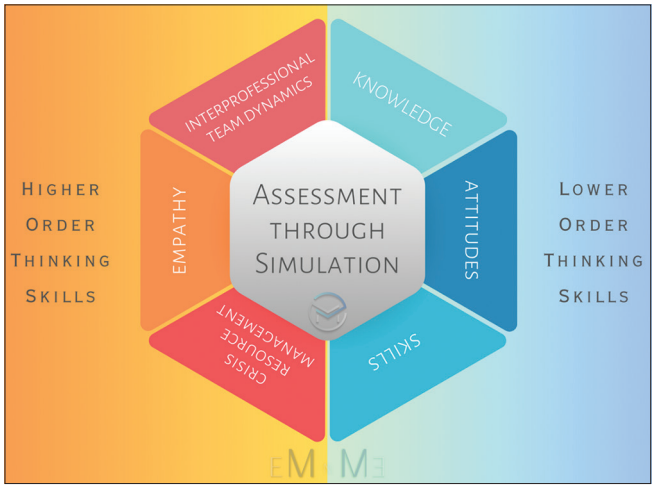

Figure 1: Extended Domains of Competence

PEDAGOGY–ANDRAGOGY–HEUTAGOGY

The success of the simulation curriculum hinges on awareness of the concepts of adult learning principles, including an understanding of pedagogy–andragogy–heutagogy [Figure 2].[6] Pedagogy is 'focused on teacher-led instruction and is for dependent personalities.' Andragogy is the 'facilitation of learning for adult self-directed learners.' Heutagogy is the 'management of learning for self-managed learners.'

Learning constitutes an internal process under the learner's control, requiring reflecting on daily experiences. Therefore, educators are not expected to merely "teach"; they facilitate learning. While pedagogical approaches rightly apply to teaching skills the learner is unconsciously incompetent of, andragogy and heutagogy are better suited to higher levels of competency-based training required by residents and fellows. With this in mind, it is also the role of the teacher to enable double-loop learning, focusing not just on results but their underlying assumptions [Figure 3].[7]

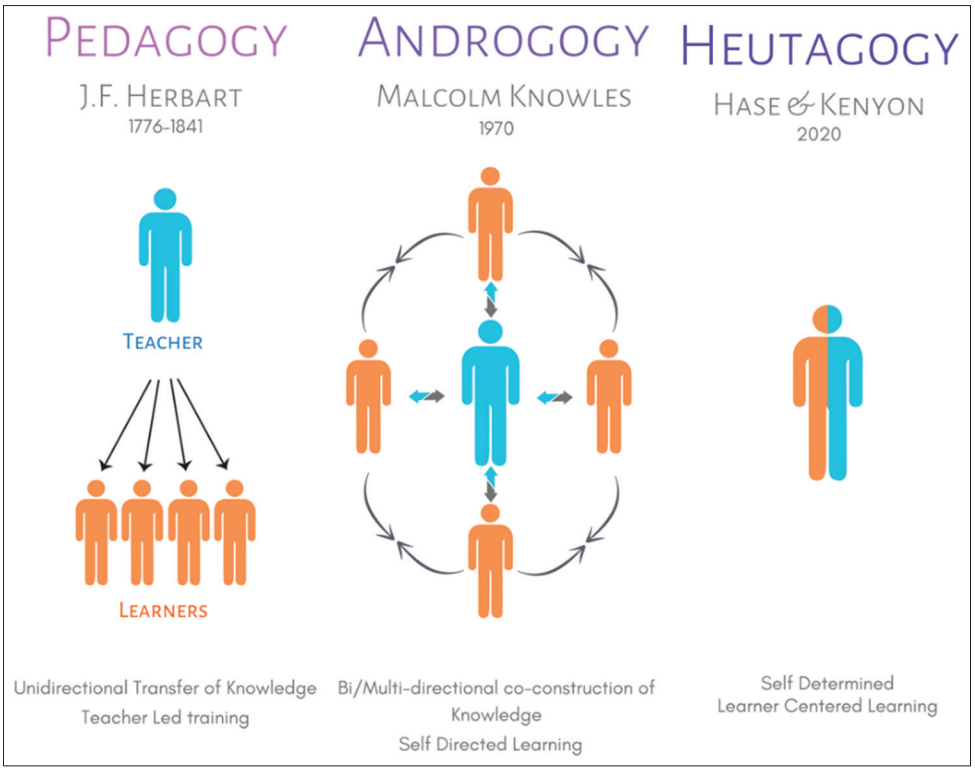

Figure 2: Adult learning principles

Planning of Scenarios

Before we delve into specific solutions, Figure 4 will illustrate a broad overview of the flow of a simulation scenario and the possible challenges the facilitator may encounter in a low-resource setting. The examples throughout the rest of the article are an extension of the solutions offered in the infographic [Figure 5].

Scenario design

Generative Artifical Intelligence (AI): Chat Generative Pre-Trained Transformer (ChatGPT) and other productive AI tools can be leveraged for medical simulation scenario planning by creating realistic and interactive scenarios that mimic various healthcare situations.[8] It is available online freely with an optional add-on subscription. Generative AI can be utilised to design and enlist 'Specific, Measurable, Attainable, Relevant, and Time-bound (SMART)' learning objectives in line with the curriculum strategies.

- Scenario Generation: Utilise ChatGPT to generate detailed medical scenarios, including patient histories, symptoms, and contextual information. This can help in creating diverse and challenging designs for simulation exercises.
- Diagnostic Challenges: Design complex diagnostic challenges using ChatGPT to create scenarios where learners must navigate a series of questions and responses to arrive at accurate diagnoses. This enhances critical thinking and decision-making skills.

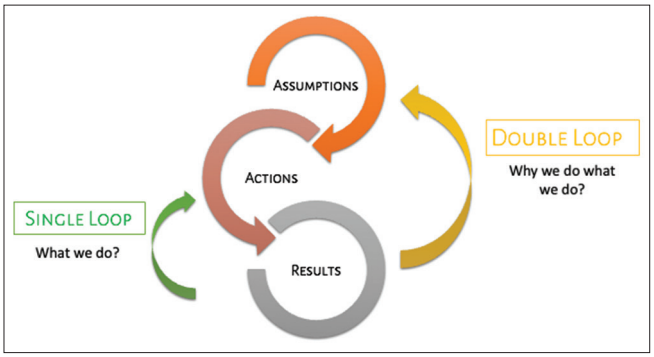

Figure 3: Double Loop learning

EM sim cases: An easily accessible online collection of peer-reviewed simulation cases tailored for Emergency Medicine programmes. The content is organised into specific medical systems, case series, and editable word templates for a do-it-yourself approach.[9] It is available freely and is browser-based.

Paediatric Emergency Medicine Resident Simulation Curriculum (EM ReSCu Peds): This complimentary e-book features 16 cases evaluated and peer-reviewed by Emergency Medicine residents. These cases cover crucial paediatric topics. Each chapter provides substantial supporting materials to assist educators

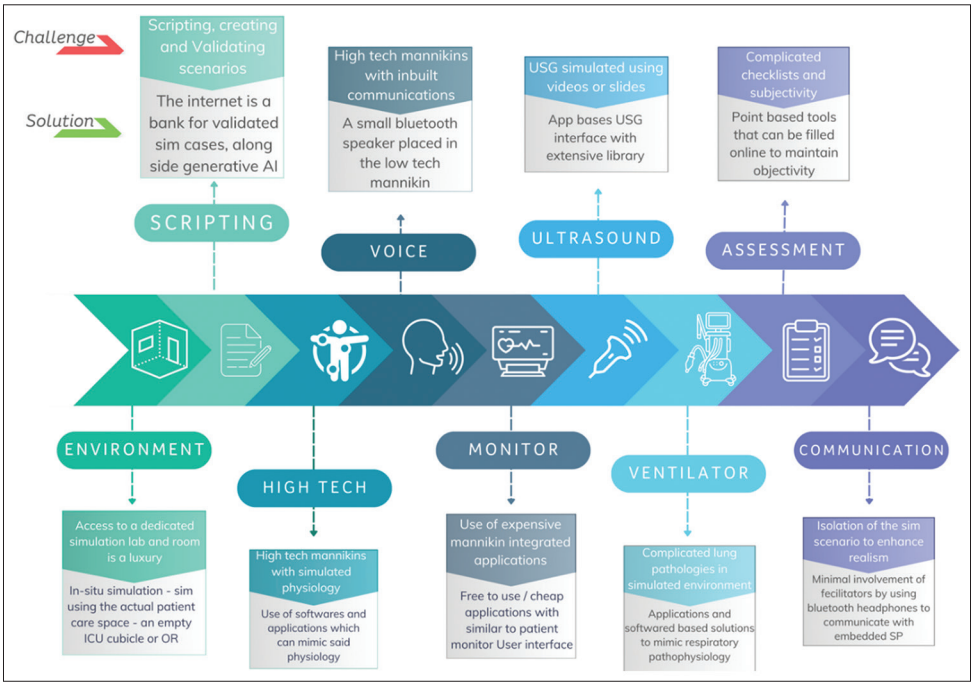

Figure 4: Challenges and solutions for simulations in low-resource settings. USG=Ultrasonography, AI= Artificial Intelligence, ICU=Intensive Care Unit, OR=Operation Room, SP=Simulated Patients

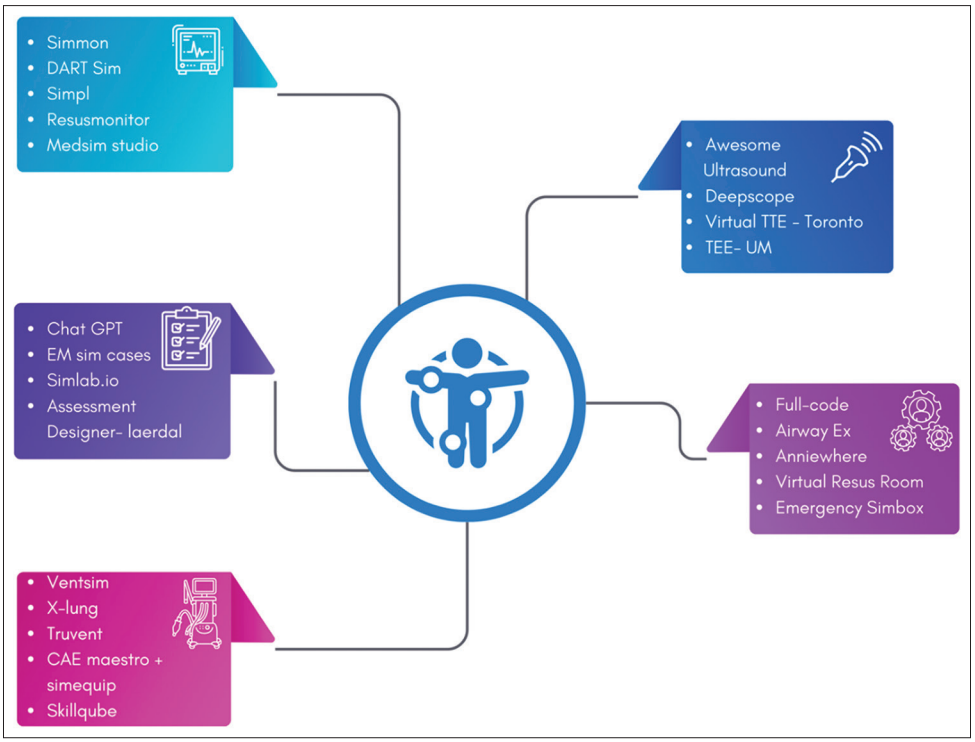

Figure 5: Ready Reckoner of Digital Simulation Tools

in planning, conducting, and debriefing cases with residents at various levels, enhancing their clinical experience.[10]

Assessment

Assessment Designer by Laerdal: This tool allows to create and score custom checklists and integrate them into sessions in the Laerdal ecosystem or download and print them.[11] The tool assigns specific scores to each criterion and creates a customised training session checklist. It is available freely and is browser-based.

Patient laboratory values

SimLab: Creating extensive lists of laboratory values for simulation cases is laborious and error-prone. Laboratory results in SimLab are generally distributed values adhering to widely accepted reference ranges or linked to other laboratory results. The trainer can generate pathological values for a wide range of diagnostic tests.[12] It is available freely and is browser-based.

Ultrasound: Training for ultrasound cases can be demanding due to the dynamics of the device. Simulations typically offer static images, such as printed copies, or verbal affirmation of the diagnosis and pathology from the simulation leader.

- Awesome Ultrasound Simulator: An ultrasound machine screen mimics that can play a wide range of ultrasonographic clips. This application integrates an interactive point-of-care ultrasound assessment into medical simulations. The two devices running the app via WiFi or Bluetooth can be linked. One device serves as a monitor, while the other is a remote held by the simulation observer. Clips of pre-loaded pathologies are activated by pressing and holding a button on the remote simultaneously with the simulated examination.[13] It is available for iOS only and is a one-time purchase.

Patient monitors

One of the underlying physiological driving forces of simulation is the patient monitor. There used to be a time when the patient monitor could only be controlled using a sophisticated yet brittle connectivity solution. Over the years, this has trickled down to multiple free browsers and app-based remote simulated patient monitors. These monitor simulators exhibit essential parameters such as heart rate, respiratory rate, oxygen saturation, blood pressure, and end-tidal carbon dioxide, along with corresponding waveforms like electrocardiography, plethysmography, and invasive blood pressure.

- ResusMonitor: The vital signs and waveforms shown can be dynamically updated in real time on a separate device, such as a computer, tablet, or phone.[14] It is a browser-based and accessible tool.

- Simpl Patient Simulator App: Establish a connection between two or more devices to execute a simulation scenario, with one device managing vital signs and the other as the monitoring tool. Notably, this device stands out by accurately simulating a defibrillator pacer console and allowing the configuration of transition times.[15] It is available for Android and iOS. It is free, with in-app purchases for the full version.
- Simmon: Like the above apps, Employ a duo of Android or iOS devices to function as a remotely controlled simulated patient monitor.[16] It is available for Android and iOS and requires a one-time purchase.
- Medsim studio: A suite with a vital sign monitor, a comprehensive library (featuring dozens of electrocardiograms, ultrasounds, computed tomography scans, X-rays, etc.), a time-stamped action log, and assessment tools.[17] It is available as a Windows application and is free.
- Vital Sign Simulator: One of the earliest free vital sign simulators, the interface facilitates automatic and manual defibrillation options, cardioversion, and pacing. It is available as a Windows application and is free.
- Defib and Rhythm Training Simulator (D.A.R.T Sim): The tool includes a virtual defibrillator and a case library that provides for pre-loaded scenarios of Advanced Cardiovascular Life Support (ACLS), Paediatric Advanced Life Support (PALS), Neonatal Resuscitation Program (NRP), paramedic and nursing programs.[18] It is available for Windows, Mac, and iOS and requires a one-time purchase.

Integration of ventilator simulation into scenarios

Remote-controlled ventilator simulators that can be fully integrated into simulated scenarios are available.

- Skillqube: An interface that integrates patient monitoring, ventilators, and assessments with a user interface that mimics actual patient monitors and ventilators.[19] Using three devices, the entirety of critical care monitoring can be simulated. The browser tool allows pre-programme scenarios for a plug-and-play experience. It is browser, Mac, and iOS-based and requires a subscription.
- Trumonitor and Truvent: A simulation interface powered through physiology can be customised as a defibrillator, patient monitor, or ventilator and adapted to Laerdal's patient monitor interface.[20] It is available for Android and iOS and requires a subscription.
- Canadian Aviation Electronics (C.A.E.) Maestro Evolve and SimEquip: A cloud-based solution that offers a full virtual simulation that includes a virtual patient and the monitoring and ventilator interface. They work together to run with or without the presence of a mannikin as C.A.E. SimEquip Anaesthesia, Defibrillator and Ventilator. This is one of the few tools that offers a virtual anaesthesia machine.[21] It is browser-based and requires a subscription.

FULL CASE SIMULATIONS

- Full Code Simulator: One of the latest additions to the gamified learning environment, this is a 3D medical simulation game with cases numbering in the hundreds. Learners can independently "play" and execute full emergency medicine scenarios. The simulator then assesses case management.[22] It is an Android and iOS-based browser and is free with in-app purchases.
- Airway Ex: A gamified learning environment that uses augmented reality to help you navigate airway instruments in a hyper-realistic virtual anatomy setting and has airway cases to manage. From administering anaesthetics to monitoring patients, performing challenging airway procedures, exploring mechanisms of action, and honing decision-making skills, it can engage in various scenarios with virtual patients.[23] It is available for Android and iOS and is free.

SKILL-SPECIFIC VIRTUAL TRAINERS

Mechanical ventilation

- Ventsim: The application uses accurate waveforms to simulate ventilation's physics and underlying physiology in-depth.[24] It manually adjusts the various parameters controlling professional and immersive simulation of interactions between patients and ventilators, altering the resulting waveforms. It is browser-based and available free.
- Xlung: This platform encompasses three tools within the Xlung Teaching and Virtual

Simulation Platform: Xlung 2.0, Physiolung, and Oxylung. Xlung 2.0 focuses on mechanical ventilation in diverse scenarios employing various ventilatory modes. Physiolung emphasises respiratory physiology, including gas exchange, respiratory mechanics, work of breathing, and acid–base balance through virtual simulation. Oxylung simulates oxygen therapy across multiple devices, explores immediate physiological effects, and enables simulation of common clinical scenarios related to respiratory failure (such as chronic obstructive pulmonary disease, asthma exacerbation, pneumonia, etc.) and metabolic disturbances.[25] It is browser-based and requires a subscription.

Ultrasound

- Trans Thoracic Echocardiography (TTE) Standard views: Developed by the Department of Anaesthesia Perioperative Interactive Education at Toronto General Hospital, the modules on this Point of Care Ultrasound (POCUS) website aim to assist users in connecting ultrasound images with the three-dimensional anatomy of the structures observed, focusing on cardiac and lung ultrasound. For each view, users have the flexibility to rotate the 3 dimensional (3D) heart model, ultrasound probe, ultrasound plane, and rib cage horizontally or vertically, enabling visualisation from any angle. Additionally, the rib cage can be removed, the upper part of the heart above the echo plane can be eliminated, and the heart model can be oriented to align with the structures seen in the transoesophageal echocardiography (TTE) image. The website also provides analogous TEE and lung ultrasound views.[26] It is browser-based and available for free.
- University of Minnesota, Minneapolis, Minnesota, Transoesophageal Echocardiography (TEE) Simulator: The TEE simulator leverages a high-resolution 3D model of the human heart and its adjacent organs. It incorporates an interactive echocardiography probe, allowing real-time manipulation for actions such as withdrawal, advancement, rotation, and flexion. Simultaneously, a 2D representation of the ultrasound image is presented alongside the 3D model, providing instant feedback on probe depth and omniplane degrees. Learners can systematically review the recommended American Society of Echocardiography (ASE) views, with corresponding 2D echocardiographic views to confirm accurate positioning. The simulator's progression guides learners from a virtual examination to a 2D image, mirroring real clinical scenarios.[27] It is browser-based and available for free.

Physiology simulator

- Harvi online: This platform is an interactive textbook and a simulation-centric environment, providing a comprehensive learning experience in cardiovascular physiology, haemodynamics, and therapeutics. Users engage with dynamic simulations that operate through waveforms and adjustable parameters, an immersive and effective educational resource extending to extracorporeal membrane oxygenation (ECMO) physics.[28] It is browser-based and requires a subscription.

VIRTUAL SIMULATION

Anniewhere: Anniewhere is an online cardiopulmonary resuscitation (CPR) training solution that empowers instructors to deliver CPR training remotely and in traditional classrooms. The application leverages the front-facing camera to track the shoulder movements of the learner, providing real-time objective feedback.[29] It is browser-based and free with in-app purchases.

Virtual Resus Room: The platform employs distinct audio and visual inputs. The visual component utilises a shared Google Slide to showcase the crucial elements of a resuscitation room. For audio communication, Zoom or any preferred teleconferencing programme is employed. Each participant and facilitator access the same slide on their computer, enabling real-time interaction. Facilitators utilise this platform to present cases and provide relevant verbal updates while team members communicate to assign roles, articulate task completion, and engage in collaborative brainstorming.[30] It is browser-based and available for free.

- Emergency Simbox: An online resource that includes YouTube videos of the patient and monitors that trend the vital signs. Based on the participants' actions, the facilitator can run, start/pause/stop/rewind the tape. The cases include common paediatric emergencies, and the scenarios can be run in either the emergency

departments or the pre-hospital setting.[31] It is browser-based and available for free.

CONCLUSIONS

The role of simulation is emerging in medical sciences. The various digital tools can make simulation accessible, transforming it into an immersive learning experience to enhance understanding and skill acquisition.

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Conflicts of interest

There are no conflicts of interest.

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