Clinical healthcare simulators

Medical simulators are increasingly being developed and deployed to teach therapeutic and diagnostic procedures as well as medical concepts and decision making to personnel in the health professions. Simulators have been developed for training procedures ranging from the basics such as blood draw, to [laparoscopic](https://en.wikipedia.org/wiki/Laparoscopic) surgery and trauma care. They are also important to help on prototyping new devices for biomedical engineering problems. Currently, simulators are applied to research and develop tools for new therapies, treatments and early diagnosis[[32]](https://en.wikipedia.org/wiki/Simulation#cite_note-32) in medicine.

Many medical simulators involve a computer connected to a plastic simulation of the relevant anatomy. Sophisticated simulators of this type employ a life-size mannequin that responds to injected drugs and can be programmed to create simulations of life-threatening emergencies. In other simulations, visual components of the procedure are reproduced by [computer graphics](https://en.wikipedia.org/wiki/Computer_graphics) techniques, while touch-based components are reproduced by [haptic](https://en.wikipedia.org/wiki/Haptic_technology) feedback devices combined with physical simulation routines computed in response to the user's actions. Medical simulations of this sort will often use 3D [CT](https://en.wikipedia.org/wiki/Computed_tomography) or [MRI](https://en.wikipedia.org/wiki/MRI) scans of patient data to enhance realism. Some medical simulations are developed to be widely distributed (such as web-enabled simulations[[33]](https://en.wikipedia.org/wiki/Simulation#cite_note-33) and procedural simulations[[34]](https://en.wikipedia.org/wiki/Simulation#cite_note-34) that can be viewed via standard web browsers) and can be interacted with using standard computer interfaces, such as the [keyboard](https://en.wikipedia.org/wiki/Computer_keyboard) and [mouse](https://en.wikipedia.org/wiki/Computer_mouse).

Another important medical application of a simulator—although, perhaps, denoting a slightly different meaning of *simulator*—is the use of a [placebo](https://en.wikipedia.org/wiki/Placebo) drug, a formulation that simulates the active drug in trials of drug efficacy.

**Improving patient safety**

Patient safety is a concern in the medical industry. Patients have been known to suffer injuries and even death due to management error, and lack of using best standards of care and training. According to Building a National Agenda for Simulation-Based Medical Education (Eder-Van Hook, Jackie, 2004), "a health care provider's ability to react prudently in an unexpected situation is one of the most critical factors in creating a positive outcome in medical emergency, regardless of whether it occurs on the battlefield, freeway, or hospital emergency room." Eder-Van Hook (2004) also noted that medical errors kill up to 98,000 with an estimated cost between $37 and $50 million and $17 to $29 billion for preventable adverse events dollars per year.

Simulation is being used to study patient safety, as well as train medical professionals.[[35]](https://en.wikipedia.org/wiki/Simulation#cite_note-:0-35) Studying patient safety and safety interventions in healthcare is challenging, because there is a lack of experimental control (i.e., patient complexity, system/process variances) to see if an intervention made a meaningful difference (Groves & Manges, 2017).[[36]](https://en.wikipedia.org/wiki/Simulation#cite_note-36) An example of innovative simulation to study patient safety is from nursing research. Groves et al. (2016) used a high-fidelity simulation to examine nursing safety-oriented behaviors during times such as [change-of-shift report](https://en.wikipedia.org/wiki/Change-of-shift_report).[[35]](https://en.wikipedia.org/wiki/Simulation#cite_note-:0-35)

However, the value of simulation interventions to translating to clinical practice are is still debatable.[[37]](https://en.wikipedia.org/wiki/Simulation#cite_note-:1-37) As Nishisaki states, "there is good evidence that simulation training improves provider and team self-efficacy and competence on manikins. There is also good evidence that procedural simulation improves actual operational performance in clinical settings." However, there is a need to have improved evidence to show that [crew resource management](https://en.wikipedia.org/wiki/Crew_resource_management) training through simulation. One of the largest challenges is showing that team simulation improves team operational performance at the bedside.[[38]](https://en.wikipedia.org/wiki/Simulation#cite_note-:2-38) Although evidence that simulation-based training actually improves patient outcome has been slow to accrue, today the ability of simulation to provide hands-on experience that translates to the operating room is no longer in doubt.[[39]](https://en.wikipedia.org/wiki/Simulation#cite_note-39)[[40]](https://en.wikipedia.org/wiki/Simulation#cite_note-40)[[41]](https://en.wikipedia.org/wiki/Simulation#cite_note-41)

One of the largest factors that might impact the ability to have training impact the work of practitioners at the bedside is the ability to empower frontline staff (Stewart, Manges, Ward, 2015).[[38]](https://en.wikipedia.org/wiki/Simulation#cite_note-:2-38)[[42]](https://en.wikipedia.org/wiki/Simulation#cite_note-42) Another example of an attempt to improve patient safety through the use of simulations training is patient care to deliver just-in-time service or/and just-in-place. This training consists of 20  minutes of simulated training just before workers report to shift. One study found that just in time training improved the transition to the bedside. The conclusion as reported in Nishisaki (2008) work, was that the simulation training improved resident participation in real cases; but did not sacrifice the quality of service. It could be therefore hypothesized that by increasing the number of highly trained residents through the use of simulation training, that the simulation training does, in fact, increase patient safety.

**History of simulation in healthcare**

The first medical simulators were simple models of human patients.

Since antiquity, these representations in clay and stone were used to demonstrate clinical features of disease states and their effects on humans. Models have been found in many cultures and continents. These models have been used in some cultures (e.g., Chinese culture) as a "[diagnostic](https://en.wikipedia.org/wiki/Medical_diagnosis)" instrument, allowing women to consult male physicians while maintaining social laws of modesty. Models are used today to help students learn the [anatomy](https://en.wikipedia.org/wiki/Anatomy) of the [musculoskeletal](https://en.wikipedia.org/wiki/Musculoskeletal) system and organ systems.

In 2002, the [Society for Simulation in Healthcare](https://en.wikipedia.org/wiki/Society_for_Simulation_in_Healthcare) (SSH) was formed to become a leader in international interprofessional advances the application of medical simulation in healthcare.

The need for a "uniform mechanism to educate, evaluate, and certify simulation instructors for the health care profession" was recognized by McGaghie et al. in their critical review of simulation-based medical education research. In 2012 the SSH piloted two new certifications to provide recognition to educators in an effort to meet this need.

**Type of models**

**Active models**

Active models that attempt to reproduce living anatomy or physiology are recent developments. The famous ["Harvey" mannequin](https://en.wikipedia.org/wiki/%22Harvey%22_mannequin) was developed at the [University of Miami](https://en.wikipedia.org/wiki/University_of_Miami) and is able to recreate many of the physical findings of the [cardiology](https://en.wikipedia.org/wiki/Cardiology) examination, including [palpation](https://en.wikipedia.org/wiki/Palpation), [auscultation](https://en.wikipedia.org/wiki/Auscultation), and [electrocardiography](https://en.wikipedia.org/wiki/Electrocardiography).

**Interactive models**

More recently, interactive models have been developed that respond to actions taken by a student or physician. Until recently, these simulations were two dimensional computer programs that acted more like a textbook than a patient. Computer simulations have the advantage of allowing a student to make judgments, and also to make errors. The process of iterative learning through assessment, evaluation, decision making, and error correction creates a much stronger learning environment than passive instruction.

**Computer simulators**

Simulators have been proposed as an ideal tool for assessment of students for clinical skills. For patients, "cybertherapy" can be used for sessions simulating traumatic experiences, from fear of heights to social anxiety.[[49]](https://en.wikipedia.org/wiki/Simulation#cite_note-49)

Programmed patients and simulated clinical situations, including mock disaster drills, have been used extensively for education and evaluation. These "lifelike" simulations are expensive, and lack reproducibility. A fully functional "3Di" simulator would be the most specific tool available for teaching and measurement of clinical skills. [Gaming platforms](https://en.wikipedia.org/wiki/Game_engine) have been applied to create these virtual medical environments to create an interactive method for learning and application of information in a clinical context.[[50]](https://en.wikipedia.org/wiki/Simulation#cite_note-DukeMag-50)[[51]](https://en.wikipedia.org/wiki/Simulation#cite_note-SteinbergCNN-51)

Immersive disease state simulations allow a doctor or HCP to experience what a disease actually feels like. Using sensors and transducers symptomatic effects can be delivered to a participant allowing them to experience the patients disease state.

Such a simulator meets the goals of an objective and standardized examination for clinical competence.[[52]](https://en.wikipedia.org/wiki/Simulation#cite_note-pmid18402731-52) This system is superior to examinations that use "[standard patients](https://en.wikipedia.org/wiki/Simulated_patient)" because it permits the quantitative measurement of competence, as well as reproducing the same objective findings.[[53]](https://en.wikipedia.org/wiki/Simulation#cite_note-pmid18462603-53)

Simulation in entertainment

Simulation in entertainment encompasses many large and popular industries such as [film](https://en.wikipedia.org/wiki/Film), [television](https://en.wikipedia.org/wiki/Television), [video games](https://en.wikipedia.org/wiki/Video_game) (including [serious games](https://en.wikipedia.org/wiki/Serious_game)) and rides in theme parks. Although modern simulation is thought to have its roots in training and the military, in the 20th century it also became a conduit for enterprises which were more hedonistic in nature.

**History of visual simulation in film and games**

**Early history (1940s and 1950s)**

The first simulation game may have been created as early as 1947 by Thomas T. Goldsmith Jr. and Estle Ray Mann. This was a straightforward game that simulated a missile being fired at a target. The curve of the missile and its speed could be adjusted using several knobs. In 1958, a computer game called "[*Tennis for Two*](https://en.wikipedia.org/wiki/Tennis_for_Two)" was created by Willy Higginbotham which simulated a tennis game between two players who could both play at the same time using hand controls and was displayed on an oscilloscope.[[54]](https://en.wikipedia.org/wiki/Simulation#cite_note-54) This was one of the first electronic video games to use a graphical display.

**1970s and early 1980s**

[Computer-generated imagery](https://en.wikipedia.org/wiki/Computer-generated_imagery) was used in the film to simulate objects as early as 1972 in the [A Computer Animated Hand](https://en.wikipedia.org/wiki/A_Computer_Animated_Hand), parts of which were shown on the big screen in the 1976 film [Futureworld](https://en.wikipedia.org/wiki/Futureworld). Many will remember the *"targeting computer"* that young Skywalker turns off in the 1977 film [*Star Wars*](https://en.wikipedia.org/wiki/Star_Wars_(film)).

The film [*Tron*](https://en.wikipedia.org/wiki/Tron) (1982) was the first film to use computer-generated imagery for more than a couple of minutes.

Advances in technology in the 1980s caused 3D simulation to become more widely used and it began to appear in movies and in computer-based games such as Atari's [*Battlezone*](https://en.wikipedia.org/wiki/Battlezone_(1980_video_game)) (1980) and [Acornsoft](https://en.wikipedia.org/wiki/Acornsoft)'s [*Elite*](https://en.wikipedia.org/wiki/Elite_(video_game)) (1984), one of the first [wire-frame 3D graphics games](https://en.wikipedia.org/wiki/Wire-frame_model) for [home computers](https://en.wikipedia.org/wiki/Home_computer).

**Pre-virtual cinematography era (early 1980s to 1990s)**

Advances in technology in the 1980s made the computer more affordable and more capable than they were in previous decades,[[56]](https://en.wikipedia.org/wiki/Simulation#cite_note-56) which facilitated the rise of computer such as the Xbox gaming. The first [video game consoles](https://en.wikipedia.org/wiki/Video_game_console) released in the 1970s and early 1980s fell prey to the [industry crash](https://en.wikipedia.org/wiki/North_American_video_game_crash_of_1983) in 1983, but in 1985, [Nintendo](https://en.wikipedia.org/wiki/Nintendo) released the Nintendo Entertainment System (NES) which became one of the best selling consoles in video game history.[[57]](https://en.wikipedia.org/wiki/Simulation#cite_note-57) In the 1990s, computer games became widely popular with the release of such game as [*The Sims*](https://en.wikipedia.org/wiki/The_Sims) and [*Command & Conquer*](https://en.wikipedia.org/wiki/Command_%26_Conquer) and the still increasing power of desktop computers. Today, computer simulation games such as [*World of Warcraft*](https://en.wikipedia.org/wiki/World_of_Warcraft) are played by millions of people around the world.

In 1993, the film [*Jurassic Park*](https://en.wikipedia.org/wiki/Jurassic_Park_(film)) became the first popular film to use computer-generated graphics extensively, integrating the simulated dinosaurs almost seamlessly into live action scenes.

This event transformed the film industry; in 1995, the film [*Toy Story*](https://en.wikipedia.org/wiki/Toy_Story) was the first film to use only computer-generated images and by the new millennium computer generated graphics were the leading choice for special effects in films.[[58]](https://en.wikipedia.org/wiki/Simulation#cite_note-58)

**Virtual cinematography (early 2000s–present)**

The advent of [virtual cinematography](https://en.wikipedia.org/wiki/Virtual_cinematography) in the early [2000s (decade)](https://en.wikipedia.org/wiki/2000s_(decade)) has led to an explosion of movies that would have been impossible to shoot without it. Classic examples are the [digital look-alikes](https://en.wikipedia.org/wiki/Virtual_actor) of Neo, Smith and other characters in the [Matrix sequels](https://en.wikipedia.org/wiki/The_Matrix_(franchise)) and the extensive use of physically impossible camera runs in [The Lord of the Rings (film series)](https://en.wikipedia.org/wiki/The_Lord_of_the_Rings_(film_series)) trilogy.

The terminal in the [Pan Am (TV series)](https://en.wikipedia.org/wiki/Pan_Am_(TV_series)) no longer existed during the filming of this 2011–2012 aired series, which was no problem as they created it in virtual cinematography utilizing [automated](https://en.wikipedia.org/wiki/Automation) [viewpoint](https://en.wikipedia.org/wiki/Camera_angle) finding and matching in conjunction with compositing real and simulated footage, which has been the bread and butter of the [movie](https://en.wikipedia.org/wiki/Film) [artist](https://en.wikipedia.org/wiki/Artist) in and around [film studios](https://en.wikipedia.org/wiki/Film_studio) since the early 2000s.

[Computer-generated imagery](https://en.wikipedia.org/wiki/Computer-generated_imagery) is "the application of the field of 3D computer graphics to special effects". This technology is used for visual effects because they are high in quality, controllable, and can create effects that would not be feasible using any other technology either because of cost, resources or safety.[[59]](https://en.wikipedia.org/wiki/Simulation#cite_note-59) Computer-generated graphics can be seen in many live-action movies today, especially those of the action genre. Further, computer-generated imagery has almost completely supplanted hand-drawn animation in children's movies which are increasingly computer-generated only. Examples of movies that use computer-generated imagery include [*Finding Nemo*](https://en.wikipedia.org/wiki/Finding_Nemo), [*300*](https://en.wikipedia.org/wiki/300_(film)) and [*Iron Man*](https://en.wikipedia.org/wiki/Iron_Man_(2008_film)).

**Examples of non-film entertainment simulation**

**Simulation games**

[Simulation games](https://en.wikipedia.org/wiki/Simulation_games), as opposed to other genres of video and computer games, represent or simulate an environment accurately. Moreover, they represent the interactions between the playable characters and the environment realistically. These kinds of games are usually more complex in terms of gameplay. Simulation games have become incredibly popular among people of all ages. Popular simulation games include [*SimCity*](https://en.wikipedia.org/wiki/SimCity) and [*Tiger Woods PGA Tour*](https://en.wikipedia.org/wiki/Tiger_Woods_PGA_Tour). There are also [flight simulator](https://en.wikipedia.org/wiki/Flight_simulator) and [driving simulator](https://en.wikipedia.org/wiki/Driving_simulator) games.

**Theme park rides**

Simulators have been used for entertainment since the [Link Trainer](https://en.wikipedia.org/wiki/Link_Trainer) in the 1930s. The first modern simulator ride to open at a theme park was Disney's [Star Tours](https://en.wikipedia.org/wiki/Star_Tours) in 1987 soon followed by Universal's [The Funtastic World of Hanna-Barbera](https://en.wikipedia.org/wiki/The_Funtastic_World_of_Hanna-Barbera_(ride)) in 1990 which was the first ride to be done entirely with computer graphics.[[63]](https://en.wikipedia.org/wiki/Simulation#cite_note-trudang.com-63)

Simulator rides are the progeny of military training simulators and commercial simulators, but they are different in a fundamental way. While military training simulators react realistically to the input of the trainee in real time, ride simulators only feel like they move realistically and move according to prerecorded motion scripts.[[63]](https://en.wikipedia.org/wiki/Simulation#cite_note-trudang.com-63) One of the first simulator rides, Star Tours, which cost $32 million, used a hydraulic motion based cabin. The movement was programmed by a joystick. Today's simulator rides, such as [The Amazing Adventures of Spider-Man](https://en.wikipedia.org/wiki/The_Amazing_Adventures_of_Spider-Man) include elements to increase the amount of immersion experienced by the riders such as: 3D imagery, physical effects (spraying water or producing scents), and movement through an environment.

Simulation and manufacturing

Manufacturing represents one of the most important applications of simulation. This technique represents a valuable tool used by engineers when evaluating the effect of capital investment in equipment and physical facilities like factory plants, warehouses, and distribution centers. Simulation can be used to predict the performance of an existing or planned system and to compare alternative solutions for a particular design problem

Another important goal of [Simulation in Manufacturing Systems](https://en.wikipedia.org/wiki/Simulation_in_Manufacturing_Systems) is to quantify system performance. Common measures of system performance include the following:[[66]](https://en.wikipedia.org/wiki/Simulation#cite_note-66)

* Throughput under average and peak loads;
* System cycle time (how long it takes to produce one part);
* Utilization of resource, labor, and machines;
* Bottlenecks and choke points;
* Queuing at work locations;
* Queuing and delays caused by material-handling devices and systems;
* WIP storages needs;
* Staffing requirements;
* Effectiveness of scheduling systems;
* Effectiveness of control systems.