Master Thesis

Maslow's Hierarchy of Needs Theory as Applied to Medical Education in Virtual Reality

Do students dream of electric patients?

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1. Summary

The present master thesis discusses application of virtual simulators in medical education. The issues of terminology, their design, construction and classification, advantages, and disadvantages of medical training in a virtual environment are considered. The paper presents the following original concepts:

- An original classification of virtual reality medical simulators is formulated.
- The advantages and disadvantages of virtual simulators are summarized.
- Maslow's Theory of Hierarchy of Needs is applied to both medical education in general and virtual reality training in particular; possibility of meeting student's needs in a virtual environment are considered from the point of view of Maslow's motivation theory.
- The possibility of the virtual systems to perform functionality of 12 medical teachers' roles (according to Ronald Harden) and potential substitution of medical teachers by virtual systems in some of these roles are considered.
- The requirements for the architecture of virtual reality medical education systems are formulated.

This paper is addressed both to educators who use virtual simulation technologies in medical education, as well as to designers, developers, and manufacturers of virtual medical didactic systems.

2. Introduction

2.1. Status quo

Computers and digital technologies have interfered and penetrated human everyday life extensively. Along with the familiar physical environment we do observe interaction with digital objects, virtual phenomena and entire worlds appeared to be kind of mixed reality. Nowadays, the Virtual Reality Simulation (further referred as VRS) is actively used in medical education as well. Simulators are presented in a wide variety of models and versions, differing significantly from each other in design, functionality, dedicated educational tasks, clinical outcomes and the cost of acquisition and operation.

Medical education and skills training of personnel with the help of virtual techniques has both positive and negative sides, but overall, it is a very promising, perspective, and inevitable development. The usage of the virtual simulation technologies for the practical skills gaining and assimilation of theoretical base of preclinical and clinical disciplines with medical manipulations training increases constantly. The more complex the training task posed, the higher the level of VRS should be in the device used to mimic it effectively. Examples of such training become more numerous every year, getting their practical embodiment in an ever-growing number of training programs and courses implemented on virtual simulation devices.

Virtual simulators have been used in medical education for more than twenty years. Thus, the first encouraging data on the effectiveness of screen-based simulators were obtained by a group of researchers from the University of Washington [Schwind HA, 2001] – according to the PubMed Search under the keywords: ("screen"[Title]) AND ("simulator"[Title]). The paper "Screen-based anesthesia simulation with debriefing improves performance in a mannequin-based anesthesia simulator" convincingly demonstrated the superiority of a group trained in 10 anesthetic emergencies using the screen-based anesthesia simulator program and received written feedback on their management, whereas the traditional (control) group was asked to study a handout covering the same 10 emergencies. All residents then were evaluated on their management of 4 standardized scenarios in a mannequin-based simulator using a quantitative scoring system. The average point score for the simulator-with-debriefing group was 52.6 +/- 9.9 out of 95 possible points. The traditional group average point score was 43.4 +/- 5.9, p = .004. Thus, residents who managed anesthetic problems using a screen-based anesthesia simulator handled the emergencies in a mannequin-based anesthesia simulator better than residents who were asked to study a handout covering the same problems. So, authors considered that "computer simulations with feedback are effective as a supplement to traditional residency training methods for the management of medical emergencies".

Virtual models are applied in the testing and examinations, including high-stake ones. Over 50,000 USMLE[1] Step 3 examinations using Computer-based Case Simulations (CCSs) were

[1] USMLE (The United States Medical Licensing Examination) is a three-step examination program for medical licensure in the USA done by all graduates of American and international medical schools

fulfilled within two years in the USA twenty years ago [Dillon et al, 2002]. Piloting testing with interactive simulation of patient cases (ISP) presented at the computer screen was described in Europe by authors from Karolinska Institute [Bergin and Fors, 2003].

Nevertheless, despite the exponentially growth of research confirming overwhelming benefits of virtual simulators in medical education and the noticeable progress and improvement in technology, now we cannot speak of their considerable usage in this field. Despite the obvious and undeniable benefits of virtual learning and teaching methods, their use in medical education was relatively limited until 2020, when the coronavirus pandemic broke out, and the application of digital technologies in medical education began to grow exponentially, like an explosion—rapid expansion and a relatively quick return to the status quo almost. Will digitalization in medical education remain at a precedent level as the epidemiological threat abates? Is learning virtualization a natural process or is it a temporary phenomenon dictated by medical precaution rules only and it will fall to pre-pandemic levels?

2.2. Aims

This present master thesis intents to provide an overview of virtual (digital, IT-based) educational systems from the perspective of Maslow's hierarchy of needs and to confirm our hypothesis that virtual technologies are able to address every human need across all the hierarchy levels.

Aims of the present master thesis are to discuss and answer the following questions:

- What are advantages and disadvantages of medical training in a virtual environment
- Are those disadvantages systemic, critical, and unavoidable?
- Can Maslow's Theory of hierarchy of needs be applied to medical education as a long-term habitat system of students?
- Can Maslow's Theory of hierarchy of needs be applied to medical education and skills training in virtual reality?
- Is it possible to meet student's needs in virtual reality systems applied to medical education as considered from the point of view of Maslow's Theory?

- Are virtual systems capable to intercept "12 medical teachers' roles" (according to Ronald Harden) from humans providing similar or higher functionality with a future potential to substitute humans in some of these roles, partially or completely?
- If this is possible, what can be the requirements for the architecture of medical virtual reality simulators?

2.3. Research value

Numerous VR simulators used in healthcare training have proven themselves well for more than several decades. This is especially true of practical manipulations in angiography, endoscopy, laparoscopy, urology, eye and neurosurgery. Virtual patients serve not only to practice diagnostics, treatment, and clinical decisions, but can also be used to assess competencies both at graduate exams and by hiring medical staff. However, in general, the overall picture is that such devices are not used as widely as they could. In 2020, during the coronavirus pandemic, there was a surge in remote and virtual technologies, but it was followed by a certain decrease in the share of use of these devices and methods. Students are frustrated with the replacement of real education with a virtual approach. Also, many teachers are not very willing to introduce them into the educational process. That is, these systems are somewhat worse than physical reality, some of their properties, parameters do not suit teachers and students, although their high didactic effectiveness has been proven by numerous studies.

What's wrong? Maybe they lack some functions or properties? Even simulators that have passed deep validation do not meet some essential requirements. We believe that virtual simulation systems should be tailored to meet all human needs, but is it possible? If yes, to what extent?

We need to consider these possibilities and, if so, rethink the necessary features of virtual reality systems. This understanding will help educators evaluate the systems they already use or plan to implement, and developers to view their creation in terms of a wide range of human needs. And if the creators of medical virtual learning platforms manage to combine functions that satisfy the basic needs of students with components aimed at meeting the needs of higher levels, then the widespread distribution of these systems in medical education will be inevitable and will only be a matter of a short period of time.

If the results of such extrapolation are positive, and our hypothesis about the ability of the virtual environment to satisfy all needs turns out to be feasible, then we can talk about the "natural" viability of virtual learning technologies and, therefore, the inevitable future integration of the virtual environment into the medical education as virtual learning technologies are gradually developed further.

2.4. Novelty

The concept of hierarchy of human needs was developed by the American psychologist Abraham Maslow in the middle of the 20th century and today is considered as one of the cornerstone theories in modern psychology. Many experts in various fields of human activity – from marketing to architecture – develop behavioral models based on Maslow's Pyramid. However, to our knowledge, consideration of medical education in virtual reality from the point of view of Maslow's theory is not described in the special medical literature. So, a search was conducted in the PubMed database of medical literature for the following search queries (in all fields):

- ((maslow) AND (virtual)) AND (simulator)
- ((maslow) AND (virtual)) AND (patient)
- ((maslow) AND (virtual)) AND (education)

The first query did not bring any results. There was one result for the second search, which however was addressed to the motivation of the patient participated in the clinical trials, not to medical education in VR [Thijs van Iersel, 2022]. And there are 2 results for ((maslow) AND (medical)) AND (education) even though one result was excluded while "Maslow" was a namesake author and another result: "What motivates medical students to select medical studies: a systematic literature review" done in 2018 by Sonu Goel et al. was addressed to student's choice of medical profession and was not related to VR simulation.

There were obtained three results in the Web of Science (maslow AND virtual AND patient) (query link: https://www.webofscience.com/wos/woscc/summary/50b8bb6d-f129-4161-a9f5-628e7f8b50dc-5521ed39/relevance/1), however two of them were dedicated to application of Maslow hierarchy in patient care (one of them was mentioned above) and the last remaining one described the understanding the motivators affecting doctors' contributions in online healthcare communities in the professional status as a moderator [Yang, HL et al. 2019], so, irrelevant for the current topic.

Searching in OVID under the same criteria did not bring any results.

3. Virtual Reality Simulators in medical education

3.1. Terminology

Due to the variety of virtual simulators available, and they differ from each other by design, application and learning objectives, it is necessary to discuss basic terms, concepts and propose a classification of VRS used in medical training.

The second edition of the *Healthcare Simulation Dictionary* issued by The Society for Simulation in Healthcare (SSH) in September 2020 gives several definitions of virtual simulators:

- The recreation of reality depicted on a computer screen [McGovern, 1994];
- A simulation involving real people operating simulated systems. Virtual simulations may include surgical simulators that are used for on-screen procedural training and are usually integrated with haptic device(s) [McGovern, 1994; Robles-De La Torre, 2011];
- A type of simulation that injects humans in a central role by exercising motor control skills (for example, flying an airplane), decision skills (committing fire control resources to action), or communication skills (as members of an air traffic control team) [Hancock et al, 2008].

As one can see, some of the above-mentioned definitions are outdated and the others can't be named "definition", they are rather descriptive narratives. All they were formulated quite a long time ago and thus may not correlate to today's rapid developing realities. It is therefore necessary to give up-to-dated clear definitions of the terms used in the field of medical virtual simulation.

To better understand the connotation of the word *virtual*, one need to trace its etymological trajectory – what historical roots and meanings the term had. It all started from antique latin "*vir*" that had a meaning "a man" with further derivative "*virtus*" – "*strength, valor, ability*, *quality*". Then, in the Middle Ages professors and scholars started to use "*virtualis*" in the meaning of "*possible (admissible), capable"*. Thus, coming to spoken French of the 15th century the word "*virtuel*" completely lost its component of power and has shifted into the elucidation of "*invented, non-existent*" with consequent travel to English language as "*imaginary, fictitious, unreal*". This transformation remained unchanged till 1980s when scientists and fictionists brought second (sic!) interpretation as "*computer-based, created with the help of computer technology and not existing in the real world*".

Therefore, in the modern English the term "v*irtual"* (beside of the meaning similar to *value*) refers also to a subject, object, or process that does not exist physically but is reproduced using computing technology.

Virtual reality is a digitally generated model of an environment where user can interact with its components producing and observing changes caused to this model.

Medical Virtual Reality Simulator is a hardware and software system that simulates medical environments, subjects, objects, and processes through computing technologies in virtual environment, interacts with users and responds to their actions in order to facilitate health care training, assessment, and experimentation.

General term "*Virtual Reality Simulator (VRS)"* is used for a wide group of systems – digitalized devices consisting of the application (software part) working on the microprocessor and of peripheral user's interface (hardware part) – simulating interaction of the doctor, his/her hands or medical instruments and devises with a patient or his/her organs or modelling other clinical processes. The VR simulators are designed for gaining variety of skills like clinical reasoning, communication with patient or medical team members, practicing a particular skill, manipulation as well as objective assessment of acquired level. This group combines rather versatile systems – from screen simulations to the VRS for practicing of the medical manipulations and skills in virtual reality (e.g. LapSim®[2] laparoscopic simulator with haptic feedback devices, by Surgical Science, Sweden).

Virtual Trainer or *Virtual Skills Trainer* is a less common term indicating a specific group of the VR simulators, usually refers to devices for the "training", "deliberate practice" – distributed and frequently repeated performance of certain actions, exercises, manipulations – in order to gain a consistent practical manipulative skill.

Screen simulation is a common term denoting various types of simulation displayed on screen and interacted via standard user's interface (keyboard, mouse, touchscreen). Even though the first articles on the computer simulators were published by the end of XXth Century [Christensen UJ, 1997; Bosse G, 1997] the term itself is relatively young, it was first mentioned in PubMed at 2001 [Schwid HA, et al, 2017] and its usage declines gradually.

Virtual Patient – a subset of virtual simulators representing a computer model of a subject and his/her pathological status, including visual signs, physiology parameters, lab results, etc. – designed to teach communication, diagnosis, treatment, and other clinical reasoning decisions, as well as objective assessment of these skills.

At the same time, it should be clarified that the word "*virtual*" has become extremely popular, and its meaning is so vague that in some cases it is used inaccurately. So, in recent years, the term *vOSCE* (*VOSCE, virtual OSCE*) has become widespread, which means the remote conduct of an Objective Structured Clinical Exam, in which the examinee and the standardized patient communicate to each other online via video link. For example, educators from the School of Medicine, Dentistry and Nursing, University of Glasgow described the VOSCE as follows: "We conceived, developed and then successfully implemented a novel Virtual Objective Structured Clinical Examination (VOSCE) using videotelephony through a cloud-based peer- to-peer software platform *Zoom*[3] [Boyle et al, 2020]. A similar meaning is attached to the concept of

[2] LapSim is a trademark of Surgical Science, Gothenburg, Sweden
[3] ZOOM is a Trademark of Zoom Video Communications Inc., San Jose, CA, USA

"virtual OSCE" by dozens of other authors (Craig et al, 2020; Pante et al, 2020; Donn et al, 2022 and many more).

This type of remote OSCE conducting, where the examinee and the SP are at a considerable distance from each other, has been used for more than twenty years [Lentz et al, 1999; Novack et al, 2002]. Since the same technical Internet solutions were used for its implementation as for telemedicine ("via a teleconferencing program designed for the World-Wide Web"), at the dawn of its development, this method of conducting the exam was called teleOSCE or webOSCE, but over time, the majority leaned towards another option – the term vOSCE. Today, these OSCE-teleconferences are regularly referred to as "Virtual OSCEs", which, in our opinion, is terminologically inaccurate. In the modern life not a single process of information transfer can do without computers – whether it can be a transmission via telephone, fax, radio- or TV-broadcasting, internet or satellite communications – they all are operated under the control of computers, and all can be attributed to the field of digital technologies. However, as before, all data transfer options are denoted by familiar terms, and our counterpart, despite the use of applications such as Skype[4], Zoom or WhatsApp[5], is perceived by us as a real interlocutor, and not a virtual character.

In the same time and as long time ago – for more than twenty years – a methodology for using virtual, digital models in the OSCE was described in literature. Those virtual models were presented at the computer screen and could be based both locally as well as can be placed on a remote computer – in other campus or in the cloud. In November 1999 the virtual clinical cases were introduced at USMLE Step 3 examination [Dillon et al, 2002] where those types of OSCE were referred to as "Computer-based Case Simulations (CCSs)". The first two years of computer-based testing for USMLE Step 3 have been completed without significant incident. Approximately 50,000 examinations were administered and, except for some delay at startup, there were no large-scale problems or disruptions in examinee testing or scoring – reported authors.

4 Skype is a trademark of Microsoft Corp., Redmond, WA, USA
5 WhatsApp is a trademark of Meta Platforms Inc., Menlo Park, CA, USA

European advanced learning system for interactive simulation of patient cases (ISP) was described by authors from Karolinska Institute [Bergin and Fors, 2003]. The system had a video based illness history-taking function using free text input, highly interactive physiological examination procedures, extensive laboratory tests and detailed user feedback. Students of different semesters (n=70) participated in computer-based simulations of the patient encounter, with the emphasis on learning to solve general medical problems at three research test trials within 1999-2001 years.

And last but not least, in step with the times, as technologies develop and change, screen simulators are replaced by immersion technologies of virtual and virtual-augmented reality. Thus, as an example of mixed reality technologies can be mentioned usage of HoloLens2[6] to conduct and augment of Objective Structured Clinical Examinations at Imperial College London [Minty et al, 2022].

How should such methods be called, where virtual characters act as the object of examination, despite the fact that the "virtual OSCE" is no longer quite fairly occupied? Computerized? Digital? Virtually enhanced? Mixed?

Of course, as virtual technologies develop, sooner or later there will be a specific designation for conducting exams with the help of virtual patients. So far, we do not have an answer to this question - only a modest attempt to draw attention to the existing terminological confusion.

Virtual Clinic is a computer model of a health care institution, unit, facility, or subdivision thereof designed to teach managerial, epidemiologic, economic, administrative, and other decision-making abilities, as well as objective assessment of these skills.

It should be noted that textbooks, atlases, and other printed training aids digitized and converted into electronic format (E-book, Internet, etc.) should not be classified as virtual simulators. Firstly, they exist or can exist not only in digital (virtual) form, but in contrast to the virtual world, for example, on paper (real) media. Secondly, they are not simulators

[6] HoloLens is a trademark of Microsoft Corp., Redmond, WA, USA

because they do not simulate the real environment in the virtual world, but simply display it, copy it on a different technological medium.

The same applies to videos posted on streaming servers such as YouTube. In the last 17 years since its foundation, this service has become one of the leading educational tools for medical educators and trainees around the world [Frongia G, 2016]. However, just as in the example of e-textbooks, the videos by themselves are not interactive models generated solely in a computer microprocessor, and therefore cannot be classified as virtual simulations.

It is possible that some of the terms used today will soon lose their relevance or acquire a different meaning like it happened earlier with the meaning of the word "virtual". For example, the term "screen simulator" was relevant in the times, when user programs ran on personal computers. Currently, these programs can be displayed on mobile devices – tablets, smartphones, flowing seamlessly through virtual reality glasses into an immersive environment. Is it still "a screen"? The same simulated case can be represented at smartphone, 50-inch screen-board or in VR-helmet. Moreover, screen simulators have acquired many additional functionalities that users did not even know existed ten or twenty years ago – for example, screen vibration when palpating the pulse or collecting physiological parameters from the trainee wirelessly gathered by external sensors and incorporating them into the virtual case.

3.2. Design and features of virtual reality simulators

Every virtual simulator consists of the following components: a) software application that mimics reality in virtual environment; b) computing device that processes data, and c) peripherals (user's interface) responsible for interaction with user – input of external commands and output (display) processed results in virtual reality. Based on different types of interfaces, virtual reality elements, and virtual reality interaction options one can talk about a wide variety of devices.

3.2.1. Data input

A user can input commands to interact with the virtual objects through numerous types of the user's interfaces:

- Numeric or letter keyboard
- Mouse
- Touch screen
- Microphone (voice commands)
- Optical devices, such as mono- and stereoscopic video cameras, laser devices, lidars, determining in visible or infrared light ranges distance, position in space (coordinates), gestures, movements of hands, eyeballs, instruments, and fulfill event recognition and analysis. Examples of such recognition technologies are Leap[7], Kinekt[8], WiiU[9], SimBall[10]
- Joystick, sensor, sensor-gloves, suits, and other sensory and haptic devices based on ultrasonic, microwave, electromagnetic fields for analyzing spatial coordinates, movement, pressure, tension (e.g. made by Polhemus, Sensable, Surgical Science). Some of them realistically reproduce human body parts, such as a robot arm into which medicine is injected intravenously. Such interfaces can be interactive, working not only to input commands, but also creating a counter-effect, a physical response – tactile feedback to user like "tissue" resistance to applied force.
- Devices for recognition of mental commands, which is technologically possible today, but has so far been implemented in medical devices, such as bionic prostheses only.

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[7] Leap is a trademark of Leap Motion, Inc., San-Francisco, CA, USA
8 Kinekt is a trademark of Microsoft Corp., Redmond, WA, USA
9 WiiU is a trademark of Nintendo Co., Ltd., Kyoto, Japan
10 SimBall is a trademark of Surgical Science, Gothenburg, Sweden

3.2.2. Elements

One of the first classifications of virtual simulation proposed in 1997 by Meller identified three types of virtual simulation elements: passive, active and interactive [Meller G, 1997]. However, the modern level of technological development allows us to introduce another type of elements, which we suggest calling "hyperactive". On this basis, one can speak of four types of elements of the virtual environment:

1*. Passive* or *Inactive elements* remain unchanged during the simulation and do not interact with the trainee. User can only watch or hear them, for example, images of the environment, instruments and equipment, medical personnel or sounds of cries or ambulance sirenes. These elements are auxiliary objects and subjects that are used to "enhance the realism" of the simulation, create nice general fidelity of the virtual environment.

2. *Active elements* are changed during the simulation, thereby prompting the trainee to act. These elements are controlled by script not by user. Script transforms their characteristics during the simulation according to a predetermined scenario after certain trigger events or time point, for example, bedside monitor with the physiological status of the patient, ultrasound image or electrocardiogram. These changes are standardized and pre-determined.

3. *Interactive elements* have complex mathematic model or scrips behind, which change its characteristics due to the trainee's activity, in response to his actions. Grade, level, or extension of such reaction depends on the range of user's activity. Examples: individual, dose-dependent change of physiological parameters after the drug injection; intensity of bleeding from the organ determined by the location and depth of damage caused by surgical instrument of trainee; quantity of blood-loss related to the proper tourniquet placement; saturation level corelates with quality of CPR performed.

4. *Hyperactive elements* do not only demonstrate changes in response to the trainee's activity, but also themselves generate a counter-impact on him or on the real environment. For example, the virtual tissues of the intestine repel the virtual tube of the endoscope when it rests against its wall, and this resistance is transmitted to the trainee's hand through the handle of the device.

3.2.3. Data output

The most common types of output are visual and acoustic: the virtual reality simulators primarily render visual images and generate, or playback recorded sounds. Visual images can be rendered as flat still pictures (images), flat movable picture consequences (animated movies, films), 3D-animations that can be rotated or been surrounded and observed from different angles. If those 3D-visual objects are projected into the real physical environment and digital images are displayed over visible physical objects, one speaks about mixed reality [Fig. 1].

However, beside of visual, the results of the simulation can be perceived by other human senses. Bellow, their combinations are listed according to the frequency of use:

1. *Visual* images displayed on the computer or mobile device screen, or in virtual glasses/headset.
2. In addition to *visual* images, *acoustic* signals are reproduced.
3. *Video, audio,* and *haptics* (tactile sensitivity and or tactile feedback/pushback).
4. In the nearest future, it is to be expected that in addition to video and acoustic signal and haptic output the following effects will also be generated in virtual simulators:
5. *Equibrioceptive* (including proprioceptive feeling of the relative positioning of own body parts, proper motor skills, awareness of body position)
6. *Thermoceptive* sensations (perception by touch of the proper temperature of virtual objects, such as human organs).
7. Smell and/or taste.

Thus, it is to be expected that every human sense will be engaged without exception.

Source: Maxim Gorshkov

Fig. 1. Mixed reality: virtual images are displayed over visible physical objects

3.2.4. Immersion

In virtual reality research, the concept of *immersion* or *immersive effect* is used widely. It refers to the state of an individual who has crossed the boundary of the transition of environments, from the real world to the virtual world and realize himself acting not in the real world but in this new, virtual reality completely. And just as in real life one can immerse in water either a fingertip or a hand, or entirely plunge down into it, so in virtual reality there are different kinds of immersion – cognitive, emotional, sensorium-motoric, spatial immersion, which reflect the extent of the immersion effect, and therefore, in our opinion, it makes sense to talk about the components, the components of immersion.

The *cognitive* (or *strategic*) component of immersion occurs when reflecting on the strategy of action, e.g., during the diagnosis and making clinical decisions about the treatment of a virtual patient. It is not necessary to use complex high-tech interfaces to create such an immersion – a simple screen simulator, the so-called "*Strategy simulator*", is sufficient. The classic example of cognitive immersion is the detached, concentrated state of grandmasters during an intense game of chess. Similar cognitive immersion in medical simulation can be observed by decision making simulation like "Triage mass casualty in hospital emergency".

The *emotional* (or *descriptive*) component is provided by an exciting scenario, and introduction of relevant environmental elements into the virtual simulation, due to which the learner gets involved in a certain plot, feels his involvement in what is happening, gets into the role. Such emotional immersion develops e.g., by simulated communication scenario even though conversion is held on the screen.

The *sensorimotor* (or *tactical*) component of immersion is manifested in the training of practical skills when the trainee is required to interact quickly and skillfully with the virtual environment. In some situations where the learning objective is to train a complex skill, such as palpating simulated abdomen or practicing an endosurgical suture, all the trainee's attention is absorbed by the physical interaction with the virtual object. The learner sometime even closes his eyes not to be distracted from the simulation by surrounding reality non-relevant to the trained case. This type of immersion places very high demands on the technological level of the simulator design. The immersion effect is immediately lost if the simulated tissue is unrealistically reproduced to the touch or the "picture is slowed down" and does not match the movements of trainee.

The *spatial (space)* component of immersion is manifested by a sense of complete, global fusion with the simulated world, one's own physical transition from reality to virtuality, like Alice fallen into Wonderland. As with sensorimotor, achieving spatial immersion is ensured not so much by the content but by the quality of its simulation, and this depends directly on the level of technological solutions used: virtual helmets, haptic devices, interactive gloves, and entire costumes. By implementing the sensorimotor and spatial components of immersion, the developer has unlimited possibilities in implementing training applications at any level, up to large-scale training sessions with team interaction in scenarios like "Life support in moving ambulance".

3.3. Classification of the medical simulators

As mentioned above, the variety of virtual reality medical simulators is extensive, which is determined by the large number of different manipulations, skills, techniques, operations, tissue types, pathologies, critical conditions, medical specializations, learning objectives and training levels to be replicated. This current section – Classification of virtual simulators – is dedicated to bringing some systematization in finding common features and functionalities.

Following the description of groups of devices with similar features, several typical examples from the field of medical education are given. First of all, medical simulation devices were divided into the several traditionally named groups of products with characteristic attributes and functional features:

1. Live model (actor, animal)
2. Biological model (cadaver, organs)
3. Moulage
4. Phantom
5. Mannequin (Manikin, Dummy, Patient Simulator, Robot-Simulator)
6. Trainer, training device, model
7. Screen-based simulator
8. Virtual reality or mixed reality simulator
9. Model (Imitation) of medical equipment

The flowchart "Types of the medical simulators" can help to distinguish and determine proper type of the simulation device [Fig. 2].

In addition to these historically established types, a few contemporary authors proposed original taxonomies, many of which mention virtual simulators as well. So, the pioneer of the methodology of simulation training Prof. David Gaba, the head of the Simulation Center of Stanford University Medical School, in 2004 proposed eleven dimensions of simulation application. As a part of the classification of simulators based on technology applicable or required for simulations can be highlighted – it has five groups [see Table 1, left]. Except of first two groups based on humans playing role, all three remaining groups include VRS [Gaba D, 2004].

Another well-known classification was proposed three years later by Prof. Guillaume Alinier [Table 1, middle]. It compares the functions of simulators and the degree of instructor involvement in training, as well as the realism of the experience that can be obtained through them [Guillaume Alinier, 2009]. Virtual reality simulators in this classification are designated to the second group – "products with a screen" only.

We have offered in 2012 a new classification [Table 1, right and Fig.3] and presented it at several conferences (Surgicon, Gothenburg, 2012; SESAM, Paris, 2013). In this typology of simulation devices, the level of realism or better saying realistic interaction between user and simulator became the main decisive feature underlying the classification. All types of medical simulation equipment were categorized into seven levels of realism based on the degree of visual, tactile, and functional similarity to the original [Maxim Gorshkov, 2012].

Table 1. Classifications of the medical simulators

Classification by David Gaba, 2004	Classification by Guillaume Alinier, 2007	Classification by Maxim Gorshkov, 2012
1. Verbal Role playing 2. Standardised patients (Actor) 3. Part-task trainer: Physical; Virtual reality 4. Computer patient – Computer screen; screen based "virtual world" 5. Electronic patient Replica of clinical site; mannequin based; full virtual reality	Level 0. Written simulations include pen and paper simulations or "Patient Management Problems" and latent images Level 1. 3D models which can be a basic mannequin, low fidelity simulation models, or part-task simulators Level 2. Screen-based simulators Computer simulation, Simulation software, videos, DVDs, or Virtual Reality (VR) and surgical simulators Level 3. Standardized patients Real or simulated patients (trained actors), Role play Level 4. Intermediate fidelity patient simulators Computer controlled, programmable full body size patient simulators not fully interactive Level 5. Interactive patient simulators or Computer controlled model driven patient simulators, also known as high-fidelity simulation platforms	I. Visual Visual appearance of a person, organs, tissues are reproduced only II. Tactile Besides visual, tactile characteristics of the object are imitated also III. Reactive The model has the simplest feedback, reacts to the trainee's typical actions with standardized reaction(s) IV. Automatic The programmed manifold reactions to various external influences and manipulations. Response is scripted (standard), not calculated (e.g. doses-depended, etc.) V. Technical Besides of above features simulation device can be "treated" and /or inspected with real medical technic, clinical equipment VI. Interactive Bilateral interaction with a trainee and medical equipment in the form of autonomous individual response to their actions, including haptic (tactile interaction) or doses-depended calculated physiological changes VII. Integrated Complex interaction as a whole system of several simulators of the highest, VI level with each other, trainees, medical equipment, pharmaceuticals and other elements of the external environment

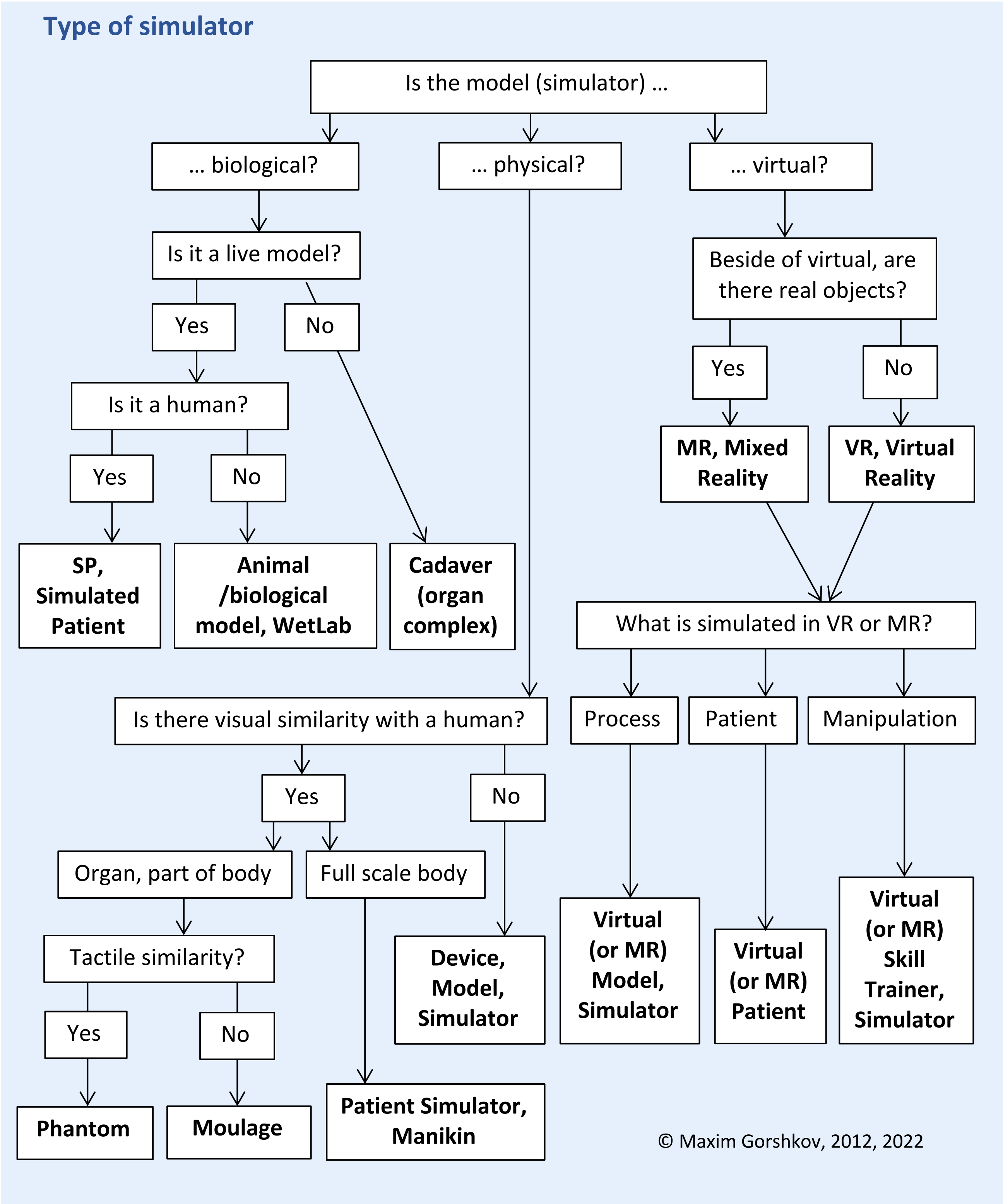


Fig. 2. Flowchart: Types of the medical simulators

However, virtual simulators have several own properties that were previously absent in physical and mechanical simulation models. As one can see in the table above, these features were not taken into consideration in the existing taxonomies of medical simulators. As such, a proprietary classification of virtual simulators is required, extending only to simulation devices that simulate objects exclusively in virtual environment

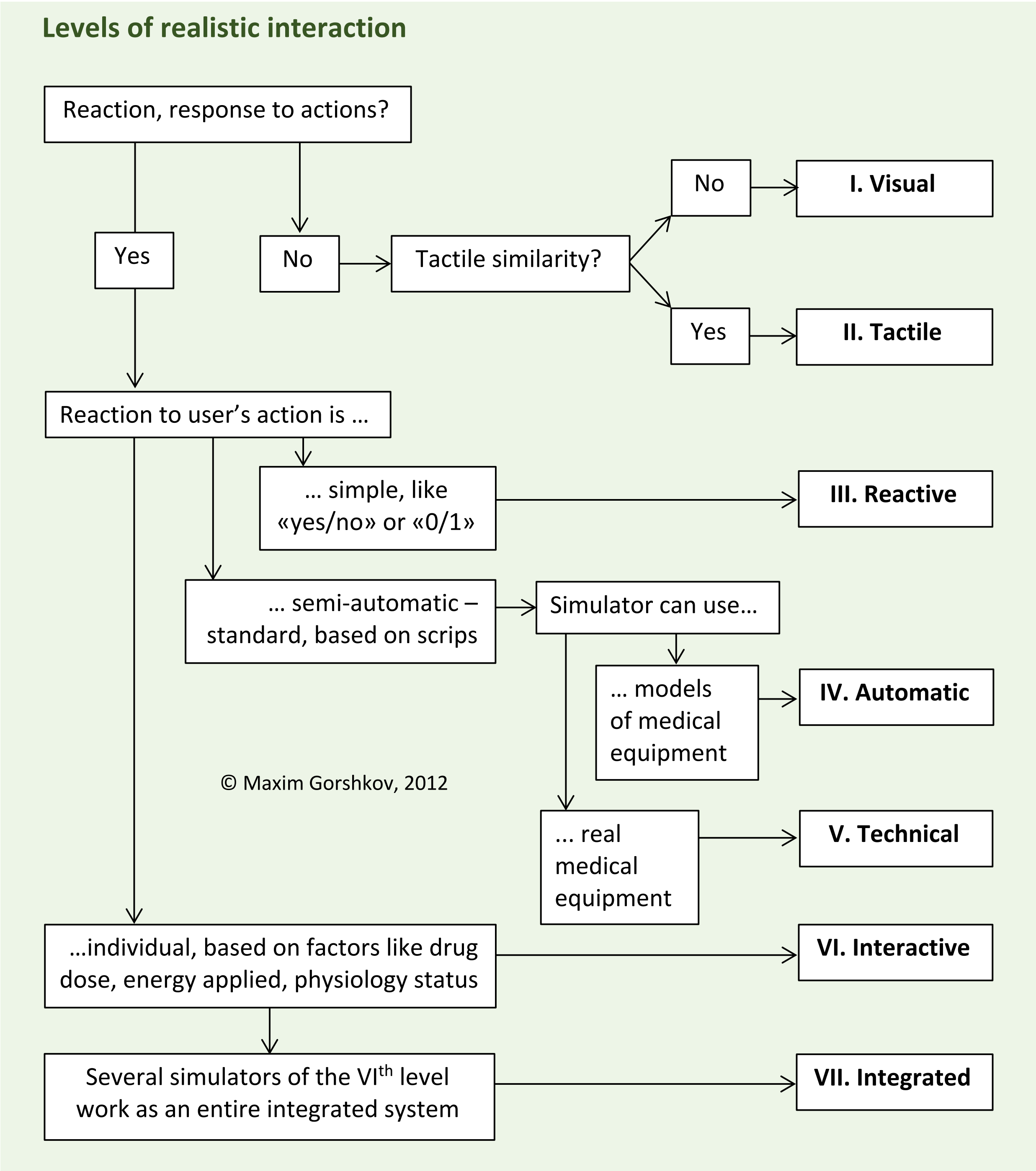


Fig. 3. Flowchart: Classifications of the medical simulators based on realism levels

3.4. Classification of the medical virtual reality simulators

Considering the growth of simulation realism, the training tasks to be solved and the complexity of the technological solutions used, and, most importantly, the degree of trainee involvement in the simulated virtual environment and the level of interaction with its elements, virtual simulators can be divided into the following four levels or, if considering the initial zero level, into five ones [Gorshkov, 2017]:

Level 0 – Devices with passive VR elements

The "Zero" Level is described here as a part of the taxonomy, but its devices are not considered as virtual simulators, rather a precursor.

At this level the images, sounds and vibrations can be reproduced. The reproduced environment does not interface with user in any way. The integrated sensors are passive, there is no any interaction with the sensory perception of user, the trainee remains to observe virtual objects passively. The actions of the person are not detected, so there is no assessment system.

Why is this group mentioned within the Classification of VR Simulators? The reason of it is the formal presence of signs and elements of the virtual environment ("a digital reproduction of the medical environment, subjects, objects or processes"... "generated by a hardware and software device" – according to the definition given in section "3.5. Terminology").

Why can't audiovisual recordings be classified as a virtual simulation? They lack a key feature – "interaction and response". Thus, this allows us to consider digital educational audiovisual materials as a kind of forerunner, a precursor of virtual simulation, but at the same time not to refer as a simulator.

In medical education at this level, virtual courses are presented for the assimilation of theoretical material, during which the trainees are not required to interact with the simulator, without active or interactive elements. Their examples include informational videos supplemented with comments, diagrams, 3D models and other virtual objects that demonstrate to the patient or doctor the course of the upcoming intervention, manipulations posted on a specialized or universal video hosting. The following examples of the "Zero Level" can be presented:

- **YouTube**[11] (https://www.youtube.com).
  YouTube is a free video hosting service that provides users with video storage, delivery, and display services of any types, length and subjects. YouTube has become the most popular video hosting service and the second most visited website in the world. Besides of material for liens it hosts highly specialized materials as well, which allowed the platform to become one of the most important sources of medical video-education – over 2.5 thousand medical research articles are dedicated to usage of this platform in medicine and 1.131 contain word "youtube" in its title (PubMed, search on 28 July 2022).
- **MEDtube**[12] (https://medtube.net).
  MEDtube is a video-centric social eLearning platform which is free to use by the health care professionals worldwide. Beside of videos MEDtube provides other technologically advanced tools for medical education and communication like library of multimedia, collaboration and eLearning platforms, eBooks.
- **WebSurg**[13] (https://websurg.com).
  WebSurg is a web-platform, specialized in minimally invasive surgery and dedicated to the promotion of medical and surgical training skills and is free of charge. It was launched by Professor Jacques Marescaux and his team at the *L'Institut de recherche contre les cancers de l'appareil digestif* (IRCAD) in 2000 in Strasbourg and nowadays is the world oldest and probably the most renominated online source of endovideosurgical videos, lectures and other educational materials.
- **GibLib**[14] (https://www.giblib.com).
  GibLib [see Fig. 4] is a paid educational, streaming media platform offering the extensive library of on-demand medical lectures and surgical videos in 4K and 360-degree virtual reality. The most of educational videos are developed with Mayo Clinic expert physicians and surgeons. The educational content is addressed to students, physicians, surgeons, physician's assistants, and nurse practitioners.

[11] YouTube is a trademark of Alphabet Inc., Mountain View, CA, USA
[12] MEDtube is a trademark of MEDtube sp. z o. o., Warsaw, Poland
[13] WebSurg is a trademark of IRCAD, Strasbourg, France
[14] GibLib is a trademark of GibLib Inc., Los Angeles, CA, USA

- **CSurgeries**[15] (https://csurgeries.com). Specialized on surgical videos CSurgeries is a physician owned and operated company that publishes high-quality surgical content that is open to students, residents, surgeons, and patients regarding both common and complex surgical procedures.

Source: Maxim Gorshkov

Fig. 4. Video-streaming surgical education platform GibLib

Level 1 – Active

Virtual simulators of the First Level contain active elements in addition to passive ones. The virtual environment equipped with such elements encourages students to act, although it remains unchanged itself. Visual images and acoustic signals are dynamically generated, the system responds to user actions. This is a key property of this level: on the one hand, the system is active, it addresses the user, for example, with questions or offers to choose a

[15] CSurgeries is a trademark of CSirgeries Inc., North Little Rock, AR, USA

variant of further development of events. On the other hand, although the user can control the system e.g., rotating the 3D model to get a better view of it, turning off the anatomical layers – student does not create changes in it. At this level, simulations of pre-clinical and clinical subjects are presented, encouraging the trainee to perform elementary actions that can be assessed. The presence of the scoring system for evaluating the actions of the student is possible feature, but not the necessary one.

Some forms of immersion – cognitive and emotional can be observed starting from this level already. Such immersion however cannot be regarded as "complete immersion in virtual reality", rather, it is a kind of "presence effect", affective participation.

There are a lot of examples of virtual simulators with active elements, so in the list below they are grouped by educational goals and medical specialties. Here are just some examples of the mobile and web-applications for virtual anatomy learning (given alphabetically):

- *3D Anatomy* by Education Mobile, Guildford, Surrey, UK
- *Anatomy 3D Atlas* by Catfish Animation Studio, Milan, Italy
- *Anatomyka* – 3D Anatomy Atlas by Woodoo Art s.r.o., Bratislava, Slovakia
- *BioDigital Human* – 3D Anatomy by BioDigital, New York, NY, USA
- *Complete Anatomy* – by 3D4Medical from Elsevier, Amsterdam, Netherlands
- *Daily Anatomy Flashcards* by Kenhub GmbH, Berlin, Germany
- *e-Anatomy* by IMAIOS SAS, Castelnau Le Lez, France
- *Human Anatomy Atlas* by Visible Body, Boston, USA
- *Netter's Anatomy* by Skyscape Medpresso Inc., Marlborough, MA, USA
- *Teach Me Anatomy* by TeachMeSeries Ltd., Thetford, Norfolk, UK

Some of the anatomy virtual learning systems are represented not only by mobile application. There are large platforms based on sensor tables and virtual boards to be used in the classrooms:

- *Anatomage*[16] provides 3D anatomy visualization and virtual dissection tool for anatomy and physiology education that can enhance cadaver lab group lessons. Interactive 3D-anatomy and cross-section images are presented on large touch screen table that can be fixed vertically (presenting a standing human) or horizontally, like a section table with cadaver [Fig. 5].

Source: Maxim Gorshkov

Fig. 5. Anatomage at the touch screen in vertical position

- *SECTRA*[17] is another example of interactive virtual anatomy concept in solid stationary design. It provides an interaction with virtual representations of real-life bodies based on clinical imaging on the movable touch-screen table as well. Visualization tools and content are accessible from cloud-based data. Together

[16] Anatomage is a trademark of Anatomage Inc., Santa Clara, CA, USA
[17] SECTRA is a trademark of Sectra AB, Linköping, Sweden

with interactive 3D-anatomy images and sections their original CT-scans and high-resolution microscopic histology images are available.

Practically every preclinical and clinical specialty has now numerous virtual simulators that help to gain knowledge and practical skills. Just as an example, a far from complete list of mobile applications for the training of ultrasound examinations is given below. Some of these listed apps are developed by the giant manufacturers of ultrasound equipment, however, there are many of them developed by tiny start-ups around the World (in ABC order):

- *Abdominal Ultrasound Guide* by StudySpring, Lagos, Nigeria
- *Butterfly iQ* — Ultrasound by Butterfly Network, Burlington, MA, USA
- *Clarius Ultrasound App* by Clarius Mobile Health Corp., Vancouver, BC, Canada
- *Deepscope Ultrasound Simulator* by Deepscope, Bangkok, Krung Thep, Thailand
- *Diagnostic Ultrasound Handbook* by easyRadiology AG, Köln, Germany
- *ICCU Ultrasound Education* by CAE Healthcare Inc., Sarasota, FL, USA
- *LELTEK Ultrasound* by LeSono, Leltek Inc., New Taipei City, Taiwan
- *Philips Lumify Ultrasound App* by Philips Healthcare Inc., Andover, MA, USA
- *Scanbooster Ultrasound Simulat* by Scanbooster UG, Ebhausen, Germany
- *SonoAccess: Ultrasound Education* by Fujifilm Sonosite, a company of Fujifilm Holdings Corp., Bothell, WA, USA
- *VistaScan Ultrasound* by Emagine Solutions Technology Inc., Tucson, AZ, USA
- *Vscan Air Wireless Ultrasound* by GE Medical Systems Ultrasound & Primary Care Diagnostics, LLC, by GE Healthcare (USA), a part of General Electric Company, Boston, MA, USA

Level 2 – Interactive

As in the previous group, virtual simulators of the Second Level can reproduce images and sounds, but interactive elements are added on to passive and active elements. This add on is characterized by the changes of the virtual objects and entire environment that occurred as a reaction to the student's activity.

Such transformation of virtual objects and other elements of the simulated reality due to the actions of the student is observed both at the present (The Second) and at two subsequent levels. Also, starting from this level there is mandatory evaluation system presented. All actions of the students performed in virtual reality are logged, analyzed and assessed.

Good examples of this level are so called "virtual patients". These systems are designed and created to simulate clinical activities such as diagnosis, clinical decision making. In case of advanced systems, they can provide dynamic treatment in the face of changing physiological status. Just a few examples among of numerous are:

- *BodyInteract*[18] is a virtual patient simulator initially presented on the touch-screen table is dedicated to enhancing clinical reasoning and improving decision-making skills. Currently it offers over 750 clinical simulated scenarios in more than 30 medical specialties.
- *CAE Maestro Evolve*[19] and *SimSTAT*[20] are virtual systems with an advanced physiology model by that allows to run simulated scenarios in real time. CAE Maestro Evolve provides access to the simulator, equipment, healthcare curriculum, and assessment tools on one platform, it is possible to configure new patients with different conditions, from healthy one to severely ill. The patient's parameters are changed individually and dosage-depended reacting the user's activities like administered drugs, performed defibrillations, etc. These changes are fulfilled automatically by the physiology model. This feature is especially useful in training of emergencies and allows healthcare educator to focus on teaching process, not on the case facilitation. CAE Maestro Evolve includes a simulated hospital ward with a patient connected to virtual bedside monitor displaying in real time physiology signs. Another application, SimSTAT. It's interface consists of screen-based simulation scenarios, integrates CAE Healthcare's modeled patient physiology and pharmacology into each virtual patient, providing physician anesthesiologists with advanced training to manage challenging emergencies. The SimSTAT fulfills Continuing Medical Education and MOCA 2.0® Part II and IV requirements, enabling training and evaluation remotely.

[18] BodyInteract is a trademark of Take The Wind, Lda, Coimbrã, Leiria, Portugal

[19] Maestro Evolve is a trademark of CAE Healthcare Inc., Sarasota, FL, USA

[20] SimSTAT is developed by the American Society of Anesthesiologists (ASA) and CAE Healthcare Inc., Sarasota, FL, USA in collaboration with SimTabs, Los Altos, CA, USA

In medical education, virtual simulators of complex practical skills are also widely represented. Some of them have manipulators with tactile feedback, haptics. The microprocessor simulator recognizes the interaction of the virtual instrument with the virtual organ and calculates tissue resistance and other physical parameters, which are modelled by mechanical joystick devices – some of them mimic real surgical instruments. Thus, the student not only sees the contact of the instrument with the tissue on the screen, but also gets a tactile feeling in hands of the interaction with an organ.

As an example of such a haptic device can be mentioned virtual simulator LapSim, perhaps one of the most known and validated surgical simulators in the world. Its training curriculum allows to begin with basic endosurgical skills such as bimanual coordination, laparoscopic navigation, handling of delicate tissues, clip application and complete the training with a course of surgical interventions in abdominal and bariatric surgery, urology, and gynecology. Another option for simulating haptics is complex mechanical device in the form of gloves equipped with sensors and servo-actuators – the interaction of hands with the patient's body or instruments is simulated accompanied by 3D-images rendered in VR-glasses [Fig. 6].

Source: Maxim Gorshkov

Fig. 6. Interaction of haptic gloves together with VR-helmet and positioning cameras

Level 3 – Immersive

In this group of simulators, their passive, active and interactive elements are reproduced not only through visual and acoustic signals, but also through tactile and even proprioceptive impact on the trainee. The image is transformed from flat, two-dimensional to three-dimensional. All this is achieved using virtual reality helmets (full scale 3D glasses with headphones), and the use of a more sophisticated user input interface (using gestures, speech, motion sensors, pressure, stretching). This comprehensive interaction with the virtual world along with separation of the user from the external real environment creates an effect of "immersion".

In addition to passive, active and interactive elements, "superactive elements" can be used here. Superactive elements are not only changed in respond to the user's actions but also, in turn, demanding him/her to adjust their actions, such as changing degree of force applied, accelerating speed of movements, alter vector of pressure or traction, etc. And only one step left to achieve the next level – complete disconnection from the outside world and bring global immersion into virtual reality.

An example of the immersion level can be virtual simulators of practical skills, e.g. laparoscopic virtual simulators with tactile feedback, realistically reproducing the course of endosurgical interventions in VR-helmet or immersive 3D simulation of medical actions in emergency department of the hospital (LapSimVR).

There are a significant number of virtual educational products that provide simulation scenarios performed in clinical environment created in virtual reality, to name just a few:

- *EMS*[21] – Education Management Solutions, provides "integrated technology ecosystems for healthcare training", including multimodal virtual simulations.
- *DIMEDUS*[22] – Digital medical education systems: communicative and manual skills training including laparoscopic surgery, clinical reasoning, and emergency both at mobile phones, tablets, large sensor screens, and in VR-glasses. Simulated experience is supported by interactive theoretical courses with 3D animations.
- *OMS*[23] provides VR simulation solutions for medical and nursing education [Fig. 7].
- *SimX*[24] – VR Simulation in both wireless and traditional VR-glasses for solo and multiplay medical training in nursing, clinical, emergency, and military scenarios.
- *UbiSim*[25] is focused on nursing education in immersive virtual reality delivered via VR-glasses [Fig. 8].

[21] Education Management Solutions Inc., Exton PA, USA
[22] DIMEDUS Inc., Needham, MA, USA
[23] Oxford Medical Simulation, London, UK
[24] SimX, Mountain View, CA, USA
[25] UbiSim, Montreal, QC, Canada

Fig. 7. Immersive reality by OMS is demonstrated in VR-glasses

Source: Maxim Gorshkov

Fig.8. Nursing training (UbiSim) in VR-glasses presented at the screen

Source: Maxim Gorshkov

Level 4 – Global, the highest

Due to the involvement of all sense organs without exception, the effect of immersion is achieved by almost 100%. During the simulation session, the student is completely disconnected from the outside world, which is replaced by virtual reality. None of his sense organs, not a single receptor system, including thermoceptive and equibrioceptive, receive signals from the real world. Everything that happens around – visuals, sounds, noises, taste, color, smell, touch, and movement – all environmental signals are mimicked by a computer processor. The reality around ceases to exist, and instead of the "immersion effect", we can talk about the effect of "global dissolution", when a person feels his presence in the virtual world only.

With due realism in the development of didactic content and its virtual implementation, practical experience and emotional experiences obtained in a global virtual environment should correspond as much as possible to real practical experience. Interaction with virtual reality is carried out using the same interfaces as in a real environment, for example, a conversation is conducted with a virtual patient (voice commands), virtual medical equipment is controlled by buttons or from a touch screen, and tissues are sutured using a virtual needle and needle holder (reproduced using haptics with feedback). Such systems are already experimentally used in military, aviation, and space industries, but in medical education they exist at the project stage, experimental versions only. The most demanded global level will be in the implementation of comprehensive training programs, when the trainer can simultaneously work out various aspects of professional activity – making clinical decisions, performing manipulations, managing resources in a crisis, teamwork.

The main features and characteristics of the levels of VR simulators are shown in the Table 2 below.

Table 2. Classification of the medical VR simulators

Level	Interface	Elements	Simulated	Immersion	Interaction
0. Passive	Input: keyboard, mouse, touch screen Output: Screen	Passive	Image, sound	No	No interaction with user except of start/stop
1. Active	Input: Keyboard, mouse, touch screen Output: Screen	Passive, active	Image, sound	Cognitive, emotional	Virtual environment reacts to the actions of the learner but remains unchanged
2. Interactive	Input: Keyboard, mouse, touch screen, voice, gestures Output: 2D and 3D screen	Passive, active, interactive	Image, sound	Cognitive, emotional	The virtual environment is dynamic and interactive - not only responsive to the learner, but also transformed by the actions of the learner
3. Immersive	Input: Keyboard, mouse, touch screen, voice, gestures, motions, pressure sensors Output: 2D and 3D screen, virtual glasses/helmet, haptic devices	Passive, active, interactive and superactive	Image, sound, tactile and proprioceptive signals	Cognitive, emotional, sensori-motor	Hereinafter the evaluation system is obligatory. Change of virtual objects as a result of the student's actions and reciprocal effect of the virtual environment on the real one
4. Global	Input: devices for recognition of speech and movement commands and manipulations performed Output: virtual helmet, complex haptic devices, body space change simulators, odor generators, gravitation (?)	All four types of elements provide 100% virtual environ-mental substitution	The simulated signals are perceived by all human senses	Global: cognitive, emotional, sensorimotor, spatial	The effect of immersion in the virtual environment is observed. In sensations of the learner the real environment ceases to exist, and immersion in the virtual environment is replaced by dissolution, global fusion with it

[Maxim Gorshkov, 2017]

3.5. Advantages of conducting medical education in virtual reality

Having reviewed in detail the above device, technology, types and classification of virtual reality simulators, it is possible to summarize and formulate a number of advantages of medical simulation training in a virtual environment over traditional forms of mastering theoretical knowledge and acquiring practical skills. Some of them are similar to those listed earlier for simulation training in general [Knowles M. 2005; Walker R, 2009], while others are unique and inherent only in virtual learning. Let's dwell on them in more detail below.

Education, training, and the acquisition of practical experience are conducted in an environment that is safe for patients, trainees, and teachers. Patients are not involved in the learning process and cannot suffer from inappropriate actions of trainees, and they, in turn, as well as teachers, are protected from possible external threats – infections, accidents, injuries, damages, aggressive behavior of patients and their relatives.

The learning environment is fully controlled by the instructor and/or the learner. A session can be started, finished, or placed on hold at any time at their will, and all of its components are fully controlled.

The clinical situations are chosen by the instructor or the trainee and is determined by learning objectives, not by the current availability of suitable patients in the clinic.

Anatomical variations, rare pathologies, and life-threatening conditions can be easily reproduced with the VR without limitations.

The operating costs of virtual simulators are close to zero. Once created, a virtual clinical scenario can be infinitely reproduced and repeated many times without requiring, with rare exceptions, replacement of consumables - the virtual environment needs no replacement skin, cartridge refills, medication refills, or disposable supplies.

The learner-centered education (learner-centered education) is the focus of the learning process with VRS. Shifting the focus from the teacher to the learner positively motivates the latter and, in turn, encourages him to actively participate in the learning process – in this model of education it is impossible to sit passively through hours of lectures and lessons, simply moving from course to the next one.

Due to modern technologies VR education is geographically independent, suitable for "distant education". Learner can study and even train skills distantly, from any place, actually from another continent. This opens new possibilities of access to the highest level of education regardless of real physical presence and may give an advantage to scholars from low-income countries.

Management, control over the learning process can be partially or fully delegated to the learner: pace, intensity, volume, depth, direction, self-assessment. The time and sometimes the place of the training can be chosen by the trainee for himself/herself, regardless of the clinic, department, or instructor's working hours. The number of repetitions of manipulation or clinical tasks is unlimited. Thus, the student repeatedly practices a complex manipulation in VR according to the principle of "Deliberate Practice", just as a musician plays gammas, perfecting technical skills [Ericsson, 1993].

Learning with the help of VRS is practiced in simulated environment where experience is gained according to the Experimental Learning Model [David Kolb, 1984]. This way of "learning by doing" is more effective for mastering theoretical materials and skills than classical approach.

Learning on virtual simulator gives an opportunity to reflect on the learning process, to comprehend the practical experience gained in a virtual reality – to remember, identify and analyze one's actions, evaluate the demonstrated results and correct the further learning process.

Using VRS allows to create a problem-oriented learning process, where the solution of a certain situation is formulated as a learning task – diagnosis, resuscitation of a casualty, removal of a tumor, increasing the efficiency of bed fund use.

Evaluation of the level of practical skills or acquired knowledge is based on a combination of numerous objective parameters. Such evaluation is not only objective, but also valid and reliable.

Constant feedback from the assessment of knowledge and skills makes it possible to build up a progression of the learning process individually, once a set level is reached - Proficiency-Based-Progression. Students have exactly the amount of time they need, without regard for other students or "allotted time".

Linking the learning path to the results of a particular individual and introducing a minimum threshold ("passing grade") makes it possible to guarantee an appropriate level of competence upon completion of the virtual reality curriculum.

The learning environment is standardized and reproducible, which is extremely important not for the learning process only, but especially at large scale or high-stakes exams. With standardized curriculum and assessment in VR each examinee gets exactly the same conditions and is evaluated according to precisely equal criteria as all other participants.

Despite the absence of risk and the stress associated with it, virtual learning can be highly emotional and empathic, which deeply imprints the acquired skills and experiences. Fear, stress, panic, and pain can be demonstrated and limitless reproduced in virtual world – much easier as it would requires in physical simulation.

Learning in a virtual environment is possible in groups, and the number of participants and their geographical remoteness do not matter. In this case there are whole social networks, united by a common goal or solution of a single learning task (MUVE, Multi User Virtual Environment). The emerging social component, social relationships help to jointly find answers to complex questions, participants can share experiences, give advice, recommendations, leave feedback, jointly participate in a virtual team training. It is possible to introduce a competitive component.

In the virtual training student can play a role never plaid before in real life. Scholar can pretend to be a chief physician, surgeon, anesthesist, paramedic, endoscopist, etc. These roles are easy to change, which allows to feel yourself in the shoes of other members of the medical team.

Virtual reality provides additional opportunities not only in training, but also in medical science and practice – one can reproduce a real critical situation for its analysis and error detection, test new clinical techniques in a safe simulation environment (techniques, equipment, protocols, drugs), perform preoperative intervention on a virtual model of the anatomy of a real patient.

Learning in a virtual environment can supplement and partially replace the teacher. Today we take for granted that by reading a textbook or watching a learning movie the presence of a teacher is not required, and the students come to the seminar having already mastered a certain material on the topic of the upcoming session. This principle is the basis of the "flipped classroom" technique, which has already become widespread. Students are introduced to a new topic on their own and then analyze it in detail during a class with a teacher. But VRS provides much more than just preliminary reading. It can check the initial level, provide further reading, offer benchmarks to be achieved and asses gained proficiency. Over time we will not be surprised to see a student who has already mastered the basic skills of endosurgery, auscultatory signs of lung pathology, or the basics of sonography of heart defects with the help of a virtual tutor only.

The advantages of learning in a virtual environment described above are proved by the results of studies conducted around the world. It should be noted that the topic of using virtual simulations in medical education is of great interest. Over the past three decades, several thousand such studies have been published in the world's indexed literature. For example, a search of the PubMed Database showed that over 4,377 studies containing the keywords "virtual patient (in) education" have been completed in the last ten years alone, from 2013 to 2022 [query ((virtual) AND (patient)) AND (education)] and 5,092 papers with the words "virtual simulator (in) education" [query ((virtual) AND (simulator)) AND (education)], with 200 and 194 systematic reviews respectively among them.

Based on one of the most recent systematic reviews of randomized studies, the conclusions were: 1. The effectiveness of virtual patient use, as measured by knowledge gained, showed that virtual patient training was as effective as traditional training; 2. The effectiveness of mixed methodology – using virtual patients along with classical forms – was moderately higher than exclusive use of traditional forms of training alone; 3. The effectiveness of virtual patient use for clinical thinking, procedural and team skills was higher than for traditional [Gunther Eysenbach et al., 2019].

Since the issues of the teacher-replacement function by virtual reality are highly controversial and emotionally sensitive, it would be worth dwelling on this in a little more detail. Almost a quarter of a century ago Prof. Ronald Harden [Fig. 9] formulated twelve roles for the medical educator [Harden RM et al, 2000]. Today, virtual technologies have penetrated various areas of medical education, and some of the functions of teachers can be or even have been transferred to virtual systems.

VRS can provide and explain new information to the students, coach them, show practical techniques and demonstrate algorithms of manipulation performance – for this purpose they are equipped with interactive lessons and courses, educational video, and animated 3D materials (the roles of "Lecturer in classroom setting" and "Lecturer in clinical or practical class setting" according to Harden, 2000).

Source: Maxim Gorshkov

Fig. 9. Ronald Harden is awarded at IMSH-2019, San-Diego, USA

Many virtual simulators offer trainees ready-made curricula, courses compiled by leading experts. World-leading developers of VRS do not simply develop the cases and courses – they enable their beta-testing, multi-level reviews and validation before implementation into the standard offer (roles "Curriculum evaluator", "Curriculum planner", "Course organizer", "Learning facilitator", "Production of study guides", "Developing learning resource materials in the form of computer programs, videotape or print which can be used as adjuncts to the lectures and other sessions"). It is impossible for an individual teacher alone to compete with a collective work, the result of efforts of leading experts – after all, these teams consist not only of clinicians, but also psychologists, teachers, programmers, 3D-modelers, specialists in the field of user experience.

While trainee performs task, manipulation, or solves clinical problem the virtual simulator corrects his/her actions, provide debriefing, or performs another form of feedback and formative assessment. The simulator can adjust individual learning curve of the trainee during gaining determined proficiency level, changing the speed and level of complexity of the material presentation, facilitate and mentor entire curriculum depending on the depth and quality of its acquisition (the role of "Mentor, personal adviser or tutor").

Virtual simulators are already used today not only in formative, but also in summative assessment, in final, including high-stakes examinations (Role "Planning or participating in formal examinations of students"). Thus, only two role models remain out of the twelve medical teacher models - "On-the-job role model" and "Role model in the teaching setting," which are currently not performed by virtual reality simulators in any way – except for the formal demonstration of the sequence of actions in manipulations or standard procedures, like virtualized "See one, do one, teach one" model.

Of course, none of the roles of a teacher can be 100% replaced by a computer, at least at current technology level. Thus, the above-mentioned substitution of a teacher by a virtual tutor should not be taken literally, directly, but as a potential vector of development. The teacher would like to explain some points in more detail while some topics may be especially relevant due to local geographical, cultural, endemic or epidemiological reasons and the training course should be adjusted accordingly.

In our opinion, the situation will evolve in the same way as in other areas of human development. Computer technology coming to the aid of medical education will allow the teacher to get rid of routine, standard, monotonous, non-creative activities. There is no need to explain the same theoretical material over and over again, to show hundreds of times the same techniques and manipulations, to ask boring, though important, test questions or control the correctness of the algorithm of standard operating procedures. The instructor will be able to focus on complex concepts, creative discussions, development of clinical thinking and action in non-standard situations, consider unique clinical cases, and teach how to solve non-standard situations. Since the problem of replacing a teacher with a virtual model is not the topic of the present section, which describes the benefits of learning in a virtual environment, a detailed discussion of this issue can be found in the section "6.3. Twelve Roles of Medical Teacher" below.

Thus, the benefits of applying virtual reality simulation in medical education are summarized in Table 3 below.

Table 3. Benefits of virtual reality simulation applied in medical education

- VRS provides safe learning environment, which is risk-free for patients, teachers, and learners
- VR learning is conducted in fully controlled by teacher and/or learner environment
- Rare, difficult, and life-threatening cases can be reproduced and trained by VRS, not depended on the current situation in the hospital
- VRS has low operational costs, has no need in consumables
- VRS enables distant learning, without learner's physical presence in the classroom
- Learner-centered process – pace, number of attempts, duration, intensity of VR lessons – is tuned to the learner's needs
- Number of repetitions in VRS is unlimited and can be determined by trainee according to the principles of deliberate practice
- VRS successfully uses Kolb's Experimental Learning Model
- Immediate feed-back in VRS ensures reflection in the learning process
- VRS tasks and cases are problem-oriented
- VRS ensures individual learning curriculum based on proficiency (competency) progression
- VRS provides for objective, validated, and standardized assessment
- VRS ensures achievement of pre-determined competency level
- The learning and assessment in VR are standardized and reproducible
- VRS can provide highly affective situations and emotionally charged clinical cases
- VR Learning is possible in groups, social networks, or multi-user virtual environment
- Learners can choose and exchange their roles in VR
- VRS can be used for education, formative and summative assessment, scientific research, clinical trials, and practical experiments
- VR Learning can enhance and partially replace the educator, play varied roles of teacher, can provide "instructor-free environment"

[Maxim Gorshkov, 2017]

Looking through this list one can notice that the learning process in virtual environment has both – some advantages common to any simulation, as well as specific ones, presented in virtual reality training only.

So, during the lessons on mannequins or physical simulation devices it is difficult and sometimes impossible to set up real-time feedback, continuous assessment of student's actions. This requires presence of a tutor who will provide formative assessment – otherwise, repeating incorrect actions will lead to the consolidation of a false skill. In general, the ability to replace an instructor, to conduct learning process on physical simulators independently, without the participation of educator, is much lower. It is also quite difficult to replicate the same case in physical reality over and over again – there will be always some deviations, nuances, differences. Even well trained experienced simulated patients being humans allow certain discrepancies with exemplary performance. Such variations can have negative impact on the standardization of assessment, which is especially important in high-stakes exams (Staatsexamen, USMLE, MBBS, etc.). Training on a mechanical, physically existing device may require expensive consumables – interchangeable skin, bones, tissue blocks. It is difficult or impossible to organize training on physical simulators in a remote format – to practice a skill or pass a case, the tutorial and the student must be in the same room, interacting with each other. This limitation also applies to the class schedule, it is necessary to provide access for students to the training rooms, to organize the queue, and the schedule for operating the manual. Potential subjectivity in assessment and other human factors inherent in the instructor can affect the objectivity of assessment, compromise students' achievement of a given level of competence. Emotionalism and the involvement of large social groups in learning on physical simulators is also impossible compared to virtual ones.

Thus, the learning process in a virtual environment, in addition to the advantages common to simulation in general, has several unique features inherent in learning specifically in virtual reality.

3.6. Disadvantages of using virtual reality simulation in medical education

At the same time, the prevalence of virtual simulators in medical training cannot be called comprehensive, flowless and impeccable. The variety and scale of application of virtual technologies in medical education, in our opinion, is undeservedly small, especially considering all the advantages discussed above. This is partly based on existing shortcomings and a certain skepticism of key decision makers in medicine and on the other hand is due to natural (system) or temporary surmountable difficulties.

The first and leading drawback, which many users immediately note, is the lack of realism of the SVR. This is especially true for skills trainers that require not only visual but also tactile perception – from CPR simulators to endosurgical virtual trainers. In general, the absence of a detailed "lifelike" similarity does not prevent the solution of the main task – the achievement of educational goals, but it interferes with the emotional perception, the degree of trust of the teacher and student in this technology. They must convince themselves, make them "believe" in the reliability of the training and the effectiveness of the methodology.

To the same disadvantage of haptic helplessness another problem is added on – capturing objects using joysticks-manipulators makes simulating clinical activity in a virtual environment using a VR helmet extremely inconvenient, especially for unexperienced users. Working with these joysticks requires the development of a special skill that has nothing to do with clinical manipulation. Without that kind of VR gamer knack (typical for younger generation), it can take several minutes of excruciating effort just to grab in VR a simple syringe and perform a routine intramuscular injection. This problem can be solved by hand movement recognition, which is already a standard feature, but it does not work without failures and is not yet used in all models.

Unlike face-to-face classes in the clinic, at the patient's bedside, when training in virtual reality, the “doctor model” is very conditional and, as a rule, is limited to demonstrating a sequence of certain actions only. Such algorithm gathering, memorization of the protocol for carrying out this procedure is very useful indeed, but it stands far away from the real role model of the human teacher. Thus, training in virtual reality by its very nature (or better saying due to lack of nature) is deprived of an important educational humanistic component.

In virtual reality, there is no direct communication with a suffering person, a patient. It's difficult to develop empathy towards computer avatar. It is hard to believe in compassion regarding to an ironclad. It is impossible to create in VR truly sensual situations of triage of severely ill or traumatized patients under conditions of lack of time or other clinical resources, euthanasia, transplantation, complex communications. When making clinical or logistical decisions, the user does not face a moral choice, does not learn to take into account the full range of humanitarian and social issues and nuances.

These significant gaps can and should be filled by the combined use of virtual simulators with classical training – at the bedside, in the operating room. Virtual training of the current technological grade is to be regarded as basic preclinical one, laying down the so-called technical skills – knowledge, thinking, procedural competencies, manual dexterity, while "soft skills", in particular those related to interpersonal communication, remain the responsibility of traditional clinical training methods.

The low operating costs of VRS go toe-to-toe with high cost of software product development and overpriced hardware components. Even a simple transfer of classic teaching aids to a virtual environment requires the participation of entire team consisted not only of programmers and 3D modelers, but clinicians also who control, review and correct a virtual product at all stages of development. If the training does not involve mass replication and repeated use of the model is not expected, then it is easier and cheaper to make it on a 3D printer or “in the old-fashioned way” just do it manually from auxiliary materials – cut it out of wood, knit it from wool, mold a model from plasticine, wax or clay or glued from papier-mâché. If the necessary component of the hardware interface is not available on the mass market, then the parts required for many virtual simulators are made only in piece quantities - several hundred or even tens of units. And the software applications themselves do not find distribution in the millions of copies, like ordinary consumer mobile applications. All this leads to an increase in the unit cost of a unit of this type of teaching aids.

Medical content relocated to the virtual environment requires validation after such transfer. Most VRS systems are innovative products that have appeared in medical education only recently. For many of them, the evidence is low, their validity has not been sufficiently studied, and the medical community, being professionally skeptical, is not inclined to rely too much on the reliability of new unfamiliar devices and programs if their use is not supported by a well-composed evidence base. This “healthy conservatism” helps them not to incline to indiscriminately trust discoveries and innovations which may save lives from, slows them down on the way towards innovative, but suspicious for them technologies.

In the context of rapidly changing clinical views and approaches to the diagnosis and treatment of pathologies, it is very difficult for the creators of VRS to organize effective and timely updating of the content of virtual simulators. It often happens that during the time it took to develop, test and debug a virtual simulator, those clinical recommendations that were originally the basis of the product have already undergone significant changes.

Working on VRS, using this technology in teaching settings requires extensive preparation – both the student-user and the teacher need to go through an initial briefing, learn how to work on different virtual systems, turn them on and off, calibrate VR glasses, edit scripts, and export test results. Such activity is far away from routine medical professional competencies, and for some educators, especially of the older generation, work in the virtual world is too complicated, psychologically uncomfortable, incompatible with their real world. As a matter of fact, it is this factor that causes a subconscious, unaware protest, which is clothed in camouflage arguments about the "unrealism, inefficiency, and potential harmfulness" of teaching doctors in a virtual environment.

Some of the high-fidelity VRS, especially simulators for intricate procedures like angiography or endovideosurgery, composed of a complex set of elements – software and hi-tech hardware devices that require technical support and system administration. The organization of such service which is implemented by employees of the engineering and technical service entails additional financial, administrative and resource costs.

The complexity of their technical device predetermines other problems and risks associated specifically with the technological aspect of the use of virtual simulators. So, under the pressure of competitive offers, manufacturers try to speed up the development and implementation of the product in educational practice, deliberately offer unfinished versions of simulators, launch them for commercial use under the designation "beta testing", continuing to refine products already during their operation, "on the fly."

In addition to internal, system errors, VRS like any other high-tech products are subject to technical failures caused by external factors. Some reasons e.g. weak internet signal, low-speed connection, interference from other WiFi devices, a hung operating system can interfere smooth flow of the lesson or exam.

VRS software solutions are not completely autonomous – their functioning depends on the auxiliary plugins, functionality of download portals like Google Play or AppStore, software versions of hardware components, such as VR glasses, version of operating system. Most of these components are developed by third parties and are updated at their own discretion, without approval or prior notice. The more VRS interface and interact with other software solutions, the more failures of compatibility occur.

Difficulties in the development and operation of VRS also depend on the hardware component – mobile devices, interactive panels, tablets, computers, virtual reality helmets. Today, the commercial life of a product is very short, sometimes a few months, rarely a year or two. Components are updated quarterly or annually, and discontinued models that were previously used in the system can no longer be purchased. Obsolete models may cause performance issues, and newer hardware elements may have different specifications that do not match the optimized image, calibrated haptics, or command elements. Entire teams of developers are forced to keep track of these changes and make appropriate adjustments due to the program code malfunction.

The same computer security problems we meet in everyday life are fully correlated with VRS. Hackers attacks dedicated to stealing source code, license activation keys, or users' personal data are daily routine for virtual application developers. This risk, of course, is taken into account by manufacturers, and they install protective systems, monitor user activity and check non-standard requests, but no firewalls and anti-virus programs provide a 100% guarantee of security.

Another previously unexpected shortcoming of medical learning in VR was the physiological incompatibility of a human organism with virtual sensations, a kind of "sensory dissonance" caused by the inconsistency of signals coming from various organs. While the eyes see realistic movement in space, the vestibular apparatus indicates the absence of movement, and our own proprioception system signals the preservation of our position in space. In such controversial situation the central nervous system becomes completely confused, which is expressed in vestibular disorders – dizziness, nausea, overwork and headaches. This happens not only with older people, but also among younger users, especially when using virtual reality devices for a long time. However, for the most users, after short workouts – several hours of total VR use – such "seasickness of the virtual world" disappears.

Another not so rare "complication" of using virtual immersive training is an injury. Scholar wearing VR-helmet is disoriented in real space and may collide with objects in the environment. There are also a number of means of handling with this shortcoming, from visual barriers built by the simulator in virtual reality to physical borders, such as stretched bands, limiting the educational space like a boxing ring but bad stuff still happens.

Thus, the training of health personnel using virtual methods has both positive and negative sides (summarized and formulated in Tables 3 and 4 respectively). However, in general, it is a very promising, budding and rapidly developing field. Every year, the range and total number of devices is growing, which allows using virtual simulation technologies both to practice manipulations – from basic medical skills to the most complex high-tech operations, and master theoretical material – from virtual lessons in anatomy and pathology to clinical thinking and teamwork interaction. The more complex the educational task is, the higher the level of VRS will be used for its effective learning achievement. Examples of such training are becoming more numerous every year, and they are being implemented in an ever-growing quantity of training programs and courses on virtual simulation devices.

Another factor that could contribute to a wider penetration of the virtual world into medical education could be a fundamental revision of the design philosophy of virtual simulators, an attempt not only to satisfy the desire of students and teachers to use more advanced, innovative teaching aids, but also to realize the higher needs of the individual according to Maslow's theory - we will dwell on this in detail in the next chapter.

Table 4: Disadvantages and risks of using virtual reality simulation in medical education

- Lack of realism, distorted reproduction of the real environment, especially sensorimotor sensations during manipulations
- Lack of a "living example" of an exemplary doctor, minor upbringing component
- Difficult to develop a humanistic attitude of the profession, the scholar is not faced with a moral choice
- Low sense of compassion, since there is no direct interaction with a suffering being
- High cost of development of virtual programs and non-standard hardware components
- During development of the content becomes outdated while new clinical recommendations were released
- Insufficient medical knowledge of software developers in combination with poor peer review by health care professionals
- Insufficient or non-obvious validation of VRS
- Considerable efforts are required to learn the operation of high-tech virtual simulators, introductory learning and complex briefings to train teachers and staff in usage of VR equipment
- General distrust of faculty and clinicians to virtual reality in general
- Necessity for IT-staff, technicians, administration, and service
- Technical failures caused by internal (software, hardware) or external factors (Internet, interference, third-party application updates, unavailability of components)
- Computer security, vulnerability of confidential or personal data
- Poor tolerance, vestibular disorders in virtual reality, possible traumas

[Gorshkov MD, 2020, 2022]

4. Maslow's hierarchy of human needs

Abraham Harold Maslow (1908–1970) [Fig. 10], an outstanding American psychologist, published in 1943 his fundamental theory on hierarchy of human needs [Maslow, 1943], where he distributed them onto five levels. This structure was later typically presented and known as "Maslow's pyramid" [Table 5].

Source: wikipedia.org

Fig. 10. Abraham Harold Maslow (April 1, 1908 – June 8, 1970)

In the second edition of his book "Motivation and Personality", author continued to develop his theory and provided more explanations, additions, and comments [Maslow, 1954]. So, important extension was given to the description of the highest self-actualization level: "Cognitive needs" – desire for new knowledge, and "Aesthetic needs" – pleasure from beauty of surrounding objects and natural phenomena, as well as creations in the form of musical and artistic images, works of art. Transcendence of these needs, people's attempt to surmount the physical self in search of meaning, helping others, spiritual practice, and connecting with nature are some of the ways we can meet entire spectrum of these needs.

Table 5. Traditional five levels model of human needs motivating human behaviors

[Abraham Maslow, 1943]

In his final version of the motivation theory, the author expanded the further division of the highest level of self-actualization in the hierarchy into three steps, thus creating a seven-level hierarchy [Table. 6].

Table 6. Seven levels of Maslow's hierarchy of needs

[Abraham Maslow, 1954]

Also, it is worth mentioning that all the needs of both higher and lower levels constitute the fundamental nature of an individual as an integrated whole and cannot be considered separately from each other, although their priority ranking is subject to the principle of relative dominance. “None of the needs arises separately, in isolation from others… and truly important processes are necessarily dynamically interconnected with everything that is important for a person in general", according to Maslow.

His research publication became widely known, its popularity extending far beyond the professional community of psychologists and is more often characterized in literature as "Maslow's Pyramid of Needs".

In marketing, Maslow's pyramid is used for market analysis and audience segmentation. This helps to find out what needs are most pronounced in the selected target audience. Then you need to explore how the audience sees for themselves the satisfaction of a particular need. In the management of personnel, it is used in building ways to motivate employees, in long-term planning to make forecasts about future needs for various goods and services. Understanding the needs of employees, it is possible to apply the most effective management mechanisms for certain groups of personnel.

5. Maslow's motivation theory applied to medical education

An individual with unsatisfied basic physiological needs won't think of high matter, just like a man choking in the fire only seeks salvation, or a stranger dying from thirst in a desert has no other dream but a glass of water. It is no coincidence that Abraham Maslow created his theory during the Second World War, when the visible threat of physical destruction was hanging over all mankind and personally over him, a man of draft age. However, just a glimmer of hope underpinned by vaguest improvement of living conditions and the slightest hint of comport would pull the trigger and urge an individual to seek friendship, love, strive for recognition, creative fulfillment, and self-actualization. As Maslow put it, "it is a mistake to think that the all the needs lower down the pyramid must be 100% satisfied before the next need emerges. It would be more appropriate to say that the degree of satisfaction de-creases as an individual moves up the hierarchy pyramid".

In medicine, the process of mastering a profession, especially the initial educational stage (graduation diploma and initial postgraduate specialization), takes up a significant part of the future doctor's life, mental effort, and endeavor. This period is not merely important, but also relatively long, as no less than a third of a future doctor's life has already been devoted to studying at university and residency! In a matter of fact, the university years are just the time when young people, as a rule, begin to meet their own needs by themselves, without or with limited assistance of their parents. Once they have entered adult life, this task becomes their own responsibility. Students begin to satisfy not only their basic needs, but also shape their own mindset, define their individual safety and security principles, make friends, seek love and recognition, explore the world around them. And while their knowledge acquisition and high notes are very important to them, many other desires and aspirations are not completely superseded by learning, and the needs of all levels without exception must also be met during their long, multi-year period of medical study. "The life must go on!".

The University of Bologna [Fig. 11], the oldest in the world founded in 1088, still uses another name given to it centuries ago – *"Alma Mater Studiorum"* ("Nourishing Mother of studies" or "Mother who feeds the students"), and the graduates of colleges or universities are called *"alumni"* (Latin for "those who have been nurtured"). This emphasizes the fact that university gave its students not only knowledge, spiritual food, but also earthly, fleshly food, satisfying their needs all around.

Source: Maxim Gorshkov

Fig. 11. Bologna University, Palazzio Archiginnasio

Alma Mater, classical full-time university provides conditions that are necessary to meet needs of an individuum – from basic till the highest.

As for *basic needs (food, house, health)* student receives a scholarship, lives in a student domicile often provided by university, attends of lectures and practicums, goes in for sport in gyms, undergoes annual health examinations in a university out-patient clinic.

By satisfying the need for *safety (job, career, order, security)* the student understands that his current efforts are laying the cornerstone for the future professional career that will provide life-long high social and financial status, respectable and interesting job. Scholar studies in a safe environment and if all requirements will be fulfilled his/her professional future is secured and guaranteed.

Socialization (friendship, love, communication) flourishes during the period of study: a student is surrounded by peers and mentors, participates in sport games or competitions between faculties and other universities. Friendly or romantic relationships arise during the scholarship years, and often last throughout rest of the life.

The esteem needs (success, reputation, recognition, status) is targeted right away by getting the prestigious status of a "future doctor", by full respect from their parents, relatives, former school classmates and new friends. Student can hold a formal or informal leadership position in a group or faculty as a chairman of the student council or captain of the sports team. Well-performing scholars can be justly proud of their high grades and even be rewarded for them in the form of diplomas, incentives, awards, grants, or scholarships.

The pursuit of knowledge (*Cognition, exploration, understanding, research*) is satisfied by gaining unique insights into human body and its pathological processes, learning how to heal patients. At some point the future doctor extends the scope of own activities specified in the syllabus, takes additional clinical shifts and training sessions at simulation center, even performs independent scientific research under young-scientist programs *(Self-actualization, self-development, independence, creativity).*

Thus, like any other kind of human life, medical education system in its traditional form can provide the student with all needs in terms of Maslow's hierarchy [Table 7].

Table 7. Seven levels of Maslow's hierarchy of needs applied to medical education

Level	*Needs in Maslow's Hierarchy*	*Needs realization in the University*
7. Self-actualization	Self-actualization: self-development, originality, autonomy, freedom, independence, transcendence.	Self-development, independent problem solving, personal growth under self-paced trace during medical study
6. Aesthetics	Aesthetics, beauty, art	Social student life offers many cultural and aesthetic events and phenomena
5. Cognition	Exploration of the world, understanding of the essence of things and phenomena, creativity	Learning new things, reaching beyond the traditional curriculum, scientific research
4. Recognition	Esteem needs. Success, reputation, recognition, respect, status, prestige, positive image	Student belongs to highly respectable social community. High academic achievements cause respect among groupmates, friends, parents and relatives
3. Social needs	Love, friendships, acceptance, and socialization – belonging to the family, team, group, confession, professional society	Student years offer unprecedent possibilities for social life, friendship, belonging to the student corporation (Germ. *Zunft*), fraternities and sororities, communication with groupmates and teachers
2. Security and Safety needs	Peace, security, order, control including available high quality health care system, and financial security (home, job, income, pension)	Gain knowledge and skills in secure environment to get a good grade at the test, current examinations, and high stakes certification exams
1. Basic needs	Fundamental ("physiological") needs. Food, clean water and air, appropriate temperature, clothes, reproduction (breeding, sex).	Study medical specialty, become professional, get medical degree – basic need and function of medical education

[Maxim Gorshkov, 2021]

Large-scale modification or replacement of the presence phase of study mode with an external or distance forms will not only change the formal format of educational process but will interfere with other aspects of the student's life also, sometimes in a very significant, painful way. An average student spends much more time at university with mates and teachers than at home, with his relatives or alone in his domicile room. So, stress caused by the lack of their habitual microsociety when switching from traditional classic presence way to online learning mode, can hardly be overestimated. Evaluation of anxiety, stress and the quality of life showed an overall detrimental effect of distance learning on the medical students [Demirekin BZ, 2022]. Moreover, some students were forced to stay in the hometown, as there was no need for relocation, so they stopped communicating with the most of their groupmates in person and dropped out of the student community.

At the same time, obvious benefits of distant learning could not be ignored. Thus, moderate to strong correlations were found between the item "Zoom lectures have reduced stress compared to in-person lectures" and preference for Zoom, quality of education using Zoom compared to the in-person lectures, belief that Zoom lectures should continue as part of the curriculum delivery method, staying motivated with lectures fully online with Zoom, and liking that Zoom lectures save commute time to campus [Altaf, Rida at al. 2022].

Consideration of unavoidable negative consequences of VRS and their on-time compensation should be taken into account when creating virtual medical education curricula, especially if their remote use is planned. Virtual learning environment should be regarded as an essential part of the individual's microcosm, a place of their daily pastime intended to satisfy all the needs of their personality, just like in face-to-face learning.

6. Maslow's theory applied to medical education in virtual reality

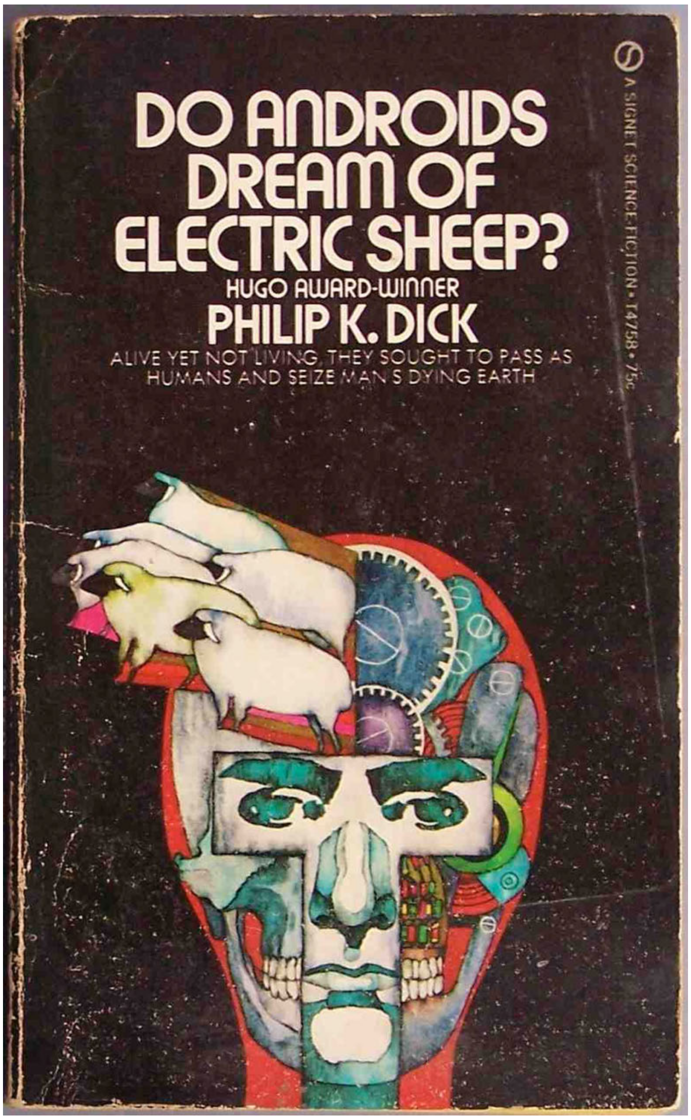
Despite obvious and indisputable advantages of virtual methods of learning and teaching described above and multiple efforts to integrate it into medical education system, its usage was relatively limited until the year 2020, when the coronavirus pandemic broke out, and the use of digital technologies in medical education began to grow exponentially. In fact, that distant learning outbreak was similar to explosion – swift expansion and relatively rapid collapse a year after, return to the status quo level. Will digitalization in medical education remain at a precedent level as the epidemiological threat abates? Is virtualization of learning a natural process or is it a temporary phenomenon imposed provoked by quarantine regulations only? Will the prevalence of digital technologies in education remain the same or will it drop to the levels observed before the pandemic?

Apparently, technological and methodological advantages and disadvantages of traditional and innovative training methods will not be the only factors to influence the use of IT technologies in education; subjective features such as motivation of the participants of educational process based on the students' and teachers' needs will also be of critical importance. If virtual systems will be able to respond to all of their demands and satisfy all of their needs, from the basic to the highest, the ubiquity of digital technology will become inevitable.

In the previous chapter we discussed possibility of realization of all seven levels of needs of the individual in the conditions of receiving higher education at the university, the higher school of medicine. Alma Mater Studiorum provides students with all the conditions and prerequisites for this – from the basic, fundamental needs (medical education confirmed by diploma necessary for their future profession), to the self-actualization and transcendence, especially in the final years of higher education. So, what happens when the focus shifts from face-to-face learning – attending lectures, anatomy theaters, and clinical classes – to a virtual and distal format? Does the introduction of virtual simulators deprive of something important, not only in professional and educational, but also in social and human terms? The current Chapter aims to discuss learning in a virtual environment from the perspective of Maslow's Theory of Hierarchy of Needs.

6.1. Do medical students dream of electric patients?

In 1968, Philip K. Dick wrote a book "Do androids dream of electric sheep?" [Fig. 12], which was later adapted into the popular movies "Blade Runner" and "Blade Runner 2049". Androids' dream of a status object, an "electric sheep", implies satisfaction of basic needs in the future world and thinking about deep things not only among humans, but also among cyborgs [Dick, Ph. K., 1968].



Source: flickr.com/photos/cdrummbks/3809652408

Fig. 12. "Do androids dream of electric sheep?" by Philip K. Dick

Paraphrasing the writer, in terms of medical education using simulation in virtual reality we can ask: "Do students dream of electric patients?". Would today's students appreciate the use of 3D human models when it comes to studying human anatomy, would they use PC atlas to study histology, or smartphone headphones to train auscultation skills, or a virtual patient to perform differential diagnostics? Or would they prefer the traditional physical learning methods we all used to?

Many who have experience in introducing informational technologies into the educational process noted that, to their surprise, students are often reluctant to use scientific materials developed and recommended by the university, turning for consultation or lecture to “Doctor Google” or "Professor Facebook" instead. When studying the structure of the human body, they may address not to the textbooks like "Grey's Anatomy” or “Sobotta”, but to sources like “YouTube's Anatomy”, which are often of low scientifical and didactical quality, unstructured and sometimes even misguided.

Obviously, providing educational product of high educational value, even if it is innovative, high-tech, approved by the Academic Council and strongly recommended by the head of the department, is only half of the battle. A paper textbook converted into electronic format becomes an electronic version of a textbook only, like “hardcover, paperback and Kindle” options of the same book, not a genuine virtual educational product. A classic face-to-face lecture recorded on video becomes a video lecture, but not a digital teaching product. It is not a secret that online courses and computer programs are often introduced at the initiative of the University administration, which means that the already available technologies, old software products, ready-made solutions and available teaching faculty qualifications will prevail over the students' needs when it comes to the course development process.

Such online courses typically lack the components of communication, interactivity, encouragement and learners' recognition. Abraham Maslow emphasized the importance of “focusing on problems, not methods” [Maslow A, 1943]. Mastering any brand-new method often leads to the desire to push the boundaries of its intended use, and at the same time, boils the process of solving any problem down to the use of one customary method. As once Maslow expressed “If the only tool you have is a hammer, [you] treat everything as if it were a nail” [Maslow A, 1966].

This is even more surprising considering that long ago social networks have replaced in some areas most of the components of communication, interaction, recognition, and self-actualization, especially among young people – that generation that now graduates from high schools and gymnasiums and study in universities. The triumphal march of social networks and specialized online communities is precisely based on the possibility of successful replacement of the real world.

People share their ideas, opinions, comments and conclusions through *Twitter*[26] and *LiVEJOURNAL*[27], initiate petitions and collect signatures on them through *Change.org*[28], read and comment on news on *Reddit*[29]. Some social networks specialize in specific social, age or professional audiences. Many people's job searches and career paths are inextricably linked to *LinkedIn*[30], *Xing*[31] and *Facebook*[32]. Young people connect, share, and become millionaires on *SnapChat*[33], *Instagram*[34], *Tumblr*[35], and *TikTok*[36]. IT-professionals use code hosting services for developers to collaborate on the projects they are building in *GitHub*[37], DJs and musicians "live" in *SoundCloud*[38], illustrators and animators use *Flickr*[39], *Pinterest*[40], and *EyeEm*[41], artists exchange ideas and post photos of their paintings for sale in *DeviantArt*[42].

There are social networking sites in the medical field as well, both for patients and healthcare professionals, with some combining both audiences. London-based *HealthUnlocked*[43] is according to their statement the world's largest virtual patient community. It is social platform connecting 1.3 million patients, representing over 300 diseases and conditions. The next example of medical networking solution is *Sermo*[44] that engages more than 1.3 million Health

[26] Twitter Inc., San Francisco, CA, USA
[27] LiVEJOURNAL is a trademark of Rambler and Co., San Francisco, CA, USA
[28] Registered by Change.org, San Francisco, CA, USA
[29] Reddit, Advance Publications (majority shareholder), San Francisco, CA, USA
[30] LinkedIn Corp., Sunnyvale, CA, USA
[31] Xing, Hamburg, Germany
[32] Facebook, Meta Platforms Inc., Menlo Park, CA, USA
[33] SnapChat, Snap Inc., Santa Monica, CA, USA
[34] Instagram, Meta Platforms Inc., Menlo Park, CA, USA
[35] Tumblr, Automattic Inc., San Francisco, CA, USA
[36] TikTok, ByteDance Ltd., Beijing, China
[37] GitHub Inc., San Francisco, CA, USA is a subsidiary of Microsoft Corp., Redmond, WA, USA
[38] SoundCloud Global Limited & Co. KG, Berlin, Germany
[39] Flickr, SmugMug, Mountain View, California, USA
[40] Pinterest Inc., San Francisco, CA, USA
[41] EyeEm, Talenthouse AG, Baar, Switzerland
[42] DeviantArt is a subsidiary of Wix.com Ltd., Tel Aviv, Israel
[43] HealthUnlocked Holdings Ltd., Altrincham, Cheshire, UK
[44] Sermo Inc., New York, NY, USA

Care professionals across 150 countries (according to company's data) that offers online community of clinicians to communicate about medical issues. *Doximity*[45] is another professional social site with over half a million users. It targets U.S. based physicians in all specialty areas and is also dedicated to the pharmacists, physician assistants and nurse practitioners.

Vast and rapid introduction of IT technologies is impossible without the consistent desire of the trainees to use informational technologies and virtual reality environment in their studies. Lack of interest, curiosity, motivation on the part of the trainees can lead to a passive boycott, silent protest that even the control and constraint mechanisms built into the digital device cannot over-come. And if the creators of medical virtual learning platforms manage to combine features that fulfill the basic needs of learners with components aimed at meeting the needs of higher levels, then the ubiquity of these systems in medical education will be inevitable and will only be a matter of a short period.

However, before making such a recommendation, it is necessary to discuss and confirm the hypothesis about the constructive ability of virtual reality medical education systems to satisfy all students' needs. To do this, it is necessary to dissect each level of the hierarchy in relation to them, to analyze virtual learning aids in terms of Maslow's theory of hierarchy of needs.

6.2. Extrapolation of Maslow's hierarchy of needs to virtual learning

Let us discuss level by level, if and how all individual's needs can be met in virtual medical educational systems.

1. The *basic needs* of individuum within the framework of "medical student" are to obtain an officially confirmed medical education - the realization of the intention to become a doctor, the acquisition of all the necessary knowledge, skills and receive a diploma of higher education according to the rules of the country (location) of future medical practice. Ideally, all

45 Doximity, Inc. HQ, San Francisco, CA, USA

educational materials should not only correspond to the current level of medical knowledge, but also have appropriate certificates or other documents confirming this fact, issued by an authorized body. Thus, the digital learning material in order to implement basic needs must comply with national clinical guidelines, the current level of medical knowledge, approved in this university program and be recognized by its teachers and administration. In other words, the completion of a training course or program must be noted by the issuance of an official diploma, certificate or CME points, just as if the course was taken not in virtual reality, not online, but in a medical school by physical presence.

2. *Security, safety needs*. The educational organization is obliged to create safe environment for studying, getting a profession. In the distance (and often in virtual) learning format, student is essentially responsible for his or her own physical safety. However, the concept of a "Safe, secure learning environment" is not about physical safety only, it is much broader – didactical, psychological, social, mental. Will a textbook be "safe" (reliable) if a student fails to pass an exam after thoroughly studying it? Is it possible to call a practical course as "secure" if after its faithful completion a student fails at the practical test? The university is responsible, among other things, to provide trainees with a full, high-quality learning environment in the broadest sense of the word: recommended (provided) textbooks of the best available level in adequate quantity, provided sufficient access to the anatomical theater, histological specimens library or atlas of medical images. In the case of virtual education, the system must be guaranteed full and effective mastery of the required knowledge and skills, necessary to pass current and final assessments so that the student feels safe and secure. If virtual materials will not be enough to pass the graduating exam, or their quality and composition will not meet the requirements of the examiners, then the trainee will justifiably experience anxiety, worry, as when there is a real physical threat. Thus, for an individual to feel calm and confident about the virtual simulator, it should provide training material of high quality, with a clear and logical presentation in it, the system should use modern interactive techniques for effective acquisition of theory and practical skills, while the presentation of the material should correspond to the official position of future examiners.

3. *Socialization* suffers the most when learner shifts to distance education. Implementation of informational technologies into the educational process naturally cuts off the student from physical communication with their groupmates and teachers, replaced, at best, by a mosaic of windows with listeners' faces in zoom.

Students try as much as they can to fill this belongingness gap by every available means, discussing educational and personal issues at their free time through social networks, instant messengers, chats and video meeting applications, thereby prompting the development of new digital solutions to this educational problem.

The conclusion suggests itself that virtual platforms in which the students study on their own for long periods of time – alone, deprived of communication with classmates and friends – should be equipped with the functionality of social networks allowing them to compensate for this social vacuum.

Family psychologists claim that "the most unhappy people in the world are eighteen-year-old girls." But the first semesters are no less difficult for new students! They are the most unsure of themselves, those first-year students, exhausted by the race of abitur class-works, final tests and entrance examinations to a medical university, now hesitantly trampling around in the university campus, thinking about what place in the lecture hall they should take, which group of classmates to join, and handle right pathway in the social hierarchy of senior students and professors facing them in the next ten-twelve semesters. Many of them have just parted ways with their parents, younger siblings, classmates, and friends from their street. This sudden loss creates anxiety, social isolation, sadness and even depression in them. And, on the other hand, the resulting emptiness gives rise in their soul to a huge craving for new social contacts, friends and mates.

Therefore, in virtual systems, it is important for students to be able to communicate within its framework, without going beyond it, without switching to other applications and devices. For this, identification account is a prerequisite – creating a profile with basic data (this does not have to be personal information – perhaps just having a nickname and avatar is enough). More advanced profile options – posting a photo, indicating a group, course, professional and personal interests, achievements in studies and in this virtual application – allow you to realize the function of self-presentation and recognition by other members of the virtual community, to grow friends. In any case, it is important that profiles could be grouped on the basis of administrative division by university groups or by interests, specialization, and the interests. The profile allows you to identify the author of comments, conduct conversations, dialogues, divide messages into public, group or personal.

Another important feature of socialization is group activity, team interaction – from cooperation in achieving joint goals, for example, joint viewing of video materials, virtual lectures, distance learning, conducting group student projects, sharing interesting educational materials, to such topical educational tasks as conducting team trainings (practices). Already today, a number of virtual platforms provide a multi-play mode in which a group of users collectively go through a simulation scenario with elements of group collaboration, crew resource management, etc.

The opportunity to communicate with peers and like-minded people, along with socialization, is also an emotional outlet. In the course of communication there is a place for laughter, joy, delight, there is an outlet for indignation and fear – these feelings are priceless – in the Procrustean bed of everyday life devoid of emotions, filled with intense study sessions.

4. *Esteem needs*, recognition of the individual's achievements, respect from other people, confirmation of high social status – all this is impossible without mates, friends, associates, and even tutors and teachers. Like in a mirror, students reflect these achievements in their minds and opinions.

Without fans, a singer would not know whether their new song is a hit or not. A writer cannot just create manuscripts and hide them in the drawer – he needs readers. Without a red carpet with crowds of photographers a movie-star will never feel own celebrity status. But all that can be totally virtual reflected by number of likes in under YouTube clip or number of printed copies sold (never seen real crowds of viewers or readers at all).

So, meeting the need for esteem requires the presence of both components, that is, assessment of the achievements (prix, medal, grade, score points, award), and also publication of the information about success among the target audience, bringing this information to fellow students, friends, teachers, and above all, obtaining feedback from them in one form or another (an emoticon, a "like", an "excellent" grade, becoming a tutor or moving up to the next year of study).

5. *Cognition*, at first glance, obviously can be realized through implementation of digital technologies – by virtue of its nature, it was dedicated to this main purpose – to bring knowledge and skills. However, there is more to this than meets the eye. The mechanical process of memorizing an incoherent set of information, formulas, cramming Latin terms, recipes or dosages cannot be regarded as a process of "cognition". Only self-directed study of

the relationships between phenomena, detection of correlations, prediction of the consequences of actions are real drivers of real cognition process which make a person feel content.

Students and residents, as adults, are taught according to the principles of andragogy, formulated by Malcolm Knowles in 1967. To mention just one, the process of acquisition of knowledge and skills should come together with a clearly formulated goal, rely on the initial basis, remain under control of the trainee, be specific, relevant, focused on solving applied problems. A virtual training aid can only be regarded as meeting all adult student's cognition needs if the above principles are observed. Only self-paced and self-directed cognition brings emotional satisfaction, not just memorizing facts, terms or schemes, but analyzing this information, bringing himself to the upper level of comprehension, making discoveries – this is what was meant under "cognition" by Abraham Maslow.

6. *Aesthetics* and virtual technologies go hand in hand. A simple, convenient, effective program is always beautiful, evokes a sense of aesthetic pleasure, delight and admiration. Steve Jobs, founder of Apple, said that "design is not just what it looks like and feels like. Design is how it works" [Walker R, 2003]. Nice application is not distinguished by sparkling fonts, intricated logos or sophisticated animations. When we talk about aesthetics of a virtual program, we are referring to its extensive functionality, well-considered smooth educational process and user friendliness.

The best servant fulfills his master's wish before he says it out loud. The best learning media is that one in which learning occurs unobtrusively, with joy and pleasure. This applies first and foremost to the user interface – the beauty of which lies in functionality and convenience.

Another interesting aspect of the aesthetic need fulfillment is pleasure and fascination, which can be achieved with the introduction of game technologies into learning. If the application primarily is a game, or learning takes place in a playful way or game environment, such educational process is destined to be effective and fruitful, and its results will be profound, thorough, and long-lasting.

7. *Self-actualization* is the top level of Maslow's pyramid, reflecting a person's desire to fully identify and develop his talent, realize his/her potential, become the best one can be or wants to be – not in the eyes of surrounding crowds but in owns mind. Not everyone can reach this state, although the environment plays a secondary role in accomplishment of this goal.

However, proper designed virtual educational product ensures satisfaction of the needs the pyramid including cognition, exploration and professional growth beyond the specified scope – transcendental properties which are necessary for self-development and self-expression of the individual.

If on top of that the student can create his own projects, clinical cases, or cures, then this functionality of creativity is sufficient for personalities ready for transcendence, to satisfy his need within this virtual environment.

Table 8. Extrapolation of Maslow's hierarchy of needs to virtual learning environment

Level	*Needs in Maslow's Hierarchy*	*Medical education VR-Systems*
7. Self-actualization	Self-actualization: self-development, originality, autonomy, freedom, independence, transcendence.	Self-development, independent problem solving, personal growth, scientific research in virtual reality
6. Aesthetics	Aesthetics, beauty, art	Aesthetics of VR App – beautiful and awesome. It's simply cool! Nice and playful functionality brings pleasure even during learning process in VR
5. Cognition	Exploration of the world, understanding of the essence of things and phenomena, creativity	Learning new things, reaching beyond the traditional curriculum, analyzing facts, and getting to new knowledge level
4. Recognition	Esteem needs. Success, reputation, recognition, respect, status, prestige, positive image	High academic achievements cause respect among groupmates, friends and relatives, other digital environment users clearly displayed and presented in VR
3. Social needs	Love, friendships, acceptance, and socialization – belonging to the family, team, group, confession, professional society	Communication within VR with friends, mates, tutors and teachers, exchange of views, create communities, complete collaborative projects
2. Security and Safety needs	Peace, security, order, control including available high quality health care system, and financial security (home, job, income, pension)	The VR Simulator offers learning materials in the quantity and quality to give students the confidence and composure that they will score high on a test, midterm, or final exam
1. Basic needs	Fundamental ("physiological") needs. Food, clean water and air, appropriate temperature, clothes, reproduction (breeding, sex).	Designed to fulfill basic need –providing information and other functionality for getting knowledge and skills necessary to learn a profession, graduate from university and get a job

Maxim Gorshkov, 2021

Therefore, when it comes to medical students and residents, we can say that a carefully thought-out digital training aids allow learners to realize all of their needs, from the lowest (to study, become a doctor, receive education) to the highest (to communicate, learn, recognize and be recognized, appreciate beauty and comfort, develop their own personality) [Table 8].

So, do students dream of electric patients? Yes, they do, but only of those created with intention, meaning, intelligence and love for creation! Students dream of virtual training solutions that would meet all their needs without exception, from basic to the highest ones.

6.3. Twelve Roles of Medical Teacher

Almost a quarter of a century ago Ronald Harden et al. formulated twelve roles for the medical teacher [Harden RM et al, 2000]. The description of the roles and their relative importance rated by 251 medical educators [see Table 9]. Interestingly, later, after almost twenty years, apparently given the rapid and significant changes in the world as well as in medical education, Professor Harden attempted to rethink these ideas and co-authored with Pat Lilley the book "The Eight Roles of the Medical Educator" [Harden RM, 2018].

In our opinion, the global introduction of virtual technologies into the educational process will continue to be accompanied by a radical revision of these roles, since the performance of some of them will be taken over by a virtual tutor – significantly or even completely.

Considering which version should be taken as a keystone for the further discussion we have get an impression that to this day it is the first version that is more commonly cited not the remastered one (who knows, perhaps for teachers the idea that they play twelve roles rather than eight seems more appealing).

Even though there are two versions of the interpretation of roles, the first one is still more common and widely cited, so let us use the original version as a base for the further discussion and refer to the first of them below.

Table 9. Twelve roles of the medical teacher and their relative importance

Group	Role	Importance
Information Provider	Lecturer in classroom setting	3.6
	Teacher in clinical or practical class setting	4.2
Role model demonstration	On-the-job role model	4.2
	Role model in the teaching settings	3.6
Facilitator	Mentor, personal adviser or tutor	3.5
	Learning Facilitator	3.8
Examiner, Assessor	Planning or participating in formal examinations of students	3.9
	Curriculum evaluator	3.6
Planner	Curriculum planner	3.8
	Course organizer	3.9
Resource Developer	Production of study guides	3.5
	Developing learning resource materials in the form of computer programmes, videotape or print which can be used as adjuncts to the lectures and other sessions	3.6

[Ronald M. Harden, J. Crosby, 2000]

Let us discuss, which role can be taken and fulfilled by virtual creature – digital teacher, virtual tutor, assistant – as good as it can be done by a human being, todays medical educator.

6.3.1. Information Provider

Virtual simulators are capable to provide information and explain new material to students, show practical techniques, and communicate the algorithm of manipulations performance. For these purposes they are equipped with interactive lessons and courses, educational videos and animated 3D materials. So, that assumes that roles of "*Lecturer in classroom setting*" and "*Lecturer in clinical or practical class setting"* according to Harden can be intercepted by virtual systems.

Moreover, modern information resources with interactive 3D features offer informational materials of higher quality than lecturers often. Recognizing this, many teachers are actively using videos and interactive virtual aids in lectures and classrooms already – sometimes among their functions remains just pressing the START and FINISH buttons (however, a good teacher always enjoys the opportunity to comment on and supplement the material being shown).

As for transferring practical skills in the classroom or in clinical settings, the field of activity of the modern educator is already significantly narrowed today and this activity gradually transfers into the walls of the simulation centers, especially at the early semesters. A narrative about the algorithm for performing a manipulation is not as effective as a showing it. Of course, a live demonstration can be videotaped and viewed by the student at his/her convenience, which is happening more and more often. As for the second part – repeated independent performance for confident mastering of the skill, there are also limitations. In order to avoid risk and discomfort for the patient, more and more practical manipulations and skills nowadays are mastered using simulations, including those in virtual reality.

Yes, the most thorough and profound training is conducted by the "real" teacher. For deeper understanding and memorization as well as confident mastery of the practical skills, some interaction techniques are applied – such as the one proposed by J.W. Rodney Peyton.

The author formulated four obligatory phases of mastering manipulation:

1. Demonstration of manipulation by the teacher;
2. Deconstruction of the manipulation into individual steps with their separate execution accompanied by explanations;
3. Comprehension, with the teacher following instructions from the student while performing the manipulation;
4. Performance of the manipulation by student while saying each step out loud.

[Peyton JWR, 1998].

After initial level of manipulation is mastered, manipulation should be practiced until automaticity is achieved, which requires several more steps: assessment, correction, and repetition till the level of competence and confidence.

Even though such interaction with teacher is very high-quality and brings the best results, one cannot use it always – by numerous practical and economic reasons. Nevertheless, virtual systems have already come close to implementing this model in the skills training, providing demonstration, deconstruction, comprehension checking, and repetition of exercises with their evaluation and correction [Fig.13].

Source: Maxim Gorshkov

Fig. 13. Repetitive laparoscopic skills training with automatic computer assessment

6.3.2. Assessor

Formative and summative assessment is one of the primary roles of the teacher. Only by controlling the degree and accuracy of mastering the material, as well as by making corrections to his/her actions, one can be sure that the student has fully mastered the program and is competent to perform professional functions. In order to make this assessment as clear, structured, and less subjective as possible, the already mentioned Professor Ronald Harden published an article in the British Medical Journal in 1975 about assessing clinical competence in the form of an Objective Structured Clinical Examination – OSCE [Harden RM et al., 1975]. This fact alone speaks of a systemic deficiency, the inability of an individual to suppress his own human essence, and only attempts to bring structure and standardization into the assessment done by subject can increase the degree of its objectivity. The assessment made by humans will always suffer from "assessment bias" – deviations from the standard, have subjectivity in relation to the various examined learners. Assessment bias has the potential to affect a learner's future career and sense of self-worth especially if it concerns high stakes exams. Computer assessment is devoid of these disadvantages – a virtual simulator will clearly determine time, speed, blood loss, dexterity, accuracy and any other of hundreds of conceivable parameters of clinical competence. Virtual simulators are already used today not only in formative, but in summative assessment also, in final, including high-stakes examinations (the role «Planning or participating in formal examinations of students») – from the USMLE in the USA till the State Final Attestation exam in Kyrgyzstan [Fig. 14] – in different parts of the world [Dillon GF, 2002; Minty I, 2022; Bugubaeva M, 2022].

Of course, at today's level of technology development, this mostly refers to technical skills or clinical reasoning – a machine is not yet able to compare with the human assessment of professionalism in the field of communication with a patient or team interaction. But the pace of development of Artificial Intelligence systems gives hope that this may come in the coming decades or even years.

Source: Makhabat Bugubaeva

Fig. 14. Student exams a patient in DIMEDUS virtual clinic (Osh Medical University, Kyrgyzstan)

6.3.3. Planner and Resource Developer, Facilitator

Many virtual simulators offer trainees ready-made curricula, holistic programs compiled by leading experts. Those curricula have undergone multi-stage review and validation during their creation and testing (the roles of «Curriculum evaluator», «Curriculum planner», «Course organizer», «Learning facilitator», «Production of study guides», «Developing learning resource materials in the form of computer programs, videotape or print which can be used as adjuncts to the lectures and other sessions» according to R. Harden).

One must admit that it is impossible for a teacher alone to compete with the group of experts on different fields. Virtual systems incorporate results of such collective work – after all, these teams consist not only of clinicians, but psychologists, UX-specialists (researching user experience), teachers, programmers, 3D-modelers.

During the educational session the user's manipulation, action, or clinical problem solving is corrected by the virtual simulator through scoring or another form of feedback, via *formative assessment*. While mastering the training material by trainees a simulator can adjust his/her individual learning curve, changing the speed and level of complexity of presentation of the material depending on the depth and quality of its assimilation (the role of «Mentor, personal adviser or tutor»).

6.3.4. Role Model Demonstration

Only two of the twelve roles remain outside the range that virtual systems can play today successfully – «On-the-job role model» and «Role model in the teaching setting». Current level of available virtual technologies does not provide us with such highly realistic role models so far, only a person can serve as a such one for another individual, only a human mentor can set an example for the students of how one should and can perform one's professional duty especially in complex psychological and moral settings. Nevertheless, if by performing the "role in the clinic" we mean inanimate algorithm of actions in a standard situation, then mastering such a script is also possible in a virtual environment.

Thus, ability of virtual systems to fulfill twelve roles of medical educator at the present level of technologies is summarized in the Table 10 bellow.

Table 10. Ability of virtual systems to fulfill twelve roles of the medical teacher

Group	Role	Virtual Teacher vs. Human
Information Provider	Lecturer in classroom setting	Better than human
	Teacher in clinical or practical class setting	As good as human
Role model demonstration	On-the-job role model	Worse but possible in some cases
	Role model in the teaching settings	Worse
Facilitator	Mentor, personal adviser or tutor	As good as human
	Learning Facilitator	Better than human
Examiner, Assessor	Planning or participating in formal examinations of students	Better than human
	Curriculum evaluator	Initially a human is needed. Repeatedly better
Planner	Curriculum planner	Better than human
	Course organizer	As good as human
Resource Developer	Production of study guides	Initially a human is needed. Repeatedly better
	Developing learning resource materials in the form of computer programmes, videotape or print which can be used as adjuncts to the lectures and other sessions	Initially a human is needed. Repeatedly better

6.4. Do teachers need VR?

Of course, none of the roles of a teacher can be completely replaced by a computer. That is why the above-mentioned substitution of a teacher by a virtual tutor should not be taken literally, directly, but as a potential vector of development. Some points the teacher will want to explain in more detail, some topics may be more or less relevant due to local geographical, cultural, endemic or epidemiological reasons, and the training course should be adjusted accordingly.

In our view, the situation will evolve in the same direction as in other areas of human development. Computer technology coming to the aid of medical education will allow the teacher to get rid of routine, standard, monotonous, non-creative activities. There is no need to explain the same theoretical material over and over again, to show hundreds of times the same techniques and manipulations, to ask boring, though important, test questions or monitor the correctness of the algorithm for performing standard operating procedures.

Even now, in the system of training health care professionals, the devices and platforms of independent mastering by students of certain basic medical manipulations and even entire interventions is quite wide (in the majority of manual medical specialties and basic general practical skills), although not complete, fragmentary. So far, although their list is not complete, the gaps between them are being filled very quickly, and with the same high rate of development, in a few years there will not be a single manipulation or procedure in the medical study of students and residents that could not previously be studied and mastered in a virtual environment. The educators will be able to focus on complex concepts, creative discussions, development of clinical thinking and action in non-standard situations, review unique clinical cases, and teach how to solve non-standard situations.

And it is this ability to concentrate on such creative interesting tasks, leaving routine duties to virtual systems, that allows us to argue that teachers, like students, are dreaming of electric patients and digital assistants.

6.5. Main characteristics of medical VRS and practical recommendations for developers

At the end of this thesis, let's revisit the question, why does it all matter? For what reasons should virtual learning systems meet the human needs of students and faculty? Why do the developers of these systems must consider these needs?

Maslow's hierarchy doesn't just describe what people want (or need) to have. These needs are a kind of driving force behind human behavior, they dictate and motivate human performance, and these driving forces should not be underestimated.

Andragogy tells us that effective adult learning is possible only if involved individuals are motivated. Without a purposeful and conscious desire to master the subject, without structured activity, the explicit goal and strong desire to improve performance during process of "deliberate practice" [Ericsson, 1993] the disciples' time, effort and energy will be directed to other, more important for them areas, including avoiding this "unnecessary", time-wasting training.

The problem of insufficient, undeservedly small usage of virtual technologies in medical education, discussed above, can be solved by changing the design and construction of medical training virtual systems. Significant transfer of medical education to virtual reality is possible only if learning tools can meet most or all the needs of the individual.

Based on the described above facts and discussions, we can formulate the main characteristics and practical recommendations for the design, functionality and list of the most important components of medical virtual reality simulators.

1. VRS should have a clear focus on solving the main task, **basic need** – gaining knowledge and skills on a given medical discipline, subject, topic. This requirement is not as obvious and self-evident as it might seem at first glance. Yes, with the help of VRS, the main task of obtaining relevant, modern knowledge that corresponds to the formulated learning goals should be solved. This knowledge and skills should be based on up-to-date clinical guidelines and protocols (which are constantly being revised!), and the level and quality of knowledge should be comparable or higher than what would be obtained using classical, traditional teaching approaches.

2. User confidence (and hence **safety, reliability**, peace of mind) lies in the fact that VRS should not only provide knowledge and skills, but also give them in the proper form, definitions and sufficient volume that will guarantee to get relevant CME credits, pass test or exam. Thus, there must be a clear, precise correlation between the curriculum of the virtual course and the requirements formulated by the institution or national/international educational system.

In order to guarantee passing the exam and getting a high mark on it, training should be oriented to the student. It should be individualized and take into account the peculiarities of the assimilation of the material by the individual. It is necessary not only to check good mastery of the curriculum by the student, but also to evaluate the retention of knowledge regularly. This means that formative control should be constant, repeatable and include not only recently covered topics, but also previously given lessons. What has been forgotten should be repeated, re-explained and consolidated. In essence, the formative control system is a data source for managing individualized learning.

3. Another essential feature of VRS is **socialization**. When a user needs to establish friendly and professional contacts, such a communication tool should be provided within the system so that such contacts are made without switching to other applications or devices. To do this,

VRS system must provide for the creation of a personal account with a professional (educational) profile of the user – indicating the group, year, semester educational and personal interests, academic achievements, etc. The profile allows to keep educational statistics, academic performance, conduct conversations, dialogues, post messages to public, groups or persons. The user should be able to give feedback – leave their comments and reviews with the identification of their author, set ratings for educational materials. This profile is necessary not only for communication – its presence enables to carry out the functions of assessment, and hence the management of the educational process. Without a user profile, there is no anchor where to attach rewards and achievements.

4. Looking for **esteem, recognition** by the others – friends, groupmates, students of other semesters or even universities and countries. The high academic achievements are indicated on the public side of the user's profile. The disciples can be ranged in the "Halls of Fame" – Ranking tables, list of best performances. This kind of charts, never ending contest and competitions generate additional motivation to learning.

5. Another important need of any individual is **knowledge, cognition**. This need is much stronger by medical students, most of whom have long dreamed of this profession and now, given the opportunity to master it, are particularly zealous about learning material.

To help meet this need with ease and pleasure, the virtual system should have a number of features. Thus, educational material of any volume and complexity should be divided into separate fragments, constituting elements. Each fragment has to be relatively short, simple and easy to understand, revise, repeat, and control in a short, limited interval of time (distributive learning). These fragments should be lined up with increasing complexity, making up a coherent, logically constructed story, a complete theme, but not a disconnected mosaic, not a "didactic potpourri".

Each element should end with a formative assessment that guarantees understanding and mastery of the learning material. Having mastered the simple elements - on their basis – move on to more complex stages: from basic to in-depth, from general to private, from the standard flow - to variants and features. There must be an interrelation of the individual elements - not only of the individual theoretical lessons, but also of the interrelation of theory and practice. Any clinical or manipulative case must be grounded in background knowledge. Theory is interconnected with practice - one arises from the other and builds on the previous level.

Each element should end with a formative assessment that ensures understanding and assimilation of the learning material. Having mastered the simple elements, on their basis we proceed to more complex levels: from the basic to the in-depth, from the general to the particular, from the standard pathology variant to the derivations and abnormalities of the disease. There must be a link, an interconnection of individual elements – not only interlinking of individual theoretical lessons, but also the union of theory and practice. Any clinical or manipulative case should be based on the preliminary basic knowledge, one follows from another and is built on the previous level.

6. The pleasure of owning and using a beautiful thing – **aesthetical** needs – this desire of users should be taken into account by the creators of medical training virtual systems as well. The student should get pleasure from their appearance, from the user interface, get inspired by the interiors of the virtual clinic in which he "works". Cool and nice functionality not only brings fun and pleasure to the learning process, but ultimately affects learning outcomes.

7. For **self-actualization, self-realization** individual goes beyond one's essence, overcomes one's own boundaries and rushes toward a new reality, pushes the boundaries of identity, while remaining oneself. The student, having satisfied his basic, urgent needs, having reached a certain degree of competence, and hence comfort level, comes to the idea of creating something that can change his inner world, his attitude toward the surrounding reality. He has a growing need for creativity, a desire to create new knowledge and pass it on to others.

In order to ensure the possibility of self-realization within the virtual system itself, it is necessary to provide a certain functionality, not only learning, but also research, not only cognition, but also creativity, not only absorption, but also spreading, donating. Thus, an important feature is the ability to conduct research (e.g., collecting and analyzing statistics, forming and conducting surveys, constructing scientific hypotheses and testing them), creating your own virtual projects, such as editing and writing new lessons, tests, clinical cases.

7. Conclusion

The virtual technologies are an outstanding auxiliary tool that complements the classical methods of teaching in medicine, but their importance and prevalence is growing every day. Learning a virtual environment has not only advantages, but also certain disadvantages and risks that need to be considered. An educational institution must apply an end-to-end program that compensates for risks, levels out the shortcomings of the virtual component and takes into account its advantages.

An analysis of virtual /digital technologies in medical education from the standpoint of Maslow's hierarchy of needs theory suggests that within their framework all user's needs can be realized – from the basic levels of Maslow's hierarchy of needs (study, pass exams, get an education, become a doctor) to the highest (communication, cognition, recognition, appreciate beauty and comfort, develop one's own personality).

Based on this analysis, a list of recommended elements and functional features has been formulated, taking into account which, when developing and implementing a virtual course, can improve the quality of the educational product, identify their weaknesses and find ways to improve their effectiveness in order to increase the effectiveness of the educational process.

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