Digital Learning. Tele-Simulation and Avatar-Based Activities

By Fernando Salvetti, Roxane Gardner, Rebecca Minehart, Barbara Bertagni

e-REAL® by LOGOSNET

CENTER FOR MEDICAL SIMULATION

Abstract—Digital learning may happen online and in mixed or hybrid reality environments. Our focus is about e-REAL®, the enhanced reality for immersive simulation that is the merging of real and virtual worlds: a mixed reality environment for hybrid simulation where physical and digital objects co-exist and interact in real time, in a real or virtual place and not simply within a headset. The first part of this paper discusses e-REAL: an advanced simulation within a multisensory scenario, based on challenging situations developed by visual storytelling techniques. The e-REAL immersive setting is fully interactive with both 2D and 3D visualizations, avatars, electronically writable surfaces and more: people can take notes, cluster key-concepts or fill questionnaires directly on the projected surfaces. The second part of this chapter summarizes an experiential coursework focused on learning and improving teamwork and event management during simulated obstetrical cases. Effective team management during a crisis is a core element of expert practice: for this purpose, e-REAL reproduces a variety of different emergent situations, enabling learners to interact with multimedia scenarios and practice using a mnemonic called Name-Claim-Aim. Learners rapidly cycle between deliberate practice and direct feedback within a simulation scenario until mastery is achieved. Early findings show that interactive immersive visualization allows for better neural processes related to learning and behavior change.

Keywords: Enhanced Reality; Virtual, Augmented and Mixed Reality; Virtual Worlds; Hybrid Simulation; Teamwork; Mnemonics; Name-Claim-Aim.

1. Enhanced Reality

Enhanced reality for immersive simulation (e-REAL®) is the merging of real and virtual worlds: a mixed reality (MR) environment for hybrid simulation where physical and digital objects (VR) co-exist and are available for tactile interaction, in a real learning setting—and not within a headset (Salvetti & Bertagni 2018; Salvetti, Gardner, Minehart & Bertagni, 2019). e-REAL integrates tools and objects from the real world onto one or more walls, embedded with proximity sensors enabling tactile or vocal interaction with the virtual objects. Examples of physical objects include:

- Ultrasound and sonography simulators
- Pulmonary ventilators
- Defibrillators.

Examples of digital objects include:

- Realistic avatars and medical imagery (figure 1)
- Human organs and systems (figures 2 and 3)
- Overlay of electronic information and images onto projected surfaces (figures 3, 4, and 5).

Figure 1 illustrates a real medical tool operated on a patient simulator by learners who are in a dialogue with an avatar (that is, the virtualized colleague displayed on the wall), with medical imagery displayed both on a monitor and the walls.

Figures 2, 3 and 4 illustrate 2D, 2.5D and 3D images visible without special glasses, which can be manipulated by the hands without special joysticks (active pens). Learners are able through hand gestures to virtually take notes, highlight, erase, zoom inside/outside or rotate virtual organs and other displayed objects 360 degrees, to cluster concepts by grouping them within boxes or by uploading additional medical imagery to gain a better understanding about what they are analyzing, to take screenshots and share them, to complete questionnaires, etc.

Figure 5 exemplifies the mirroring of a perioperative environment which can be overlaid with digital computer-generated information pertaining to a simulated patient, ultrasound images, ECG tracks, outputs from medical exams. The overlay of information is to enhance the user experience.

In a nutshell, the e-REAL system enables a multilayer vision: the many levels of the situation are made available simultaneously, by overlaying multisource info—e.g. words, numbers, images, etc.—as within an augmented reality display, but without needing to wear special glasses. By visualizing relations between topics, contextual factors, cognitive maps and dynamic cognitive aids, e-REAL improves the learners’ cognitive retention (Salvetti & Bertagni 2014; Salvetti 2015; Guralnick 2018; Gardner 2018; Gardner & Salvetti 2019).

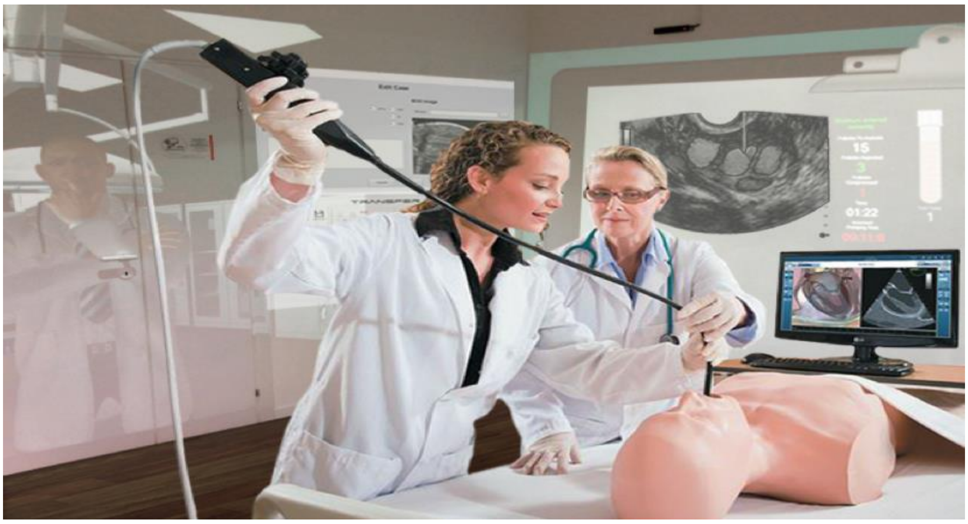

Figure 1 – Courtesy of the Red Cross Simulation Center “Gusmeroli” and Accurate Solutions S.r.l., Bologna (Italy): Learning medical procedures by a skill trainer during a hybrid simulation within an e-REAL environment, with interactive medical imagery displayed on both the two walls and a monitor; a highly realistic avatar (left wall) looking at and verbally interacting with them.

Figure 2 – Courtesy of the Environmental Design and Multisensory Experience Lab at the Polytechnic School of Milan (Italy): Learners within an e-REAL lab are facing 2D, 2.5D and 3D images (left wall) and a beating heart (right wall) that can be 360-degree rotated and analyzed also internally with a multilayer approach (by a zoom), with an overlay of digital information on both walls.

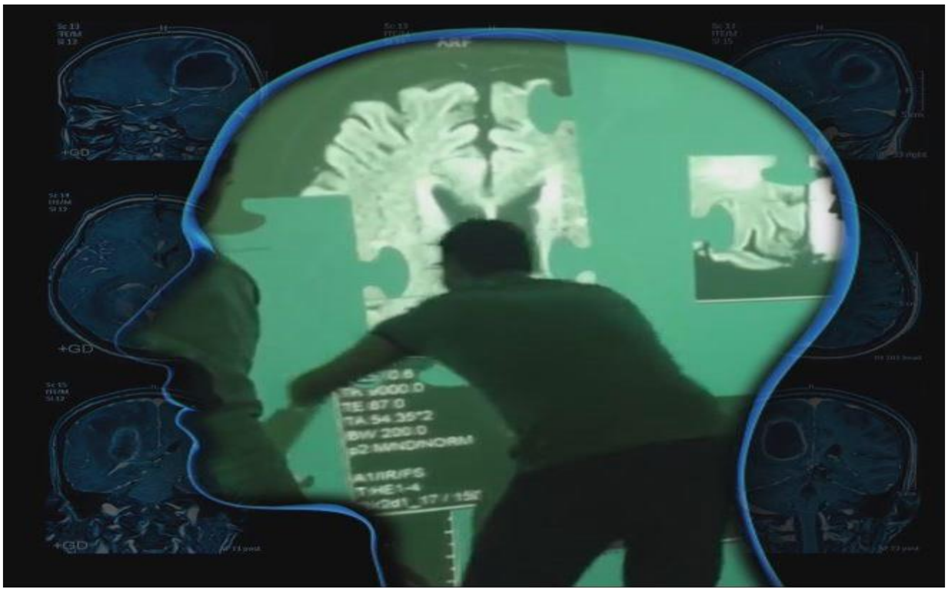

Figure 3 – Courtesy of the Red Cross Simulation Center "Gusmeroli" and the University of Bologna (Italy): A learner facing an e-REAL wall and manipulating a 2D image showing a brain cancer, divided in 8 pieces, during an experiment aimed at determining whether cognitive retention improves when visualization is broken into multiple smaller fragments first and then recomposed to form the big picture.

Figure 4 – Courtesy of the Center for Medical Simulation in Boston (MA, USA): Overlay of information manually added on the e-REAL wall using a tracking system that allows for electronic writing, due to proximity sensors tracking the nails of the writer.

Figure 5 – Courtesy of the Centre de Simulation Médicale CARE at the University of Liège (Belgium): Mirroring of a perioperative environment expected to be overlaid with e-REAL digital computer-generated information regarding a simulated patient—such as ultrasound images, ECG tracks, outputs from medical exams—for the purpose of enhancing the user experience, a deep and multisource understanding of the situation.

2. Enhanced hybrid simulation in a mixed reality setting, both face-to-face and in telepresence

e-REAL is a synthesis of virtual reality (VR) and augmented reality (AR) within a real setting, a one of a kind mixed reality (MR) solution based on immersive interaction. In a nutshell, AR alters one's ongoing perception of a real-world environment, whereas VR replaces (usually in a complete way) the user's real-world environment with a simulated one.

VR is a communication medium that makes virtual experiences feel highly realistic. The term 'virtual reality' has been widely used and often creatively exaggerated by Hollywood producers and science-fiction writers for decades. Consequently, there are many misconceptions and expectations about the nature of the technology (Bailenson, 2006). We define 'virtual reality' as synthetic sensory information that leads to the perception of environments and their content as if they were not synthetic (Blascovich, Loomis, Beall, Swinth, Hoyt, Bailenson, 2002). Since the 1960s, VR has been used by the military and medicine for training and simulations, but it has also become fertile ground to evaluate social and psychological dynamics in academic settings (Aukstakalnis 2017). For example, journalists use virtual reality to situate their readers within stories, educators use virtual technologies for experiential learning, and psychiatrists leverage virtual reality to mitigate the negative effects of psychological traumas (Markowitz and Baileson, 2019).

AR is a general term applied to a variety of display technologies capable of overlaying or combining alphanumeric, symbolic, or graphical information with a user's view of the real world (Aukstakalnis 2017). We define 'AR' as an interactive experience of a real-world environment where the objects that reside in the real-world are augmented by computer-generated perceptual information—sometimes across multiple sensory modalities, including visual, auditory, haptic, somatosensory, and olfactory. Overlaid sensory information can be constructive (i.e. additive to the natural environment) or destructive (i.e. masking of the natural environment) and is seamlessly interwoven with the physical world such that it is perceived as an immersive aspect of the real environment (Rosenberg 1992).

MR takes place not only in the physical world or in the virtual world, but is a mix of the real and the virtual (De Souza, Silva & Sutko, 2009; Milgram & Kishino 1994). We define 'mixed reality', as a hybrid reality, in other words the merging of real and virtual worlds to produce new environments and visualizations where physical and digital objects co-exist and interact in real time. There are many mixed-reality applications to help students learn through the interaction with virtual objects. For example, teachers can instruct students remotely by using 3D projections within a head-mounted display.

In e-REAL digital and physical objects co-exist in the real world, not within a headset, making e-REAL currently unique. e-REAL, as a MR environment for hybrid simulation, can be a stand-alone solution or even networked between multiple places, linked by a special videoconferencing system optimized to process operations with minimal delay (technically: low latency). This connectivity allows not only virtual objects sharing (like medical imagery, infographics, etc.) in real time, but also remote cooperation by co-sketching and co-writing (Figure 6).

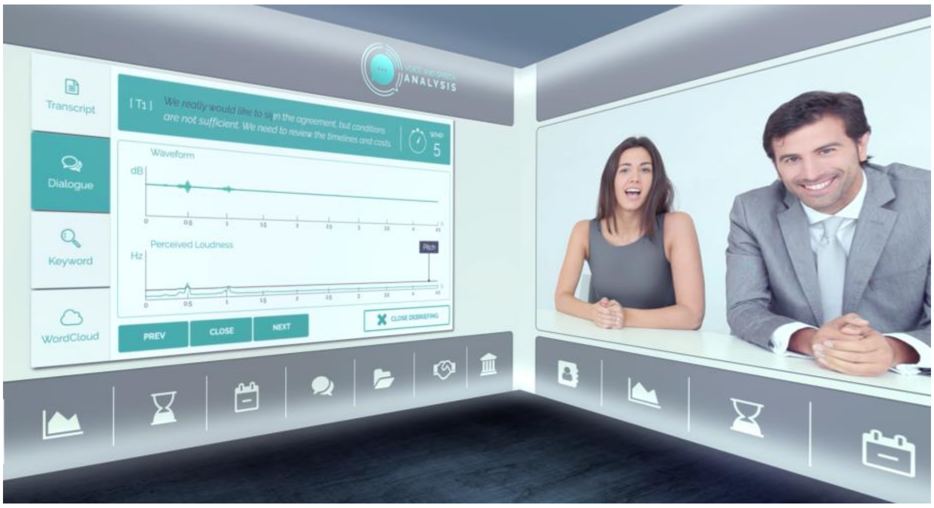

Figure 6 – e-REAL Multimedia Design Labs at Fondazione Piazza dei Mestieri in Turin (Italy): Interactive teleconferencing system enhanced with the speech analysis app developed by Centro Studi Logos jointly with the Tiny Bull Studios and the Polytechnic School of Turin (Italy).

e-REAL is a futuristic solution, designed to be “glocal” (Salvetti & Bertagni 2010), “liquid” (Bauman 2000), “networked” (Castells 2009) and “polycentric” (Vasconcelos 2011), as well as virtually augmented, mixed, digitalized and hyper-realistic (Salvetti & Bertagni, 2018). The keywords characterizing the main drivers that guided the design of this solution, and that are leading the further developments, include:

- *Digital mindset*, that is not merely the ability to use technology but is a set of attitudes and behaviors that enable people and organizations to foresee possibilities related to social media, big data, mobility, cloud, artificial intelligence, and robotics.
- *Visual thinking*, that according to Rudolph Arnheim implies that all thinking—not just thinking related to art—is basically perceptual in nature, and that the dichotomy between seeing and thinking, or perceiving and reasoning, is misleading.
- *Computer vision*, an interdisciplinary scientific field that deals with how computers can gain high-level understanding from digital images or videos; from the perspective of engineering, it seeks to understand and automate tasks completed by the human visual system.
- *Advanced simulation* that is a highly realistic imitation of a real-world object, process or system.
- *Multimedia communication* that is a system of relaying information or entertainment that includes many different forms of communication: for example, it might include video, audio clips, and still photographs.
- *Immersive and interactive learning*, that encourages students to learn by doing and allows learners to cross conceptual and theoretical boundaries with the help of simulation or game-based tools. It is one of the most promising methods in the history of learning by immersing the students or professionals in an interactive learning environment in order to teach them a particular skill or technique. (Salvetti & Bertagni 2018; Auer, Guralnick, Uhomoibhi 2017).
- *Augmented and virtual reality* within a hybrid environment allows learners to experience abstract concepts in three-dimensional space, transforming the passive learning into technology-assisted immersive learning.

- *Human and artificial intelligence cooperation*, that does not require sheer computational power, but relies on intuition, and pre-evolved dispositions toward cooperation, common-sense mechanisms which are very challenging to encode in machines.
- *Cognitive psychology and neurosciences*, that are different domains overlapping in the area of the neural substrates of mental processes and their behavioral manifestations.
- *Anthropology and sociology of culture*, whose viewpoints are inspired by observing cross-cultural differences in social institutions, cultural beliefs and communication styles.
- *Hermeneutics* that refers to the interpretation of a given text, speech, or symbolic expression such as art. It also fosters a multi-layer approached by opening the meta-level related to the conditions under which such interpretation is possible. Consequently, hermeneutics foster learners' metacognition by activating thinking about thinking and knowing about knowing, which contributes to higher-order thinking skills.
- *Narratology* that is the study of narrative strategies and structures as well as the ways that these affect human perception.
- *Design thinking applied to andragogy and pedagogy* that revolves around a deep interest in developing an understanding of the learners for whom educational content are designed— for example, questioning and re-framing problems in learner-centric ways, questioning assumptions and implications, helping to develop empathy with the target users.
- *Epistemology* that is the study of knowledge, justification and the rationality of belief which addresses such questions as: What makes beliefs justified? What does it mean to say that we know something? And fundamentally: How do we know that we know?

All these domains in our opinion must be related with a systemic and interdisciplinary approach: the one that is at the core of the research guidelines developed by Centro Studi Logos in Turin (Italy) since 1996.

3. e-REAL as a CAVE-like environment enhanced by augmented reality and interaction tools

e-REAL uses ultra-short throw projectors and touch-tracking cameras to turn blank walls and empty spaces into immersive and interactive environments. It is designed as an easy, user-centered and cost-effective solution to the old CAVE environments, which are too rigid, difficult to be managed, and expensive.

CAVE—computer-assisted virtual environment—is an immersive VR and AR environment where projectors are directed to between three and six of the walls of a room-sized cube; usually the image projections change as the user walks around and moves his or her head. The name is also a reference to the allegory of the Cave in Plato's Republic, in which a philosopher contemplates perception, reality and illusion (Aukstakalnis 2017; Cruz-Neira 1992). As shown in Figure 7, these systems come in a variety of geometries and sizes, including rear-projection or flat panel-based displays, single and multi-projector hemispherical surfaces, each typically displaying field sequential stereo imagery. Most are designed to accommodate multiple users, each of whom wear LCD shutter glasses controlled by a timing signal that alternately blocks left- and right-eye views in synchronization with the display's refresh rate. Most systems incorporate some method of tracking the position and orientation of the lead user's head to account for movement and to adjust the viewpoints accordingly. In such multiuser scenarios, all other participants experience the simulations in 3D, but passively.

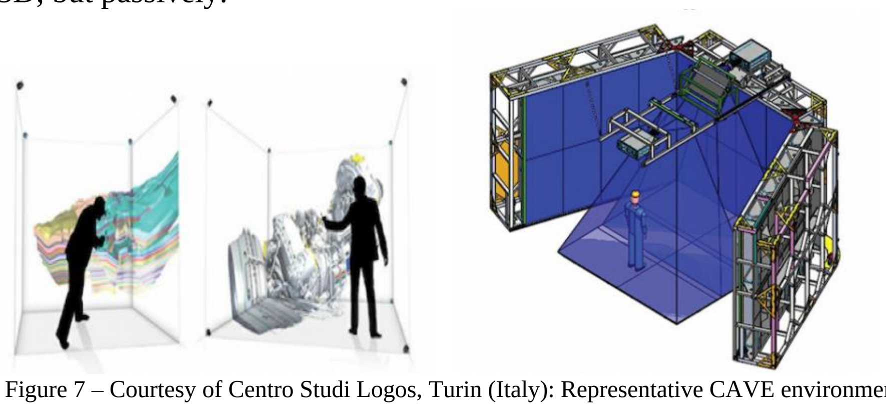

Figure 7 – Courtesy of Centro Studi Logos, Turin (Italy): Representative CAVE environments.

There are a number of critical reasons to develop e-REAL as an alternative to the CAVE for immersive simulation in education and training. Allowing users to work without special glasses is an important reason. Avoiding joysticks or other devices (usually haptic gloves) in order to interact with the visual content is another reason. Other reasons include a higher degree of realism and the opportunity to have all the users, and not only one person at a time, interact with the content.

e-REAL is an innovative solution, it is very easy to use and 10 to 12 times less expensive than a CAVE. With both permanent or portable fixtures, it is so simple that two buttons are enough to manage it all—from a control room or remotely by the Team Viewer™ software, without the need for 3D glasses or joy-sticks to interact with the virtual objects (see Figures 8 and 9).

Figure 8 – Courtesy of the University of Eastern Piedmont, Simnova Center, Novara (Italy): e-REAL portable pop-up designed as an immersive and interactive setting for the "SimCup" of Italy.

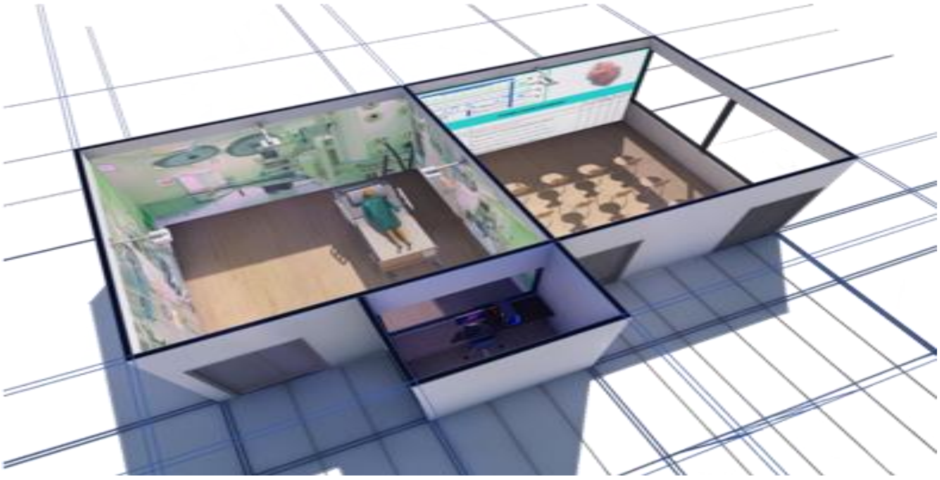

Figure 9 – Courtesy of Centro Studi Logos, Turin (Italy), Logos Knowledge Network, Lugano (Switzerland), LKN, Berlin (Germany), Logosnet (Houston, TX, USA). Representative e-REAL permanent installation: 1) a regular control room, 2) a briefing and debriefing room with an entire common wall transformed into a large electronic and interactive whiteboard, which allows avoiding a regular projection or a standardized electronic whiteboard, 3) the immersive and interactive room for both the simulation and a first rapid onsite debriefing—enriched by the contextual factors displayed on the walls. This setting is also very useful for simulations that can be enhanced by pausing and adding further visualizations and notes.

e-REAL offers a unique user experience, a combination of visual communication and direct interaction with the content—by gesture or spoken commands—immersing people in an entirely interactive ecosystem. Figures 10-19 provide a visual explanation about the main features of the system.

Each e-REAL lab comes packed with a starter kit that enables countless activities using simple gesture and spoken commands. A number of apps and contents are available off-the-shelf, and many others can be quickly tailored. Each e-REAL can be customized with a number of multimedia contents and MR tools:

- Multimedia libraries;
- Interactive tutorials;
- Holographic visualizations;
- Real-time and live holograms;
- Podcasts and apps;
- Task (or skill) trainers, healthcare tools, wearable devices such as glasses, headsets, watches and gloves.

Summarizing, the main technical features are:
- VR and AR that happens in the real world (MR for hybrid simulation) using 2D-2.5D-3D projections on the walls, not within special glasses;
- Visualization is interactive, immersive and often augmented;
- Speech recognition may be part of the adventure as well;
- Users do not require special glasses, gloves, head-mounted displays, etc.;
- It is very easy to use: only two buttons are needed (one to start and stop the server, and another from a remote controller, to switch on and off the projectors);
- A number of pre-loaded scenarios are available;
- It is easy to import and show existing content (images, videos);
- It is easy to create and edit new content, with tailored multimedia editors;
- Both permanent and portable fixtures are available.

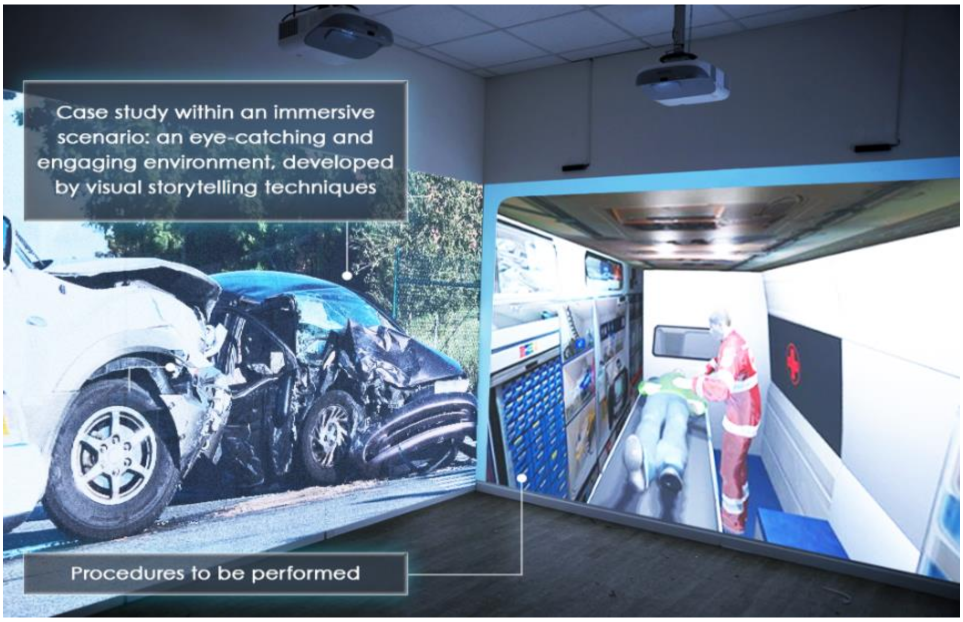

Figure 10 – Courtesy of the Red Cross of Italy in Bologna (Italy). e-REAL representative setting based on a multimedia animated visual storytelling made interactive by touch sensors tracking fingers or by vocal commands. Ultra-short throw projectors are working on common walls (level 4 or 5 finish) transformed into a maxi and touchable screen by the proximity sensors.

Figure 11 – Courtesy of Logos Knowledge Network, Lugano (Switzerland). e-REAL setting with medical imagery on the side walls, a 3D beating heart on the top-right corner of the main screen which can be rotated 360 degrees and can be overlaid with annotations and visualization of medical exams on the top-left corner of the same central wall.

Figure 12 – Courtesy of the Red Cross of Italy in Bologna (Italy). e-REAL setting with a perioperative environment mirrored on a wall displaying interactive procedural guidelines. A second small surface (right), made by a simple curtain, is used to project visual mnemonics and checklists that can be commanded vocally or by the flick of the hands.

Figure 13 – Courtesy of the Red Cross of Italy in Bologna (Italy). e-REAL setting designed for crisis resource management enhanced by visualization of the available therapeutic alternatives, with a tracking system to keep track of all the decisions taken. By clicking a virtual button, learners may directly pop-up medical imagery to achieve a deeper understanding of the situation they are dealing with.

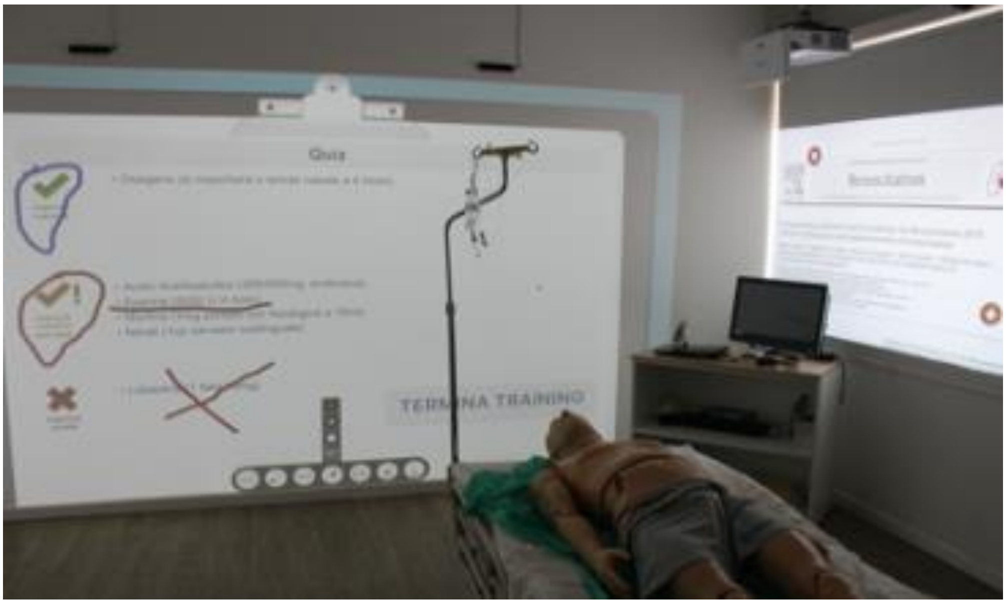

Figure 14 – Courtesy of the Red Cross of Italy in Bologna (Italy). Simulation’s closing phase designed to allow the instructors to provide a rapid first debriefing regarding both the therapeutic decisions taken by the learners and the verbal communication with the patient. On the side curtain (right) guidelines are available for a rapid search.

Figure 15 – Courtesy of the Red Cross of Italy in Bologna (Italy). Wall mirroring with personal tablets and smartphones within an e-REAL setting.

Figure 16 – Courtesy of Logosnet, Houston (TX, USA). In situ simulation setting for residents and interns, enhanced with an e-REAL system displaying interactive checklists and mnemonics, 2-3D images and videos on two common walls.

Figure 17 – Courtesy of Logosnet, Houston (TX, USA). Setting for in situ simulation enhanced with an e-REAL system displaying 2-3D images and videos on a common wall.

Figure 18 – Overlaying of notes on a brain cancer displayed on the CMS-e-REAL wall. Courtesy of the Center for Medical Simulation in Boston (CMS - MA, USA) and—from the left to the right—of Robert Simon (Principal Consultant at CMS), Roxane Gardner (Senior Director Clinical Programs and Director of the Visiting Scholars and Fellowship Program at CMS), Sarah Janssens (Director of Clinical Simulation at Mater Education in Brisbane, AUS), David Gaba (Associate Dean for Immersive and Simulation-based Learning and Director of the Center for Immersive and Simulation-based Learning at Stanford University School of Medicine, CA), Stephanie Barwick (Head of Partnerships, Programs and Innovation at Mater Education in Brisbane, AUS).

Figure 19 – Courtesy of the Center for Medical Simulation in Boston (MA, USA). Use of behavioral and cognitive key performance indicators during a debriefing: the e-REAL features allow writing and annotation, highlighting, erasing, moving, clustering, packing within the boxes or unpacking again two or more tags.

The following link provides a more detailed description of the settings and the available tools: https://www.youtube.com/watch?v=RZn3fdZNp3w&feature=youtu.be (courtesy of the Center for Medical Simulation in Boston, MA, USA, and the Polytechnic School of Milan, Italy).

4. The simulation's phases enhanced by e-REAL and the main tools made available by the system

a. Briefing and debriefing phases

Briefing and debriefing phases are strongly enhanced by e-REAL, by facilitation of cooperative learning and systems thinking fostered by dynamic visualization—an approach aimed at building a shared understanding of the non-linear behavior of complex systems (e.g. communication within a working team, car crashes, internal feedback loops or flows), based on representations that go beyond traditional static forms such as sketches, animations, or real time graphics (Arnheim 1969, Bergstrom 2008, Knight & Glaser 2009, Murray 2013, Lowe & Ploetzner 2017, Ridgway 2018, Lira & Gardner 2020). Systems thinking focuses on the way that a system's constituent parts interrelate and how systems work over time and within the context of larger systems—contrasting with traditional analysis, which studies systems by breaking them down into their separate elements.

With e-REAL, briefing and debriefing phases are performed by:

- Representing or summarizing a case with visual storytelling.
- Showing a video during which, you can write relevant keywords, highlight details, and add related multimedia content to the screen to enrich the cognitive map.
- Clustering relevant concepts and keywords on an electronic whiteboard.
- Moving content from one wall to another.

b. Use of the interactive wall with the smart interactive whiteboard tool for briefing and debriefing phases

The e-REAL touch-walls (or e-Walls) work both as virtualized electronic whiteboards and as interactive scenarios. This is a virtualized model, developed without the limitations of the electronic whiteboards.

The e-REAL system is commonly operated using simple gesture or spoken commands. The system is an interactive surface designed to: 1) enhance briefing and debriefing sessions; 2) dynamically visualize on a large surface; 3) cluster concepts and notes; 4) to physically touch and grasp ideas and multiple perspectives; 5) make the intangible, tangible; 6) facilitate cooperative learning; and 7) encourage systems thinking.

- A number of writing and annotation functions make it possible to write, draw, highlight, color pick, erase and delete on any background (movie, scenario, written text…).
- A snapshot function allows users to save a screenshot (in PNG format) into a user's predefined folder, securing all the annotations. If mailing lists are available, screenshots may be directly sent.
- A multimedia gallery is available to store content that can be uploaded (videos, audios, images, PDF files) by the instructor and projected on the wall simply by tapping on them, to facilitate the instructor’s ease to undertake briefings and debriefings.

- Another tool allows users to move, rotate and scale content. It is also possible to create a group in order to cluster concepts and elements (words, images, etc.) that can be packed in boxes and unpacked, moved, rotated and scaled all together.
- Puzzles can be created and played on the wall as a multi-perspective exercise. Puzzle pieces can be moved and rotated. When a piece fits, it is "magnetically" stitched to the other(s), when the puzzle is complete, it is converted to an Image Widget (so that it can be moved, rotated, etc.).

c. *Simulation phase*

The simulation phase is strongly enhanced by the e-REAL system, through the multisensory scenarios embedding virtual and augmented reality elements and tools.

Digital content can coexist with tools from the real world, such as a patient simulator and/or a medical trolley that can be on-stage during a briefing or a debriefing phase or a simulation phase within a virtualized environment.

Learners usually work on and around one or more patient simulators—i.e. mannequins with lifelike features and, usually, with responsive physiology—or simulated patients like actors or avatars, or in a disaster scenario. They are asked to make critical decisions, complete physical exams, recognize a situation requiring rapid intervention, practice technical skills, communicate with a patient, and the health care team, interpret test results. Learners are also trained to manage unforeseen events between parallel processing (that is, more than one task at a time) or performing one task at time in a sequence—taking into consideration critical contextual factors such as a lack of time, scarcity of resources and tools, and previous impacting factors.

Similar to being immersed within a videogame, learners are challenged by facing cases within multifaceted medical scenarios that present a "more than real" wealth of information. This is augmented reality in a hybrid environment which contributes to individual cognitive maps by enabling a multilayer view and making the invisible, visible, as the anatomy under the skin of the patient simulator can be enlarged, turned or rotated to appreciate how structures are interrelated.

d. Virtual patients and other avatars, real or virtual tools and devices

Within the e-REAL simulation setting, medical tools and devices can be real or virtual. When they are virtual, usually they are high fidelity models.

It is also possible to replace physical simulation mannequins with custom-made 3D virtual patients (avatars). Whether obese, pregnant, young, old, vomiting, missing limbs, bleeding, or expressing any number of other physical signs and symptoms, e-REAL enables reproduction of patients (in a number of places, such as the Simnova Center for Medical Simulation from the University of Eastern Piedmont in Novara, Italy).

e. Augmented reality (AR) displays

AR displays can be easily embedded within the e-REAL setting. Using AR, for example, a procedure can be performed partly in the real world and partly in the AR environment, or an entire procedure can be performed in "telemedicine" by an operator wearing special glasses and guided by an expert, who is tracking and keeping record of the info captioned by the AR displays.

AR allows knowledge sharing and cooperation among persons and teams. Learners can cooperate by sharing a virtualized common scenario, displayed on the e-REAL wall, even when they are performing in different physical environments. They can talk to each other and look at their own avatars acting in the same virtualized scenario because of special sensors capturing the body's dynamics.

f. Holograms

Holograms may be part of the e-REAL setting, utilizing wearable augments such as special glasses: Microsoft Hololens™, Epson Moverio™, etc. https://youtu.be/nrzdKzvKbIw (courtesy of the Polytechnic School of Turin, the University of Eastern Piedmont, Simnova Center in Novara, and Centro Studi Logos, Turin, Italy).

Also human-sized holograms can be reproduced within the e-REAL setting. Those holograms may be pre-recorded or may be even live, talking and interacting dialogically with the learners. https://youtu.be/E2awcWvfgNA (courtesy of Logosnet, Houston, TX, USA).

g. Speech analysis as a further option for the debriefing phase

Speech analysis is a powerful training tool to track—individually—both the tone of voice and spoken words of the learners, providing a semantic and pragmatic overview of interpersonal communication.

According to the Polytechnic School of Turin and to ISTI-CNR (a branch from the Italian Research Council), the fidelity of a speech recording and transcription is approximately 94%. An operator, such as a simulation engineer, may be able to amend and modify the transcript so that the fidelity of the transcript achieves 100% semantic accuracy (Lamberti & Pratticò 2018; Coro 2019).

Functions and visual outputs include the following:

- An integral transcript or a dialogue which can be visualized.
- Audio clips, automatically divided phrase by phrase, are also available.
- A word counter shows the number of spoken words per minute.
- An internal search engine enables keyword search, highlighting the words in the transcript.
- A word cloud tool visually summarizes the most spoken words.
- A Voice Analysis tool is available in order to measure and visualize waveform (Decibel), perceived loudness (Hertz) and pitch.

Some of these features are visible in Figure 6.
A video introduction is available via the following URL: https://youtu.be/3-hOdSYOmwg (courtesy of Centro Studi Logos, Turin, Italy).

5. Visual storytelling and contextual intelligence, cognitive aids, apps and tools to enhance the education process in a simulation lab or in situ

Visual storytelling techniques are part of the simulation scene, to represent a realistic context where learners are proactively involved to analyze scenarios and events, to face technical issues, to solve problems. The most effective learning occurs when being immersed in a context: realistic experience is lived and perceived as a focal point and as a crossroad (Guralnick 2018).

Effective visualization is the key to help untangle complexity: the visualization of information enables learners to gain insight and understanding quickly and efficiently (Tufte 1997 and 2001, Eppler & Burkhard 2004). Examples of such visual formats include sketches, diagrams, images, objects, interactive visualizations, information visualization applications and imaginary visualizations, such as in stories and as shown in the Figures 20 and 21.

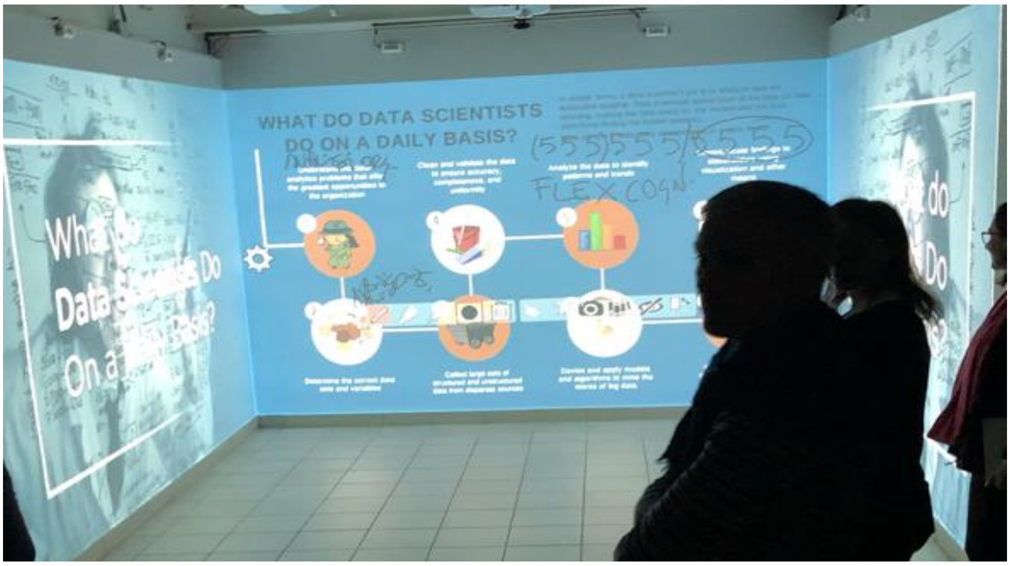

Figure 20 – Courtesy of Centro Studi Logos, Turin, Quadrifor, Rome, and the Polytechnic School of Milan (Italy): e-REAL simulation lab to deliver the training program "Big Data for Beginners" (designed and taught by Fernando Salvetti) aimed at growing a digital mindset and skills related to big data visualization.

Figure 21 – Courtesy of Centro Studi Logos, Turin, and Simnova, Novara (Italy): e-REAL simulation lab at the Simnova Center from the University of Eastern Piedmont in Novara (Italy) held during the SimCup of Italy 2019, open to all the Italian medical and nursing schools students and attended by hundreds of learners cooperating in teams comprised of 4 members each.

Visualizations within e-REAL show relationships between topics, activate involvement, generate questions that learners didn’t think of before, and facilitate memory retention. Visualizations act as concept maps to help organize and represent knowledge on a subject in an effective way (Tufte 1997 and 2001, Eppler & Burkhard 2004, Ciuccarelli & Valsecchi 2009).

Half of the human brain is devoted directly or indirectly to vision, and images easily capture our attention (Vogel, Dickson & Lehman 1986). Human beings process images very quickly: average people process visuals 60,000 times faster than text (Potter, Wyble, Hangman & McCourt 2014). Humans are confronted with an immense amount of images and visual representations every day: digital screens, advertisements, messages, information charts, maps, signs, video, progress bars, diagrams, illustrations, etc. (Arnheim 1969; Tufte 1997 and 2001, Fields, Hjelmstad, Margolis & Nicola, 2007; Rizzolatti & Sinigaglia 2008; Gazzaniga 2009; Friedlander, Andrews, Armstrong, Aschenbrenner, Kass, Ogden, Schwartzstein & Viggiano, 2011; Kandel, Schwartz, Jessell, Siegelbaum & Hudspeth 2013; Collins 2015; Salvetti & Bertagni 2016; Yeo & Gilbert 2017). The use of symbols and images are extremely effective to warn people, as they communicate faster than words and can be understood by audiences of different ages, cultures and languages (Kernbach, Eppler & Bresciani 2014). Images are powerful: people tend to remember about 10% of what they hear, about 20% of what they read and about 80% of what they see and do (Lester 2006).

Contextual factors are key to learning (Guralnick 2018). In e-REAL, learners practice handling realistic situations, rather than learning facts or techniques out of context. Context refers to the circumstances that form the setting for an event, statement, or idea. Context related factors can be influential and even disruptive: for example, a loud background noise within a virtually recreated operating room in e-REAL impacts negatively on the surgical team's ability to communicate and may consequently contribute to their committing an error. The most effective learning occurs through being immersed in context, requiring the ability to understand the limits of our knowledge and action, and to adapt that knowledge to an environment different from the one in which it was developed (Khanna 2014, Guralnick 2018).

A context related experience within an e-REAL setting is similar to being immersed within a videogame with our entire bodies. Characteristics of games that facilitate immersion can be grouped into two general categories: those that create a rich mental model of the game environment and those that create consistency between the things in that environment (Wirth 2007, Wissmath 2009, Blazer 2016).

The richness of the mental model relates to the completeness of multiple channels of sensory information, meaning the more those senses work in alignment, the better. The richness also depends on having a cognitively demanding environment and a strong and interesting narrative. A bird flying overhead is good. Hearing it screech is better. Cognitively demanding environments in which players must focus on what's going on in the game will occupy mental resources. The richness of the mental model promotes immersion, because if brain power is allocated to understanding or navigating the world, players are too occupied to notice all of the game's problems or shortcomings that would otherwise remind them that they're playing a game. Finally, good stories with interesting narratives (which are credible because they are as intrinsically congruent as possible) attract attention to the game and make the world seem more believable (Genette 1972; Bremond 1973; Marchese 1983; Batini & Fontana 2010; De Rossi &

Petrucco 2013; Parisi Presicce 2017). Good stories tie up mental resources (Wissmath 2009).

Turning to game traits related to consistency, believable scenarios and behaviors in the game world ensures that virtual characters, objects, and other creatures in the game world behave in the way in which learners expect (Wissmath 2009, Blazer 2016). Usually game developers strive for congruence among all these elements.

Learners are challenged both cognitively and behaviorally in a fully immersive and multitasking learning environment, within interactive scenarios that usually present also a wealth of information. The many levels of the situation are made available simultaneously, by overlaying multisource—words, numbers, images, etc.—within an environment designed by AR techniques (Aukstakalnis 2017) (Figure 22).

Figure 22 – Courtesy of Logos Knowledge Network, Lugano, Prof. Martin Eppler and the Institute for Media and Communication Management from the St. Gall University (Switzerland): Overlaying of multisource info within the e-REAL classroom at the Red Cross Training Center "Gusmeroli" in Bologna (Italy).

e-REAL submerges learners in an immersive reality where the challenge at hand is created by sophisticated, interactive computer animation. Importantly, the system includes live and real time interaction with peers, instructors, tutors, facilitators and mentors. Thus, it adds a very important social component that enhances learning outputs, skills, cognitive and metacognitive processes.

The process of learning by doing within an immersive setting, based on knowledge visualization using interactive surfaces, leaves the learners with a memorable experience (Salvetti & Bertagni, 2019b) (Figure 23).

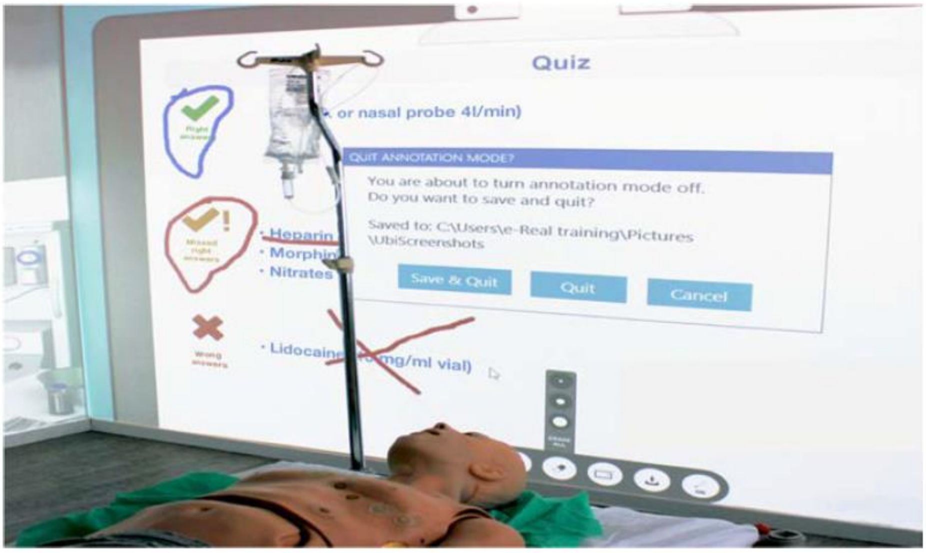

Figure 23 – Courtesy of the Red Cross Training Center "Gusmeroli" and Accurate Solutions Srl in Bologna, Prof. Michele La Rosa and CIDOSPEL from the University of Bologna, Centro Studi Logos, Turin (Italy). Overlay of digital information from different sources within the e-REAL classroom at the Red Cross Training Center.

From an educational perspective, learners are not assumed to be passive recipients and repeaters of information but individuals who take responsibility for their own learning. The trainer functions, not as the sole source of wisdom and knowledge, but more as a coach or mentor, whose task is to help them acquire the desired knowledge and skills.

A significant trend in education in the 19th and 20th centuries was standardization. In contrast, in the 21st century, visualization, interaction, customization, gamification and flipped learning are relevant trends (Salvetti 2015). In a regular flipped learning process, students are exposed to video lectures, collaborate in online discussions, or carry out research on their own time, while engaging in concepts in the classroom with the guidance of a mentor. Critics argue that the flipped learning model has some drawbacks for both learners and trainers (Salvetti 2015). A number of criticisms have been discussed with a focus on the circumstance that flipped learning is based mainly on video-lectures, which may facilitate a passive and uncritical attitude towards learning, in a similar way to didactic face-to-face lectures within a traditional classroom, discouraging dialogue and questioning (Mazur 1997; Bergmann & Sams 2012; Strayer 2008; Toto & Nguyen 2009; Tucker 2012; Szparagowsk 2014).

The e-REAL setting is a further evolution of a flipped classroom, based on a constructivist approach. Constructivism is not a specific pedagogy but rather a psychological paradigm that suggests that humans construct knowledge and meaning from their experiences. From our constructivist point of view, knowledge is mainly the product of personal and interpersonal exchange (Popper, 1972; Morin, 1986; Robilant, 1991; Bertagni, La Rosa & Salvetti, 2010; Salvetti & Bertagni, 2010; Licci, 2011; Salvetti, 2015). Knowledge is constructed within the context of a person’s actions, so it is "situated" (Morin 2018): it develops in dialogic and interpersonal terms, through forms of collaboration and social negotiation. Significant knowledge—and know-how—is the result of the link between abstraction and concrete behaviors.

Knowledge and action can be considered as one: facts, information, descriptions, skills, know-how and competence—acquired through experience, education and training (Robilant 1991; Bertagni, La Rosa & Salvetti 2010). Knowledge is a multifaceted asset: implicit, explicit, informal, systematic, practical, theoretical, theory-laden, partial, situated, scientific, based on experience and experiments, personal, shared, repeatable, adaptable, compliant with socio-professional and epistemic principles, observable, metaphorical, linguistically mediated (Morin 2018). Knowledge is a fluid notion and a dynamic process, involving complex cognitive and emotional elements for both its acquisition and use: perception, communication, association and reasoning. In the end, knowledge derives from minds at work. Knowledge is socially constructed, so learning is a process of social action and engagement involving ways of thinking, doing and communicating (Salvetti & Bertagni 2018; Salvetti & Bertagni 2018b; Wieman 2018).

Compared to a traditional learning approach incorporating didactic lessons, learner performance gain was found to be 43%, in terms of increased speed and ease of learning as reported by students, and 88% of learners also reported increased engagement and enjoyment as demonstrated in the tests performed by the applied research team at the Environmental Design and Multisensory Experience Lab from the Polytechnic School of Milan (Italy). These results have been accepted for presentation at ICELW 2020 (Columbia University, New York), and briefly discussed within a research paper (Calabi, Bisson, Venica 2019). Moreover, due to the decreased cost of the e-REAL immersive room compared to CAVE-like environments, the e-REAL's added value is even more evident.

The e-REAL environment, to be experienced in a natural way without special glasses, is supposed to reduce the extensive use of the brain's working memory that is overloaded by traditional lectures (Sweller, Ayres, Kalyuga 2017; De Leeuw & Mayer 2008; Mayer & Moreno 2003), and during conversion of a 2D to a 3D representation as what usually happens with common images used during traditional teaching (Salvetti and Bertagni, 2016). Tests and experiments are in progress at the Polytechnic School of Milan and at the Center for Medical Simulation in Boston, to explore educational outputs related to cognitive aids, displayed as VR objects, usually on a wall and sometimes within AR glasses, or by indoor micro-projection mapping directly on the mannequins or on other tools available as skill trainers (Calabi, Bisson, Venica 2019).

Throughout the simulation process (briefing, performance, debriefing) both within a simulation lab or in situ, learners can interact with the content using spoken commands or natural gestures without the constraint of wearing glasses, gloves or headsets, nor joysticks (when they wish, they can use active pens instead of their fingers). No screens are needed: e-REAL sensors turn any surface into a touch screen.

6. The epistemological pillars supporting e-REAL

The e-REAL learning approach is designed to have the learner working on tasks that simulate an aspect of expert reasoning and problem-solving, while receiving timely and specific feedback from fellow students and the trainer. These elements of deliberate practice (Ericcson, Krampe, Tesch-Romer 1993) and feedback are general requirements for developing expertise at all levels and disciplines and are absent in lectures (Rudolph, Simon, Raemer & Eppich 2008; Shapiro, Gardner, Godwin, Jay, Lindquist & Salisbury 2008; Lyons & Lazzara 2015).

During an e-REAL session, both clinical and behavioral aspects of performance are addressed. A number of skills and competencies both technical and non-technical (behavioral, cognitive and meta-cognitive) are challenged: on one side technical knowledge and know-how, and, on the other side, behavioral, cognitive and metacognitive skills leadership and followership, team-work facilitation, team spirit and effectiveness, knowledge circulation, effective communication, relationships and power distance, fixation errors management and metacognitive flexibility. Feedback is provided throughout sessions with a focus on key performance indicators.

The e-REAL system allows trainers to feedback about key aspects of performance, using different tracking options. The system also allows multi-source feedback during the simulation-based session, combining self-assessment, feedback from the other participants and the trainer. This activity improves the learners' awareness of their own competencies.

Summarizing, we can say that e-REAL is a set of innovative solutions aimed at enhancing learning with a systemic, multilayer and multi-perspective approach. Tools such as speech analysis, visual communication and conceptual clustering are part of the solution. Integrating—and enhancing—technical skills with those related to the behavioral, cognitive and metacognitive domains is a major aim. Innovations based on visual thinking and immersive learning, (such as e-REAL, other augmented reality tools, advances in tablet technology and mobile applications, wearable devices and multimedia libraries), are successful because they upgrade people's knowledge, skills and abilities.

The main goal within e-REAL is allowing a multi-perspective mindset during a simulation session. Visualizing the "invisible" by overlaying information that focuses on both technical and behavioral aspects of a performance, and merges the virtual and the real, creates a multilayer and therefore augmented, multi-perspective, and systemic simulation that contributes to a better understanding.

Nothing is revolutionary within a simple VR headset, but if VR content and scenarios are "actualized" (Lévy 1998)—or enhanced—within a real simulation setting, the merging of the real and virtual world adds value to the learning process. In such a way, e-REAL becomes more than real!

7. Case-study: Teamwork and Crisis Resource Management for Labor and Delivery Clinicians

a. The program and a key cognitive aid: Name-Claim-Aim

Teamwork and Crisis Resource Management for Labor and Delivery Clinicians (Introductory and Advanced Levels) is experiential coursework focused on learning and improving teamwork and event management during simulated obstetrical cases. It is an interprofessional program based on advanced simulation, delivered many times per year in Boston (MA, USA) at the Center for Medical Simulation (CMS) in a realistic clinical setting (Minehart, Rudolph, Nadelberg, Clinton & Gardner 2019; Salvetti, Gardner, Minehart, Bertagni 2019). Each case is immediately followed by a facilitated debriefing led by experienced instructors and faculty members of CMS. Participants include obstetricians, obstetrical nurses, midwives and obstetrical anesthesiologists. e-REAL is integrated into this program and used to deepen learning and to enhance cognitive retention of the main mnemonic used during the program (Buttimer 2020).

Effective team management during a crisis is a core element of expert practice. Medical simulation can contribute enormously to enhance teamwork during a crisis (Gaba, Fish & Howard 1994), fostering situational awareness and contextual intelligence (Khanna 2014) which refers to the abilities to apply knowledge to real world scenarios and situations, as well as cognitive retention of essential steps and procedures to be performed during an ongoing crisis.

A crisis management organizational approach using a mnemonic called Name-Claim-Aim is being used in order to facilitate crisis management and decision making: knowledge and skills are essential components of the decision-making and the actions performed during crises, but they are not sufficient to manage the entire situation which includes the environment, the equipment and the patient care team.

After several decades worth of dedicated simulation education for anesthesiologists and labor and delivery teams, teamwork experts at the

CMS have found that these teams still struggle to routinely organize themselves in crises during simulation courses, let alone in the clinical environment (Minehart, Rudolph, Nadelberg, Clinton & Gardner 2019; Minehart, Pian-Smith, Walzer, Gardner, Rudolph, Simon, Raemer 2012). Stories from course participants of all professions indicate that there exists a real challenge to both focus on the clinical picture and apply organizational principles to the team, and more often than not, the organization within the team is under-prioritized. Part of this may be due to the intense cognitive load experienced by those who are managing a stressful clinical crisis. It can be difficult to also remember the eleven crisis resource management (CRM) principles introduced by Gaba, Fish and Howard (Gaba, Fish & Howard, 1994; Welker & Cooper, 2018) and apply them routinely while actively managing a resuscitation (Figure 24).

Figure 24 – Crisis Resource Management (CRM) key points.

Appreciating the impact of stress on high level thinking (Arnsten, 1998), faculty at CMS collapsed these 11 key points into 5 key CRM concepts of role clarity, effective communication, effective use of personnel, effective management of resources and global assessment (Figure 25).

Figure 25 – Courtesy of the Center for Medical Simulation (CMS), Boston, MA. Five Key Crisis Resource Management (CRM) Concepts by the CMS©.

The role of "Event Manager," rather than "Team Leader," is expressly promoted at CMS to facilitate distributed leadership in crises. This distinction has proven to be effective in teams of expert practitioners because it deliberately seeks to flatten hierarchies which may inhibit speaking-up behavior from team members, which may successfully counteract failures of perception (Raemer, Kolbe, Minehart, Rudolph, Pian-Smith 2016). The Event Manager coordinates the communication and the team's efforts, overseeing the organization and application of CRM principles, in addition to actively soliciting input and decision-making regarding medical care, if necessary. Moreover, the Event Manager acts to facilitate role designation, orchestrate and coordinate team function.

Based on these challenges, the mnemonic “Name-Claim-Aim” was developed at CMS to incorporate 10 of the 11 CRM principles in an easy-to-remember, and easily applied, framework (Figure 26). Cognitive aids were developed to help facilitate learning of this mnemonic and an “Event Manager Checklist” was created to facilitate effective role designation. Participants have been given this cognitive aid, designed as an ID badge-sized card, to easily access during their simulation course. In addition, the “Name-Claim-Aim” and “Event Manager Checklist” have been adopted by the Massachusetts General Hospital (MGH) (Boston, MA, USA) for inclusion in the latest version of their Emergency Manuals (Figures 27 and 28).

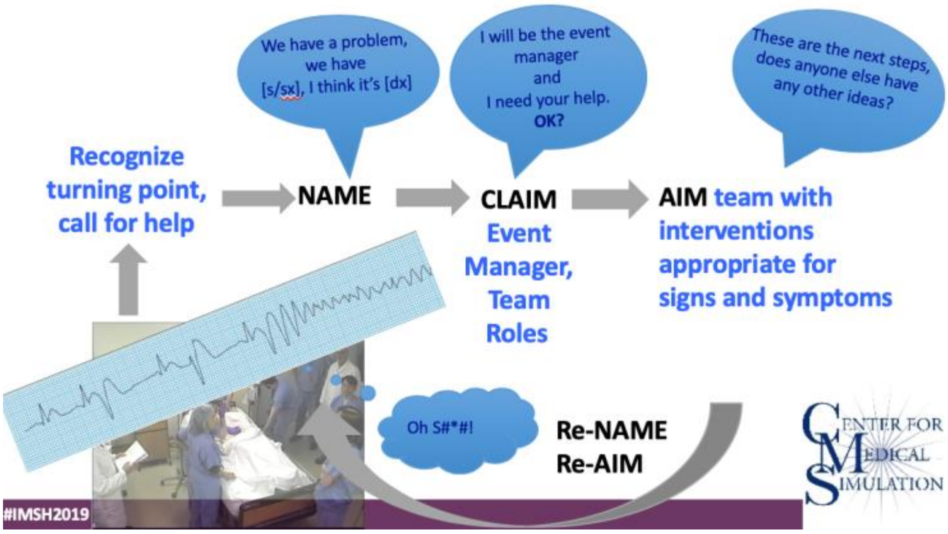

Figure 26 – Courtesy of the Center for Medical Simulation (CMS), Boston, MA. Application of Name-Claim-Aim©.

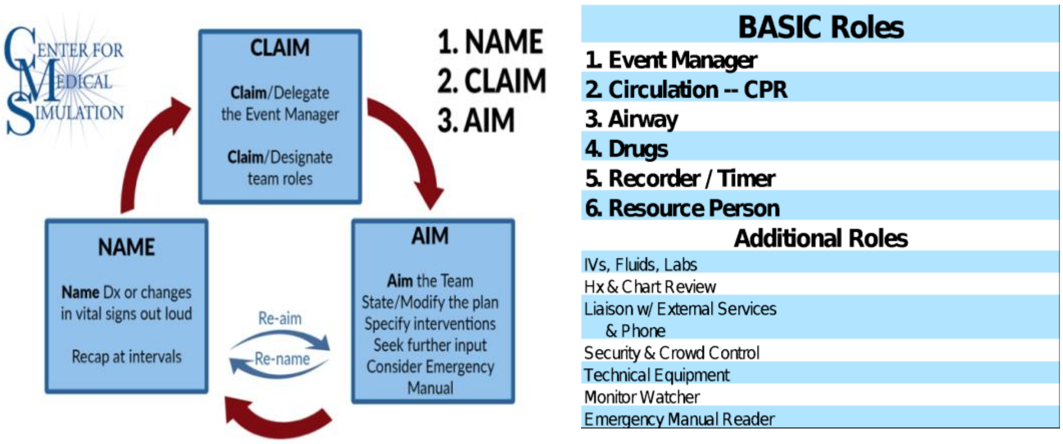

Figure 27 – Courtesy of the Center for Medical Simulation (CMS), (Boston, MA).
Name-Claim-Aim mnemonic aid ©.

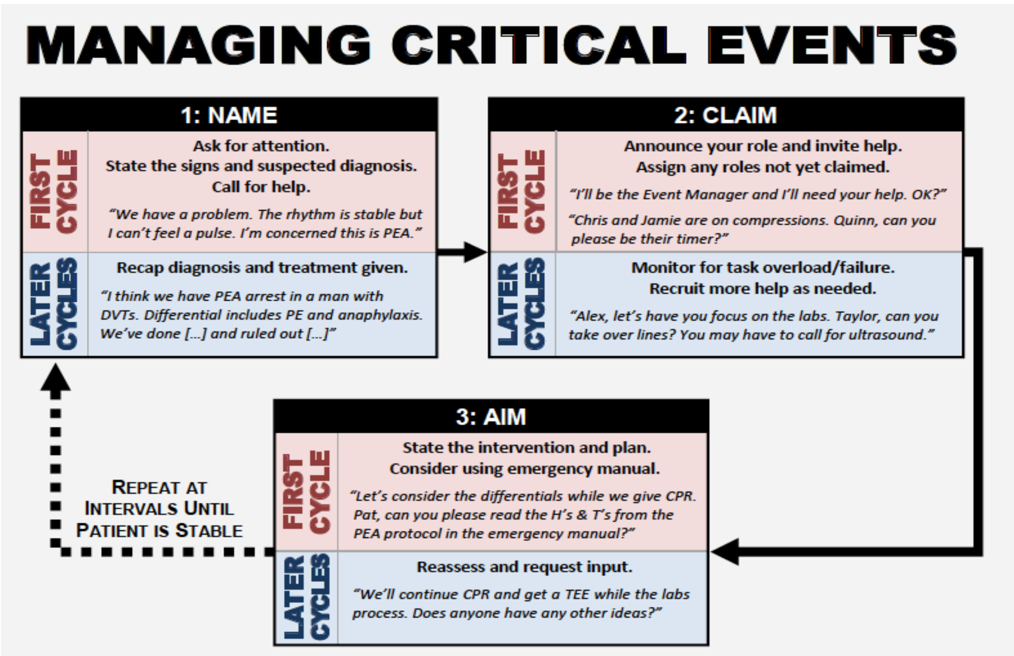

Figure 28 – Courtesy of the Massachusetts General Hospital (MGH) (Boston, MA):
Name-Claim-Aim in their Emergency Manuals ©.

b. Interactive videos and rapid debriefing

Rapid Cycle Deliberate Practice (RCDP) is a novel simulation-based education model that is currently attracting interest, being implemented, explored and researched. In RCDP, learners rapidly cycle between deliberate practice and directed feedback within the simulation scenario until mastery is achieved (Taras, 2017). Common RCDP implementation strategies include: splitting simulation cases into segments, micro-debriefing in the form of "pause, debrief, rewind and try again" and providing progressively more challenging scenarios. During the Labor & Delivery program, clinicians are shown short dynamic videos: they are challenged to recognize a situation requiring rapid intervention, communication, knowledge sharing, decision-making and management of an unforeseen event—while taking into consideration critical contextual factors such as a lack of time, scarcity of resources and tools, and a multitude of additional impactful factors. e-REAL is being used, enabling learners to interact with multimedia scenarios recreating very different situations (Salvetti, Gardner, Minehart, Bertagni 2019). Learners are requested to be compliant with the Name-Claim-Aim mnemonic to manage the crisis by coordinating the team roles and efforts. The interactive videos feature unexpected clinical or non-clinical, emergent scenarios, including extreme, dangerous environmental threats (Figures 29-31).

Figure 29 – Courtesy of the Center for Medical Simulation (CMS) (Boston, MA), the Polytechnic School of Milan (Italy) and Logosnet (Houston, TX): Interactive e-REAL wall with a number of tailored multimedia content ©.

Figure 30 – Courtesy of the Center for Medical Simulation (CMS) (Boston, MA), the Polytechnic School of Milan (Italy), and Logosnet (Houston, TX): Alpine environment with photorealistic avatars expected to occur a sport traumatism ©.

Figure 31 – Courtesy of the Center for Medical Simulation (CMS) (Boston, MA), the Polytechnic School of Milan (Italy), and Logosnet (Houston, TX): Fire accident in a final stage of execution, already overlaid by the mnemonic Name-Claim-Aim ©.

c. *Multilayer vision for an enhanced use of neural processes: key questions*

The e-REAL system enables a multilayer vision: the many levels of the situation are made available simultaneously, by overlaying multisource info—e.g. words, numbers, images, etc. Visualizations show relationships between topics, activate involvement, generate questions that learners didn't think of before and facilitate memory retention. Visualizations function as concept maps to help organize and represent knowledge on a subject in an effective way.

By visualizing relations between topics, contextual factors, cognitive maps and dynamic cognitive aids (Friedlander 2011), e-REAL allows more effective learning and storing of information into memories based on experiences and practice. At the same time, e-REAL helps instructors to immediately identify errors and difficulties of the trainees, facilitating an effective debriefing (Figures 32, 33 and 34).

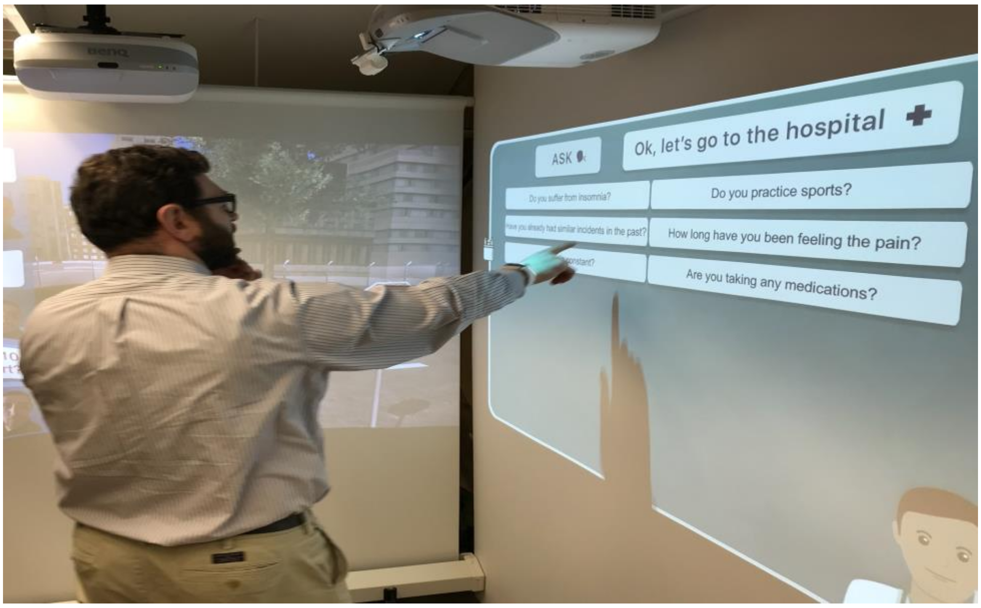

Figure 32 – Courtesy of the Center for Medical Simulation (CMS)(Boston, MA), Logosnet (Houston, TX) and Demian Szyld, Senior Director Institute for Medical Simulation and Faculty Development Program at CMS: Car accident overlaid by a decision tree designed to foster clinical observation and inquiry, verbal communication skills and active listening.

Figure 33 – Courtesy of the George Washington University School of Nursing (Ashburn, VA), and Logosnet (Houston, TX): Outdoor scenario designed to allow learners to visually detect difficulties and risks related to an emergency situation.

Figure 34 – Courtesy of the George Washington University School of Nursing (Ashburn, VA), and Logosnet (Houston, TX): A detail from an outdoor scenario designed to allow learners to visually detect difficulties and risks related to an emergency situation.

8. Conclusion

As Pierre Lévy was used to say, reality in the digital age is becoming more and more virtual (Lévy 1998) and based on being part of shared infospheres. In healthcare simulation, the dematerialization of the learning environment is allowed by new technologies that offer options to improve the usability of traditional e-learning methods. Sharing and mixing up the latest trends from digitalization and virtualization, neurosciences, artificial intelligence, and advanced simulation allows us to establish a new paradigm for education and training.

So far, the ongoing exploratory projects at the Center for Medical Simulation in Boston are:

1. The further use of the e-REAL visualizations in Labor & Delivery programs and in Anesthesia programs.
2. The design of distance-based simulations to take care of COVID-19 related situations: logistics, team safety, relationship with patients and families.
3. The introduction of online learning modules where different types of virtual objects are co-existing: artificial but realistic avatars and real actors performing as standardized patients or family members or colleagues, photorealistic 3D tools, indoor or outdoor scenarios.
4. The development of self-learning solutions to improve results related to critical conversations, debriefing sessions, video-interviews and videoconferences.
5. The use of AR head-mounted displays to provide guidance during remote on-site simulations.
6. The visualization of checklists and mnemonics (virtualized and displayed on screens or walls) to foster team performance.

In particular, we are mixing up the latest trends from digitalization, virtualization and artificial intelligence with the goal of building powerful solutions for medical simulation, with a focus on organizational behavior and leadership. Currently, we’re experimenting with highly-realistic digital humans and a new generation of avatars to improve communication skills using natural interaction and native languages (for example, to prepare for international missions).

At IMSH 2021 we are introducing the avatar Louise, that is a representative digital human who is designed to simulate real people with real personalities and real emotions. Her versatile attitudes are essential for recreating ultra-realistic interactions through a virtual environment. She can assist a team by replicating real-life situations that teach crisis management, negotiation, conflict management, or guide conversations with challenging and even difficult people.

Moreover, because of COVID-19, a large number of activities are currently not “brick-and-mortar” but migrating online. We are currently Beta testing the e-REAL online platform to allow simulations in a virtual environment that display challenging situations in 3D: the main point is that, unlike other VR and AR solutions, the e-REAL online environment allows users experience full immersion without the need for glasses or goggles. It is an easy and memorable experience with a robust learning outcome (Figures 35 and 36).

The feedback we receive most often is that they didn’t expect such easy access to an intensely engaging and meaningful experience. We are very happy about this, because our efforts are aimed at designing solutions that empower learning with a strong focus on the user experience, both for learners and trainers. We believe that flexible and user-friendly solutions are needed in learning, so we designed e-REAL in a way that makes possible both having scenarios and courses ready to use or co-designed with our team, or creating and uploading existing content with a dedicated editor in a very simple way—also last minute.

Our goal is to build significant learning solutions that help educators and “simulationistas” integrate into their practice new technologies to boost learning in easy and effective ways.

Figure 35 – Courtesy of Centro Studi Logos (Turin, IT), Logosnet (Lugano, CH and Houston, TX), Center for Medical Simulation (Boston, MA): The “lobby” area from the e-REAL Online Platform for the Labor and Delivery program designed by Roxane Gardner, PhD, Senior Director for Clinical Programs and Director of the Visiting Scholars and Fellowship Program at the Center for Medical Simulation in Boston (CMS).

Figure 36 – Courtesy of Centro Studi Logos (Turin, IT), Logosnet (Lugano, CH and Houston, TX), Center for Medical Simulation (Boston, MA): A scenario from the e-REAL Online Platform for the Labor and Delivery program designed by Roxane Gardner, PhD, Senior Director for Clinical Programs and Director of the Visiting Scholars and Fellowship Program at the Center for Medical Simulation in Boston (CMS).

REFERENCES

Arnheim R., Visual Thinking (1969). Berkeley and Los Angeles, CA: University of California Press.

Arnsten AF. Catecholamine modulation of prefrontal cortical cognitive function. Trends in cognitive sciences. Nov. 1 1998; 2(11): 436-447.

Auer M., Guralnick D., Uhomoibhi J. (Eds.)(2017). Interactive Collaborative Learning: Proceedings of the 19th ICL Conference - Volume 1. Cham, CH: Springer.

Aukstakalnis S. (2017). Practical Augmented Reality. A Guide to the Technologies, Applications, and Human Factors for AR and VR. Boston: Addison-Wesley.

Bailenson J.N., Blascovich J., Beall A.C., Noveck B., (2006). Courtroom Applications of Virtual Environments, Immersive Virtual Environments, and Collaborative Virtual Environments. Law and Policy, 28:2, 249-270.

Batini F., Fontana A. (2010). Storytelling kit. 99 esercizi per il pronto intervento narrative. Milano: Rizzoli.

Bauman Z. (2008). Liquid Modernity. Cambridge, UK: Polity Press.
Bergstrom B. (2008). Essentials of Visual Communication. London, UK: King Publishing.

Bertagni B., La Rosa M. & Salvetti F. (eds.) (2010). Learn How to Learn! Knowledge Society, Education and Training. Milan: Franco Angeli.

Bergmann J., Sams A. (2012). Flip Your Classroom. Reach Every Student in Every Class Every Day.

Blascovich J., Loomis J., Beall A., Swinth K., Hoyt C., Bailenson J.N. (2002). Immersive Virtual Environment Technology as a Methodological Tool for Social Psychology. Psychological Inquiry, 13: 103–24.

Blazer L. (2016). Animated Storytelling. Simple Steps for Creating Animation and Motion Graphics. London, UK: Pearson.
Bremond C. (1973). *Logique du récit*. Paris: Éditions du Seuil.

Buttimer M. (2020). Name/Claim/Aim Around the World. In: https://harvardmedsim.org/blog/name-claim-aim-around-the-world/

Calabi D., Bisson M., Venica C. (2019). Design and medical training experimental hypotheses for training in immersive environments, pp. 527- 532. In: 3rd International Conference on Environmental Design, Polytechnic of Milan, Italy.

Castells M. (2009). The Rise of the networked society. Hoboken, NJ: Wiley-Blackwell.

Ciuccarelli P., Valsecchi R. (2009). Ethnographic approach to design knowledge. Dialogue and participation as discovery tools within complex knowledge contexts. In: IASDR 2009 - Rigor and Relevance in Design.

Collins S. (2015). Neuroscience for Learning and Development. How to Apply Neuroscience & Psychology for Improved Learning & Training. London: Kogan Page.

Coro G. (2019). Valutazione del software e-REAL Speech Analysis. Pisa: ISTI-CNR.

Cruz-Neira C., Sandin D.J., De Fanti T.A., Kenyon R.V., Hart J.C. (1992). The CAVE: Audio visual experience automatic virtual environment. Communications of the ACM 35:64–72.

De Leeuw K.E., Mayer R.E. (2008). A Comparison of Three Measures of Cognitive Load: Evidence for Separable Measures of Intrinsic, Extraneous, and Germane Load. Journal of Educational Psychology. 100(1): 223-234.

De Rossi M., Petrucco C. (2013). Le narrazioni digitali per l'educazione e la formazione. Roma: Carocci.

De Souza e Silva A., Sutko, D.M. (2009). Digital Cityscapes: merging digital and urban playspaces. New York, NY: Peter Lang Publishing, Inc.

Eppler M., Burkhard R. (2004). Knowledge Visualization. Towards a New Discipline and Its Field of Application. Research Paper, 07-02, Lugano: University of the Italian Switzerland.

Ericcson A., Krampe R., Tesch-Romer C. (1993). The Role of Deliberate Practice in the Acquisition of Expert Performance. Psychological Review 1993, Vol. 100. No. 3, 363-40

Fields H.L., Hjelmstad G.O., Margolis E.B., Nicola S.M. (2007). Ventral tegmental area neurons in learned appetitive behavior and positive reinforcement. Annu Rev Neurosci., 30: 289–316.

Friedlander M.J., Andrews L., Armstrong E.G., Aschenbrenner C,. Kass J.S., Ogden P., Schwartzstein G., Viggiano T.R. (2011). What Can Medical Education Learn From the Neurobiology of Learning? In: Academic Medicine, 86-04: 415-420.

Gaba D.M., Fish K.J, Howard S.K. (1994). Crisis Management in Anesthesiology. Churchill Livinstone, Philadelphia, PA; Walker J.D., Spencer P.J., Walzer T.B., Cooper J.B. (2018). Simulation in Cardiac Surgery, in Cohn L.H., Adams D.H. (Eds.). Cardiac Surgery in Adult, McGraw Hill, Columbus, OH.

Gardner R. (2018). Medical Simulation Week 2018: Center for Medical Simulation. https://e-real.net/wp-content/uploads/videos/e-REAL@www.harvardmedsim.org.mp4 (ver. 15.04.2019).

Gardner R., Salvetti F. (2019). Improving Teamwork and Crisis Resource Management for Labor and Delivery Clinicians: Educational Strategies Based on Dynamic Visualization to Enhance Situational Awareness, Contextual Intelligence and Cognitive Retention, Research Abstract. San Antonio, TX: IMSH 2019.

Gazzaniga M.S. (ed) (2009). The Cognitive Neurosciences. Boston, MA : MIT Press.

Genette G. (1972). Figures III. Paris: Éditions du Seuil.

Guralnick D. (2018). Re-Envisioning online learning. In: Salvetti F., Bertagni B. (eds.). Learning 4.0. Advanced Simulation, Immersive Experiences and Artificial Intelligence, Flipped Classrooms, Mentoring and Coaching. Milan: Franco Angeli.

Kandel E.R., Schwartz J.H., Jessell T.M., Siegelbaum S.A,. Hudspeth A.J. (2013). Principles of Neural Sciences. New York, NY: McGraw Hill.

Kernbach S., Eppler M., Bresciani S. (2014). The Use of Visualization in the Communication of Business Strategy: An Experimental Evaluation. In: International Journal of Business Communication, I-24.

Khanna T. (2014). Contextual intelligence. In: Harvard Business Review, 9.

Knight C., Glaser J. (2009). Diagrams. Innovative solutions for Graphic Designers. Tables. Graphs. Charts. Forms. Maps. Signs. Instructions. Mies, CH: RotoVision.

Lamberti F., Pratticò G. (2018). E-REAL Speech Analysis. User Manual V1.0.4. Turin: Polytechnic School of Turin.

Lester P.M. (2006). Visual Communication: Images with Messages. Belmont, CA: Thomson Wadsworth.

Lévy P. (1998). Qu’est-ce que le virtuel ? Paris: La Découverte.

Licci G. (2011). Immagini di conoscenza giuridica. Padova: Cedam.

Lira M., Gardner S.M. (2020). Leveraging Multiple Analytic Frameworks to Assess the Stability of Students’ Knowledge in Physiology. In: CBE Life Science Education March 1, 2020, 19.

Lowe R., Ploetzner R. (Eds.)(2017). Learning from Dynamic Visualization. Innovations in Research and Application. Berlin: Springer.

Lyons R., Lazzara E., Benishek L., Zajac S., Gregory M., Sonesh S., Salas E. (2015). Enhancing the Effectiveness of team Debriefings in Medical Simulation: More Best Practices. In: The Joint Commission journal on Quality and Patient Safety, 41:3, 115-123.

Marchese A. (1983). L'officina del racconto. Milano: Mondadori.

Markowitz M., Bailenson J. (2019). Virtual Reality and Communication, Oxford Bibliographies. https://vhil.stanford.edu/mm/2019/02/markowitz-oxford-vr-communication.pdf (ver. 15.04.2019).

Mayer R.E, Moreno R. (2003). Nine Ways to Reduce Cognitive Load in Multimedia Learning. Educational Psychologist, 38(1), 43-52.

Mazur E. (1997). Peer Instruction, A User's Manual, Prentice Hall Series in Educational Innovation Upper Saddle River.

Milgram P., Kishino A.F. (1994). Taxonomy of Mixed Reality Visual Displays. IEICE Transactions on Information and Systems. pp. 1321–1329.

Minehart R., Pian-Smith M., Walzer T., Gardner R., Rudolph J., Simon R., Raemer D. (2012). Speaking Across the Drapes. Communication Strategies of anesthesiologists and Obstetricians During a Simulated Maternal Crisis. In: Simulation in Healthcare, 7: 166-170.

Minehart R., Rudolph J., Nadelberg R., Clinton E., Gardner R. (2019). Name/Claim/Aim for Obstetric Crises: A New Paradigm in Crisis Resource Management, Poster Communication: Phoenix, AZ: SOAP 51th Annual Meeting.

Morin E. (1986). La connaissance de la connaissance. Paris: Le Seuil.

Murray S. (2013). Interactive Data Visualization for the Web. Sebastopol, CA: O’Reilly Media.

Parisi Presicce P. (2017). Impalcature. Teorie e pratiche della narratività. Milano: Mimesis.

Popper K.R. (1972). Objective Knowledge: An Evolutionary Approach, Oxford: Oxford University Press.

Potter M.C., Wyble B., Hagmann C.E., McCourt E.S. (2014). Detecting meaning in RSVP at 13 ms per picture, in Attention, Percept and Psychophysics, 76:270–279

Raemer D.B., Kolbe M., Minehart R.D., Rudolph J.W., Pian-Smith M.C. (2016). Improving Anesthesiologists' Ability to Speak Up in the Operating Room: A Randomized Controlled Experiment of a Simulation-Based Intervention and a Qualitative Analysis of Hurdles and Enablers. Acad Med. Apr; 91(4):530-9.

Ridgway J., Nicholson J., Campos P., Teixeira S. (2018). Dynamic Visualisation Tools: A Review. ProCivicStat Project: http://IASE-web.org/ISLP/PCS

Rizzolatti G., Sinigaglia C. (2008). Mirrors In The Brain: How Our Minds Share Actions and Emotions. Oxford and New York, NY: Oxford University Press.

Rizzolatti G., Cattaneo G., Fabbri-Destro M. (2009). Mirror Neurons and their Clinical Relevance. Nature. Jan. 9(5): 24-34.

Robilant E. (1991), Conoscenza: forme, prospettive e valutazioni. La traduzione della conoscenza nell’operatività. Lessons at the University of Turin 1990-1991, Turin: manuscript.

Rosenberg L.B. (1992). The Use of Virtual Fixtures As Perceptual Overlays to Enhance Operator Performance in Remote Environments. Technical Report AL-TR-0089, USAF Armstrong Laboratory, Wright-Patterson AFB OH, 1992.

Rudolph J., Simon R., Raemer D., Eppich W. (2008). Debriefing as a Formative Assessment: Closing Performance Gaps in Medical Education. In: Academic Emergency Medicine. 15: 1010-1016.

Salvetti F. (2015). Rethinking learning and people development in the 21st century: the Enhanced Reality Lab – e-REAL – as a cornerstone in between employability and self-empowerment. In: Salvetti F., La Rosa M. & Bertagni B. (eds.). Employability: Knowledge, Skills and Abilites for the Glocal World. Milan: Franco Angeli.

Salvetti F., Bertagni B. (2010). Anthropology and epistemology for "glocal" managers: understanding the worlds in which we live and work. In: Bertagni B., La Rosa M. & Salvetti F. (eds.). "Glocal" Working. Living and Working Across the World with Cultural Intelligence. Franco Angeli, Milan.

Salvetti F., Bertagni B. (2014). E-REAL: Enhanced Reality Lab. In: International Journal of Advanced Corporate Learning, 7-3: 41-49.

Salvetti F., Bertagni B. (2016). Interactive Tutorials and Live Holograms in Continuing Medical Education: Case Studies from the e-REAL Experience. In: Proceedings of the ICELW Conference, Columbia University, New York, NY: 1-8.

Salvetti F., Bertagni B. (eds.) (2018). Learning 4.0. Advanced Simulation, Immersive Experiences and Artificial Intelligence, Flipped Classrooms, Mentoring and Coaching. Milan: Franco Angeli.

Salvetti F., Bertagni B. (2018b). Reimagining STEM Education and Training with e-REAL: 3D and Holographic Visualization, Immersive and Interactive Learning for an Effective Flipped Classroom. In: Salvetti F., Bertagni B. (eds.). Learning 4.0. Advanced Simulation, Immersive Experiences and Artificial Intelligence, Flipped Classrooms, Mentoring and Coaching. Milan: Franco Angeli.

Salvetti F., Gardner R., Minehart R., Bertagni B. (2019). Teamwork and Crisis Resource Management for Labor and Delivery Clinicians: Interactive Visualization to Enhance Teamwork, Situational

Awareness, Contextual Intelligence and Cognitive Retention in Medical Simulation, Research Paper. New York, NY: ICELW 2019 at Columbia University.

Salvetti F., Bertagni B. (2019b). Virtual worlds and augmented reality: The enhanced reality lab as a best practice for advanced simulation and immersive learning. In: Form@re, vol. 19, no. 1.

Schapiro M., Gardner R., Godwin S., Jay G., Lindquist D., Salisbury M., Salas E. (2008). Defining Team Performance for Simulation-based Training: Methodology, Metrics, and Opportunities for Emergency Medicine. In: Academic Emergency Medicine, 15: 1088-1097.

Strayer J. F. (2008). The effects of the classroom flip on the learning environment: A comparison of learning activity in a traditional classroom and a flip classroom that used an intelligent tutoring system. Dissertation Abstracts International Section A, 68.

Szparagowsk R. (2014). "The Effectiveness of the Flipped Classroom" (2014). Honors Projects. 127. https://scholarworks.bgsu.edu/honorsprojects/127

Sweller J., Ayres P., Kalyuga S. (2017). Cognitive Load Theory. New York, NY: Springer.

Taras J., Everett T. (2017). Rapid Cycle Deliberate Practice in Medical Education – A Systematic Review. Cureus 9(4): 1180.

Toto R., Nguyen H. (2009). Flipping the work design in an industrial engineering course. Paper presented at the ASEE/IEEE Frontiers in Education Conference, San Antonio, TX.

Tucker B. (2012). The Flipped Classroom. Education Next, 12 (1).

Tufte E. (1997). Visual Explanations: Images and Quantities, Evidence and Narrative. Cheshire, CT: Graphics Press.

Tufte E. (2001). The Visual Display of Quantitative Information. Cheshire, CT: Graphics Press.

Vasconcelos A. (Ed.)(2011). Global Trends 2030. Citizens in an Interconnected and Polycentric World. Brussels: European Institute for Security Studies.

Vogel D., Dickson G., Lehman J. (1986). Persuasion and the role of visual presentation support. Research paper. Management Information Systems Research Center. Minneapolis, MS: University of Minnesota: School of Management.

Wieman C., STEM Education: Active Learning or Traditional Lecturing? (2018). In: Salvetti F., Bertagni B. (eds.). Learning 4.0. Advanced Simulation, Immersive Experiences and Artificial Intelligence, Flipped Classrooms, Mentoring and Coaching. Milan: Franco Angeli.

Wirth W., Hartmann, T., Bocking, S., Vorderer P., Klimmt C., Holger S., Saari T., Laarni J., Ravaja N., Gouveia F., Biocca F., Sacau A. Jancke L., Baumgartner T., Jancke P. (2007). A Process Model for the Formation of Spatial Presence Experiences. Media Psychology, 9, 493-525.

Wissmath B., Weibel D., Groner, R. (2009). Dubbing or Subtitling? Effects on Spatial Presence, Transportation, Flow, and Enjoyment. Journal of Media Psychology 21 (3), 114-125.

Yeo J., Gilbert J.K. (2017). The Role of Representations in Students' Explanations of Four Phenomena in Physics: Dynamics, Thermal Physics, Electromagnetic Induction and Superposition. In: Treagust D.F., Reinders D., Fischer H.E. (eds.). Multiple Representations in Physics Education. Cham: Springer.

AUTHORS

Fernando Salvetti (J.D., P.P.E., M.Phil., Ph.D. – salvetti@logosnet.org), Founder of Centro Studi Logos in Turin and Logosnet in Lugano, Berlin and Houston, is an epistemologist, an anthropologist and a lawyer who co-designed e-REAL, the enhanced reality lab where virtual and real worlds are merging within an advanced simulation environment. He is committed to exploring virtual and augmented reality, cognitive aids by artificial intelligence, visual thinking, interactive and immersive learning, emerging scenarios and trends, and cross-cultural intelligence.

Roxane Gardner (M.D., M.H.P.E., M.P.H., Ph.D. – rgardner1@bwh.harvard.edu), Senior Director for Clinical Programs and Director of the Visiting Scholars and Fellowship Program at the Center for Medical Simulation in Boston (CMS), has been a principle faculty member of CMS since 2002 and Co-Director of its Labor and Delivery Teamwork and Crisis Management program since its inception in 2003. In addition to her roles at CMS, Dr. Gardner is an Assistant Professor of Obstetrics, Gynecology and Reproductive Biology at the Harvard Medical School and holds appointments in Boston at Brigham and Women's Hospital, Boston Children's Hospital, and Massachusetts General Hospital.

Rebecca D. Minehart (M.D., M.S.H.P.Ed. – rminehart@mgh.harvard.edu), Director for Anesthesia Clinical Courses at the Center for Medical Simulation in Boston (CMS), is an obstetric anesthesiologist at Massachusetts General Hospital (MGH), an Assistant Professor of Anesthesia at Harvard Medical School, and the Program Director for the MGH Obstetric Anesthesia Fellowship Program. She is an ardent education and patient safety advocate who has been involved in international efforts to both research and promote best teamwork and communication practices, especially involving speaking up and giving feedback. She is a recognized expert in educational techniques utilizing simulation and is a core teaching faculty member at both CMS and the MGH Learning Laboratory, where she serves as the Operating Room Simulation Officer.

Barbara Bertagni (B.Sc., M.Sc., B.A., M.A., M.Phil., Ph.D., Clin.Psy.D. – bertagni@logosnet.org), Founder of Centro Studi Logos in Turin and Logosnet in Lugano, Berlin and Houston, as well as e-REAL co-designer, is a clinical psychologist, an anthropologist and a practical philosopher particularly involved with personal and professional development, coaching and mentoring, immersive learning and advanced simulation. She works as a sparring partner, a coach and a mentor advising people and organizations across the globe.