How the Spanish military health school is revolutionizing medical training in CBRN environments with VR

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ABSTRACT

Workforce training continues to be a key area to help achieve some of the main targeted goals for the military and other high-risk industries: implement the most significant saving opportunities in the most efficient manner possible.

The demand of more realistic and innovative ways for training is increasing, where safety and knowledge retention are becoming even more important elements in today's social and economic environment. For instance, the possibility to train several units based in different locations but in the same large-scale virtual environment. This improves the individual, team and unit-level performance in emergency and conflict situations, but also reduces the investment in physical replicas and even the expenses of bringing the units together to one location for training.

Virtual Reality is definitely establishing itself as the standard for training across industries. The example of this paper is The Spanish Ministry of Defense and how they are shaping the training processes modernization of the medical staff of the Military Health Corps in up to three highly complex environments related to (Chemical, biological, radiological, nuclear) CBRN protocols through a warehouse scale multi-user VR simulator. The key differentiator is that they are introducing a revolutionary concept based on Virtual Reality Immersive Rooms.

The paper shows the potential of Virtual Reality to accelerate Innovation and improve workforce training with the Spanish Ministry of Defense as a best practice.

1.0 BACKGROUND

The Military School of Health, EMISAN is an educational centre integrated in the Central Academy of Defence, which provides education and advanced training for officers of the Military Health Corps of the Spanish Armed Forces: doctors, pharmacists, veterinarians, dentists, psychologists and nurses.

EMISAN began working with immersive technology and applying it efficiently to training. Early on, EMISAN developed an interactive table for the training of the military health corps in International Triage Processes of a single patient with a 3D simulator.

During 2009, EMISAN published and presented research fundings for the Cooperation in Scientific

Research and Development in Strategic Technologies (COINCIDENTE) program, of the Ministry of Defence. The project's principal objective was to develop a multi-user, virtual reality interactive simulator for the training and preparation of the Military Health Corps (fundamental specialties in Medicine and Nursing) in their capacities for providing medical assistance in three special environments:

1. Tactical Combat Casualty Care (TCCC)
2. Tactical Emergency Casualty Care (TECC)
3. Medical assistance in chemical, biological, radiological, and nuclear environments (CBRN)

Said training would be based on the latest scientific evidence and internationally recognized guidelines, and in the NATO's standardization agreements (STANAG) ratified by Spain.

The project's methodological base is based on internationally recognized procedures required by the continuing education for the Military Health Corps' personnel as part of the Defense Health Inspector General's continuing education plan (IGENSANDEF). This project's principal objective is to establish an aid for teaching so that the Military Health Corps integrates knowledge after prior training with programs that integrate theoretical content, clinical skills workshops, and high-fidelity, advanced clinical simulation scenarios. The employment of the virtual reality room would have as its principal objective to serve as an integration tool for knowledge, immersing the health professional in a virtual reality environment where she must make patient healthcare decisions in different environments. In this way, we are able to complete all last-generation teaching aids that lead to better-prepared and better-trained professionals, thereby increasing patient survival in highly complex environments which are not common in professional life.

Immersion in a virtual reality scenario allows us to assess not only clinical abilities but also highly important transversal abilities in the military field, such as: leadership, decision making under stress, communication and teamwork skills and management of human resources and materials in complex situations. Using this type of virtual reality immersion room will allow us to establish studies that improve performance in learning and retention of knowledge over time.

2.0 METHOD

The investigation project is a technology demonstrator whose objective is to create totally immersive environments where multiple users are trained in tactical matters, multiple victim incidents and CBRN environments. In addition to serving as a vitally important teaching aid in assessing the Military Health Corps health professional's ability to integrate knowledge.

The technology demonstrator consists of a multi-user immersive room for 2 teams of up to 4 members (8 persons in total), and a software simulator.

2.1 Immersive Room

The technology demonstrator room is in Madrid, at the Central Defense Academy. The space selected for same is approximately 160m2 and is divided in two distinct, though not physically-separate, areas:

1. Room control area
2. Immersive training area or arena (122m2)

VIRTUALWARE's VIROO® has been installed in the immersive training area, for the absolute positioning of the persons carrying out the virtual training. In turn, the room has a control area that power the immersive room's monitoring and management equipment. This space is located outside the arena area, so as to maximize the area for training.

Each user will carry a HP professional backpack with a computer specially manufactured for virtual reality experiences. These backpacks have a battery system which allow users to move freely throughout the space.

To visualize the experience, users are provided the HP Reverb G2 virtual reality visor. Due to their image quality and movement sensors, these visors allow each user to become completely immmersed in the virtual environment and see how their head movements are replicated with a high degree of precision, with sight possible in every direction and from every angle.

To precisely obtain each person's position in real time, a tracker is placed on the upper part of each visor. The tracker will be able to receive infrared light from the ceiling panels and thereby indicate current position with a very low margin of error.

Figure 1. Visor and VIROO® Tracker

With a view on carrying out the defined training sessions, and keeping in mind the interactions between multiple users, the room has been furnished with the following equipment:

1. 8 HP computer backpacks
2. 8 HP Reverb visors
3. 8 VIROO trackers
4. 1 CLEANBOX (to disinfect the electronic components)

To house all the accessories in the room, two custom-made cabinets have been included, with sufficient power to charge the equipment.

Figure 2. User Equipment

Figure 3. EMISAN´s Immersive Room

2.2 Simulator

The principal component of this investigation is the simulator itself. This simulator allows:

1. An interactive, immersive virtual reality simulation system capable of presenting different types of scenarios for the training of users in medical care.

2. For an approach to intervention procedures in three types of scenarios:

    a. Tactical Combat Casualty Care (TCCC)

    b. Tactical Emergency Casualty Care (TECC)

    c. Handling of victims of exposure to chemical, biological, radiological, and nuclear agents (CBRN)

3. For the management of agile scenarios.

4. For the evaluation of the correct or incorrect execution of the actions compiled in every action protocol, as well as offering a complete analysis regarding user performance during training.

5. For re-creation of the different scenarios on a real scale, and for all the environment’s elements to react to all actions taken by any user that interacts with them.

6. For the inclusion of gaming elements related to the training’s theme, with a view on maintaining a

high level of attention by the user and gain a positive response.

7. For the inclusion of positive visual, sonic and iconographic reinforcement that tells the user when the actions have been performed correctly.

8. For carrying out two modes of training:

   a. Assisted, in which a virtual assistant guides the user utilizing the simulator.

   b. Un-assisted, in which the user's actions are carried out without assistance or guidance.

9. The recording, analysis and visualization of data, to record and show information and statistics for each user, as well as the recording of sessions.

10. For the inclusion of haptic elements for the manipulation of the virtual environment by the users.

11. The simultaneous training and use of the systems by a team and in a collaborative manner, such that one user's actions have repercussions on all others.

Figure 4. Simulator´s realtime footage

Figure 5. Simulator´s realtime footage

Users utilizing the product are classified as a function of use frequency, group of utilized functions, security privileges, experience level and other parameters. There are 3 differentiated profiles:

1. **Room Operator**: In charge of powering on the room and equipment, as well as maintenance and inspection of the condition of same: charging of batteries, state of the network, etc.

2. **Instructor**: Solely in charge of the observation of the care team's performance so as to assess the integration of knowledge during health care processes in complex scenarios. This is the basis for the most important part of the simulation, which is the debriefing, the objective assessment of the simulation and learning under the trial and error model, which is the natural learning method. She will interact with the control location and will be able to execute the selection of and launching of a training scene, see the action that occurs in the VR scenario in real time, visualize the results, record and visualize the VR action to detect areas for improvement for the training team. Debriefing [works] as a tool both for the assessment of actions executed correctly, strengthening their execution, and of errors committed, offering the professional the tools and materials necessary for improving awareness of the weak areas in performance.

3. **Trainees**: These are the persons who will utilize the simulator and will face the different training scenarios. They will use the virtual reality equipment and interact with the VR space, utilizing the selected devices. Said personnel is comprised of the Military Health Corps officers in the fundamental specialties of Medicine and Nursing who are participating in training and improvement programs, as well as students in medical training at the Madrid Defense University Center.

Among trainees, the following roles can be identified:

1. **Physician's Roles**: Their objective is to coordinate and direct patient care, and should generally locate herself at the head of the wounded and from there, direct and coordinate the initial assessment

of the patient and the medical care given to same in different environments. She is in charge of controlling the airway and to set the order of the care given. She is in charge of the assessment of the airway, control of the cervical spine and neurological evaluation of the patient, confirms consciousness, assesses pupil size and reactivity, consciousness, and assesses the condition of the airway. She coordinates comprehensive care for the wounded with the other professionals.

2. **Nurse’s Role**: [The nurse] stands at one of the patient’s sides to perform the initial assessment of the patient’s injuries to the thorax, abdomen, pelvis, genitalia and back. She is in charge of setting up one IV or intraosseous line and administering the dose of medicine ordered by the physician and performing the required treatment techniques. The nurse is responsible, along with the sanitarian or the TES, for performing a proper initial assessment and performing the techniques and care that the patient needs.

3. **Roles of the Emergency Care Technician or Military Sanitarian**: The function is to assist the physician and the nurse in whatever is needed: material, immobilization, mobilization, transport, monitoring, evacuation or transmission message, etc.

Figure 6.4: Simulator interface for selection of users’ roles

In addition to the principal care roles, the military health teams must be trained to offer security during the incident, and are therefore armed and must be capable of responding to a direct threat with fire so as to neutralize it, offer security to the team and the patient and be able to provide health care, in light of the external factors that may affect it: security, etc…

Below, there is a conceptual map of the system architecture, detailing the components that comprise it.

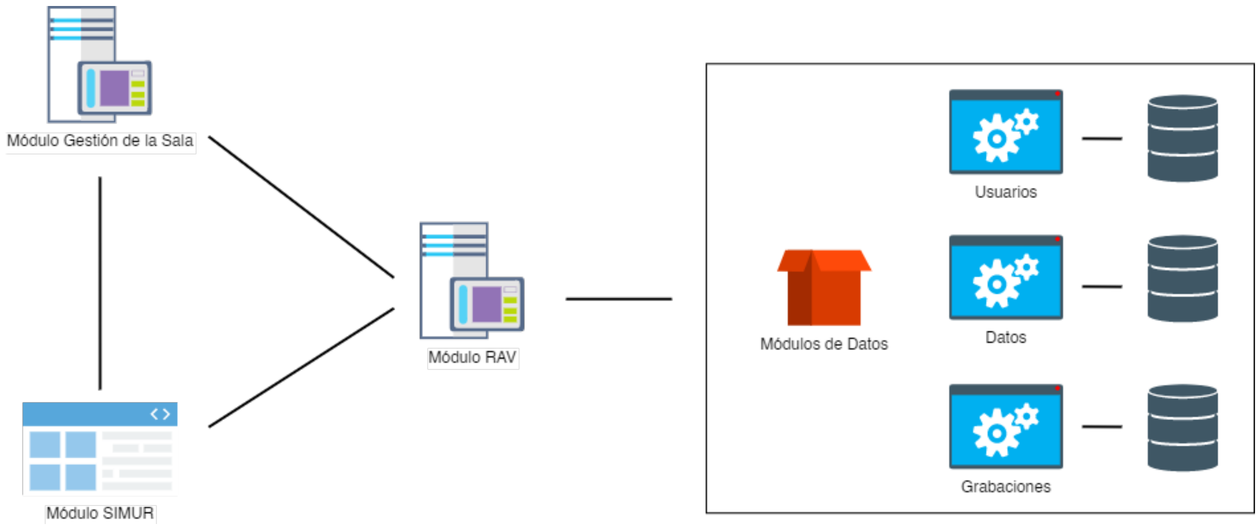

Figure 8. Conceptual Map of the SW System arquitecture

- SIMUR Module: This application is executed on the virtual reality equipment of the persons participating in the training.
- RAV Module: This module is executed on a computer that is found in the room and from that same computer, the simulation is coordinated. The action can be viewed from this equipment and same gathers analysis of the progress made by the participants in the training, and the training can be recorded.
- Data Modules: This module is housed and functions in the same equipment in which the RAV Module is found, functions autonomously and will communicate with the RAV Module to provide same with the listed functionalities. The data module will be responsible for the following functionalities:
  - User data management.
  - Analysis data management.
  - Session recording management.
- Room Management Module. From this application, the room and the virtual reality devices can be managed. This allows for knowledge of the state of the VR devices and their location in the room, as well as for the remote execution of the simulation on said equipment.

3.0 RESULTS

The project's principal objective has been reached due to the installed and functioning technology demonstrator at EMISAN in Madrid, at the Central Defense Academy. The demonstrator consists of a 160m2 space where given the installed equipment and the simulator developed and validated in a real-world environment, it is possible to create totally immersive environments where multiple users can be trained on tactical matters, intentional mass casualty incidents and CBRN environments. The demonstrator is capable of compiling, demonstrating and comparing the simulation results of each person that interacts to visualize their progress and be aware of the areas where their behavior given the situation needs improvement. Additionally, it allows for the management of the scenarios created in this project in an agile manner, launching, pausing and controlling the execution of same by the multiple users who interact in the simulated situation.

Regarding the teaching/learning objective, an aid to teaching has been achieved so that the Military Health Corps personnel integrates knowledge from a prior training with programs where theoretical content, clinical skills workshops and high-fidelity, advanced clinical simulation scenarios are integrated. The employment of the virtual reality room would have as its principal objective to serve as an integration tool for knowledge, immersing the health professional in a virtual reality environment where she must make patient healthcare decisions in different environments. In this way, we are able to complete all last-generation teaching aids that lead to better-prepared and better-trained professionals, thereby increasing patient survival in highly complex environments which are not common in professional life.

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4.0 DISCUSSION

Virtual reality is a technology that is experiencing a second spring due to the appearance in 2016 of visors that are affordable for consumers. [This was] a medium that for decades was restricted solely to the most professional use and the biggest companies, due to the equipment's high cost.

Nevertheless, thanks to the democratization of virtual reality, the market now has multiple systems and visors whose cost is significantly lower than previously, and which therefore begin to yield a return on investment much sooner and more apparent than before. From a few years back, virtual reality has positioned itself as a useful tool to integrate the knowledge of health professionals (Cook and Hata, 2011), with there being different training and education programs worldwide in this technology, in the different areas of health sciences.

Several studies show that virtual reality training and education substantially improves student learning outcomes compared to traditional training. Interaction with patients in virtual environments showed better learning results than conventional classes (Li J and li-QL, 2013), (Qavumi and Kurihara, 2004), the reading of specific syllabi (Qayuni and Kurihara, 2004), (Williams and Aubin, 2001), (Schwid and Rooke, 2001) and activities that include traditional teaching methods, including lectures or practical training with simulators (Bonnetain and Boucheix, 2010), (Botezatu and Hult, 2010), (Botezatu and Hult , 2010). The skills that improved were clinical reasoning, procedural skills, and teamwork (Kononowicz and Woodham, 2019).

The level of satisfaction of students who tried virtual reality training programs was higher compared to conventional teaching methodology, training with online tutorials or video tutorials (Kononowicz and Woodham, 2019).

Economic costs were estimated at a cost-utility ratio of $1.08 for virtual patient training versus $3.62 for simulation-based manikin training (Kononowicz and Woodham, 2019). This cost reduction was mainly due to the fact that fewer resources were required for training in virtual environments compared to training with simulators, due to reduced time spent by the instructor, the use of highly expensive simulation equipment or simulation facilities that require high cost maintenance (Liaw and Chan, 2014). Training with virtual patients can have a greater impact when combined with skills and problem solving, and when direct contact with the patient or re-creation of the special environment is not yet possible and carries high costs in simulators and setting, requiring a large number of specialized instructors for the evaluation of the simulation.

It is because of this that education through virtual reality environments provides an active and attractive form of teaching the student, which is beneficial in implementing the clinical reasoning skills and the integration of the acquired knowledge (Kononowicz and Woodham, 2019). Immersion in a virtual reality environment allows the student's senses to increase the student's attention and focus on learning, fostering meaningful learning experiences to develop new knowledge or skills in an immersive environment, eliminating external distractions during the learning process. (Gadelha, 2018), (Bracq and Michinov, 2019). In turn, the virtual reality immersive environment encourages progression in problem solving in complex environments, also evidencing its usefulness for learning transversal or non-technical skills for health personnel (Benavides and Camelo 2017). There are many published studies attempting to test virtual reality and augmented reality simulators in specific educational settings (related to different medical fields and training stages) to examine their validity, the transferability of the skills taught to the real world, the acceleration of the learning curve and the period of retention of skills (Cózar and Hernández, 2015).

All the aforementioned seems to indicate that virtual reality education and training can result in an improvement in the integration of acquired knowledge and [be] a useful tool to prepare health professionals in decision-making and problem solving in complex environments, which otherwise, would result in an increase in costs for the reproduction of these environments with conventional simulation. In addition, the development of special cognitive, perceptual, motor and temporal skills in students is enhanced, regardless of their age and academic level. It also leads to reinforcement of attention, immediate memory (short term) and intermediate memory long term in its visual and auditory forms, as well as reasoning. It makes learning more attractive, increasing motivation and interest in the topic at hand, reinforcing skills and competencies (independence, initiative, etc.…) (Benavides and Camelo 2017). The use of “serious games” and state-of-the-art simulation technology such as a virtual model of a real patientensures that healthcare personnel will acquire a high level of knowledge and skills before attending conventional face-to-face training classes .

Training with virtual reality or augmented reality environments also does not pose ethical problems, compared to other simulation models with a live animal model or corpses, and they provide user immersion in scenarios of various natures, with the ability to develop complex procedures (Pantelis and Chorti, 2017).

Nevertheless, it must be set forth that prior to including the student in immersive, virtual reality educational programs, the student must show having acquired skills and knowledge by the performance of clinical techniques and skills on real simulators (Grantcharov and Kristiansen, 2004).

5.0 EXISTING EDUCATIONAL SIMULATORS

Regarding existing simulators utilized for educational purposes, the following are analyzed below:

VirTra provides advanced combat training systems to better prepare warfighters for real-world incidents. Every military simulator is programmed with real-world scenarios, recorded with video images and projected on a polygonal, big-format screen structure, inside which the persons performing the training are placed.

V-Marksmanship® software provides ballistic training, offering a variety of objectives, courses, and scenarios. It allows multi-user training. Additionally, it allows the use of weapon replicas that when fired provoke a reaction in the projected video. Nevertheless, the system is not capable of following the users' movements and displacements.

Additionally, interaction with simulation is limited since it involves pre-recorded videos. Immersion is also reduced to being visualized on flat screens and does not use any virtual reality visor.

SimX VALOR's objective is to make VR medical simulation training more flexible, complete and accessible.

The program is being launched with the support of an initial $1 million award from the USAF SBIR, and the initial efforts will be centered on the expansion of training capacities with existing simulators for training COVID-19 first-line health workers.

There are already two free, COVID-19 training simulations generally available to the public. The simulator makes use of virtual reality visors, allowing users deep immersion, who can perform operations in a collaborative manner. Nevertheless, the use of SteamVR technology limits the tracking zone to an approximate zone of 60m2.

Inveris Training Solutions was the first company in the world to introduce interactive, weapons training simulators for law enforcement and warfighters. Its simulators offer different conditions and number of flat screens depending on the type of training. BlueFire®'s patented weapons simulators ensure a realistic handling of weapons through the use of wireless technology to communicate with the system's hardware, maintaining the weight, balance, backfire and diagnostics in real time. Its systems have become somewhat dated given the lack of immersion, compared to more current systems.

V-Armed - This multi-user virtual reality solution is utilized in the training of the New York Police Department through the use of visors and a tracking system based on Optitrack. This system precisely follows persons and extremities with a high level of immersion. The software is capable of representing each police officer's field of vision and thus analyzes its effectiveness when carrying out tactical operations. The system's principal limitation is its high cost and difficulty in scaling.

NMERSO is composed of a series of ceiling panels that emit infrared light that is gathered by the Tracker with multiple cameras placed on the upper part of the VR visor. This arrangement, different than the one commonly used to date, allows for the processing of each person's positioning to be performed by the corresponding backpack PC, instead of only one station simultaneously managing the tracking of all persons.

The principal advantage is that the limit of persons who can occupy the room at the same time is defined solely by the dimensions of the available space. At the same time, expanding the surface through the placement of more panels is significantly more feasible than the competition's systems, since in the latter, it is the cameras that are placed on the ceiling, with each of them much costlier than the light panels.

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7.0 REFERENCES

1.-Cook DA, Hata R, (2011) Technology-Enhanced Simulation for Health Professions Education: A Systematic Review and Meta-analysis. JAMA.;306(9):978–988. doi:10.1001/jama.2011.1234

2.- Li J, Li QL, Li J, Chen ML, Xie HF, Li YP, Chen X. Comparison of three problem-based learning conditions (real patients, digital and paper) with lecture-based learning in a dermatology course: a prospective randomized study from China. Med Teach. 2013;35(2): e963–70. doi: 10.3109/0142159X.2012.719651. [PubMed: 23009254] [CrossRef: 10.3109/0142159X.2012.719651]

3.- Qayumi AK, Kurihara Y, Imai M, Pachev G, Seo H, Hoshino Y, Cheifetz R, Matsuura K, Momoi M, Saleem M, Lara-Guerra H, Miki Y, Kariya Y. Comparison of computer-assisted instruction (CAI) versus traditional textbook methods for training in abdominal examination (Japanese experience) Med Educ. 2004 Oct;38(10):1080–8. doi: 10.1111/j.1365-2929.2004.01957.x. [PubMed: 15461653] [CrossRef: 10.1111/j.1365-2929.2004.01957.x]

4.- Williams C, Aubin S, Harkin P, Cottrell D. A randomized, controlled, single-blind trial of teaching provided by a computer-based multimedia package versus lecture. Med Educ. 2001 Sep; 35(9):847–54. [PubMed: 11555222]

6.- Schwid HA, Rooke GA, Michalowski P, Ross BK. Screen-based anesthesia simulation with debriefing improves performance in a mannequin-based anesthesia simulator. Teach Learn Med. 2001; 13(2):92–6. doi: 10.1207/S15328015TLM1302_4. [PubMed: 11302037] [CrossRef: 10.1207/S15328015TLM1302_4]

7.- Bonnetain E, Boucheix JM, Hamet M, Freysz M. Benefits of computer screen-based simulation in learning cardiac arrest procedures. Med Educ. 2010 Jul; 44(7):716–22. doi: 10.1111/j.1365-2923.2010.03708.x. [PubMed: 20636591] [CrossRef: 10.1111/j.1365-2923.2010.03708.x]

8.- Botezatu M, Hult H, Tessma MK, Fors UGH. Virtual patient simulation for learning and assessment: superior results in comparison with regular course exams. Med Teach. 2010; 32(10):845–50. doi: 10.3109/01421591003695287. [PubMed: 20854161] [CrossRef: 10.3109/01421591003695287]

9.- Botezatu M, Hult H, Tessma MK, Fors U. Virtual patient simulation: knowledge gain or knowledge loss? Med Teach. 2010; 32(7):562–8. doi: 10.3109/01421590903514630. [PubMed: 20653378] [CrossRef: 10.3109/01421590903514630]

10.- Kononowicz, A, Woodham, LA Edelbring, S Stathakarou, N Davies, D, Saxena N, Tudor Car, L, Carlstedt-Duke, J, Car, J, and Zary, N, Virtual Patient Simulations in Health Professions Education: Systematic Review and Meta-Analysis by the Digital Health Education Collaboration J Med Internet Res. 2019 Jul; 21(7): e14676.

11.- Liaw SY, Chan SW, Chen F, Hooi SC, Siau C. Comparison of virtual patient simulation with mannequin-based simulation for improving clinical performances in assessing and managing clinical deterioration: randomized controlled trial. J Med Internet Res. 2014;16(9): e214. doi: 10.2196/jmir.3322. http://www.jmir.org/2014/9/e214, [PMCID: PMC4180357] [PubMed: 25230684] [CrossRef: 10.2196/jmir.3322]

12.- Gadelha, R. (2018). Revolutionizing Education: The promise of virtual reality. Childhood Education, 94(1), 40–43. doi:10.1080/00094056.2018.1420362.

13.- Bracq, M. S., Michinov, E., & Jannin, P. (2019). Virtual reality simulation in nontechnical skills training for healthcare professionals: A systematic review. Simulation in Healthcare, 14(3), 188–194. doi:10.1097/

SIH.0000000000000347 PMID:30601464.

14.- Benavides AO, Camelo Real, L y García Chiribi D. Aplicación de la realidad virtual como apoyo al desarrollo de habilidades no técnicas en profesionales de la salud. Actas del congreso de videojuegos y educación (CIVE 17) ISBN: 978-84-897-3849-8.

15.-Cózar, R., del Moya, M., Hernández, J.A., & Hernández, J.R. (2015). Tecnologías emergentes para la enseñanza de las ciencias sociales. Una experiencia con el uso de realidad aumentada en la formación inicial de maestros. Digital Education Review, 27, 138-153. Recuperado de http://revistes.ub.edu/index.php/der/article/viewFile/11622/pdf

16.-Pantelidis P; Chorti A; Papagiouvanni I; Paparoidamis G; Dorsos C; Panagiotalopoulos T; Lales G and Sideris M. Virtual and Augmented Reality in Medical Education http://dx.doi.org/10.5772/intechopen.71963

17.- Grantcharov, T. P., Kristiansen, V. B., Bendix, J., Bardram, L., Rosenberg, J., & Funch-Jensen, P. (2004). Randomized clinical trial of virtual reality simulation for laparoscopic skills training. The British journal of surgery, 91(2), 146-50. doi: 10.1002/bjs.4407.