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A LITERATURE REVIEW ON IMMERSIVE VIRTUAL REALITY IN EDUCATION: STATE OF THE ART AND PERSPECTIVES

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Abstract: *Since the first time the term "Virtual Reality" (VR) has been used back in the 60s, VR has evolved in different manners becoming more and more similar to the real world. Two different kinds of VR can be identified: non-immersive and immersive. The former is a computer-based environment that can simulate places in the real or imagined worlds; the latter takes the idea even further by giving the perception of being physically present in the non-physical world. While non-immersive VR can be based on a standard computer, immersive VR is still evolving as the needed devices are becoming more user friendly and economically accessible. In the past, there was a major difficulty about using equipment such as a helmet with goggles, while now new devices are being developed to make usability better for the user. VR, which is based on three basic principles: Immersion, Interaction, and User involvement with the environment and narrative, offers a very high potential in education by making learning more motivating and engaging. Up to now, the use of immersive-VR in educational games has been limited due to high prices of the devices and their limited usability. Now new tools like the commercial "Oculus Rift", make it possible to access immersive-VR in lots of educational situations. This paper reports a survey on the scientific literature on the advantages and potentials in the use of Immersive Virtual Reality in Education in the last two years (2013-2014). It shows how VR in general, and immersive VR in particular, has been used mostly for adult training in special situations or for university students. It then focuses on the possible advantages and drawbacks of its use in education with reference to different classes of users like children and some kinds of cognitive disabilities (with particular reference to the Down syndrome). It concludes outlining strategies that could be carried out to verify these ideas.*

Keywords: *Virtual Reality; Education; Immersion; Educational Technology*.

I. INTRODUCTION

In the online oxford dictionary, Virtual Reality (VR) is defined as a "… computer-generated simulation of a three-dimensional image or environment that can be interacted with in a seemingly real or physical way by a person using special electronic equipment, such as a helmet with a screen inside or gloves fitted with sensors".

The term has first been used back in the 60s, even if its roots date back to the 19th Century when the first 360 degree art through panoramic murals began to appear. Nearly one hundred years later, a mechanical device, the Sensorama [57], engaged multiple senses to create an immersive VR. The system provided a multisensory experience of riding a motorcycle, including three-dimensional, full colour film together with sounds, smells, and the feeling of motion, as well as the sensation of wind on the viewer's face.

Since then, VR has evolved in several manners becoming more and more similar to the real world. ICT and VR have become strictly interconnected as computing power increases, and Human Computer interfaces become more and more complete and adaptive.

In VR, a concept that is frequently mentioned is "immersion" [1]. Jennett et al. [2] well define the general concept of immersion in games as the involvement in the play, which causes lack of awareness of time and of the real world, as well as a sense of "being" in the task environment. When referred to VR, "immersion" is usually used with the more restricted meaning of "spatial immersion".

Spatial immersion into virtual reality is a perception of being physically present in a non-physical world. The perception is created by surrounding the user of the VR system with images, sound or other stimuli that provide a very absorbing environment. Spatial immersion occurs when a player feels the simulated world is perceptually convincing, it looks “authentic” and “real” and the player feels that he or she actually is “there”.

Even if immersion seems to be a crucial element for VR, as Robertson et al. [3] say, VR can also be non-immersive when it “places the user in a 3D environment that can be directly manipulated, but it does so with a conventional graphics workstation using a monitor, a keyboard, and a mouse”. In this study, we focus on immersive VR since it is only with immersion that VR can reach all its potentialities.

Among the tools supporting immersive VR approach there are the Cave Automatic Virtual Environments (CAVE), where the user is in a room where all the walls, as well as the floor, are projection screens (or flat displays). The user, who can wear 3D glasses, feels floating in the projected world where he can move around freely. CAVE environments are still rather expensive, they need to have a specific space dedicated to them and they cannot be moved easily. All these characteristics make it difficult for them to have a widely spread use in education and training. As an example, CAVE technology is particularly used in Cultural Heritage education [4].

VR glasses or other sorts of Head Mounted Displays (HMD), often used with headphones, can easily produce the visceral feeling of actually being in the simulated world. For a complete immersion in a virtual world, all our five senses should be involved. Nevertheless, most VR environments today do not actually address all of them but usually focus on two: sight and hearing. In particular, according to Classen “Sight is held to be the most important of the senses and the sense most closely allied with reason” [5].

In the past, there were major difficulties in using HMDs or similar technologies. On the one hand, these technological devices were not very widely spread and were usually very expensive. On the other hand, their characteristics were such that they could often cause a feeling of aversion to their users due to mismatch between the movements of the head and the corresponding change in the scene. Now, the commercial product Oculus Rift offers a good virtual simulation at an accessible price while other affordable products are under investigation [6], making the use of such systems more feasible also in the fields of education and training. Furthermore, technology can now offer systems with low-latency and precise tracking of movements that make usability better for the user and manage to achieve his visceral reaction.

VR, in general, is widely used in the fields of education and training due to its potentials is stimulating interactivity [7] and motivation [8][9]. Furthermore, it offers an ideal manner to approach, study and remember new knowledge for all those who prefer a visual, auditory or kinaesthetic learning style [10].

II. OUR SURVEY

This paper reports a survey on the literature on the advantages and potentials of the use of Immersive Virtual Reality in Education in the last two years (2013-14).

The search has been made on three different search strings: “Immersive Virtual Reality Education”, “Oculus Rift Education” and “Head Mounted Display Education”. The first string, “Immersive Virtual Reality Education”, gave us an idea of the general use of Immersive VR in education, including also the CAVE-based approaches. We then tried to focus on VR glasses, with particular attention to Oculus Rift because we believe it to be an extremely interesting device due to its limited costs and great transportability. However, the search specifically focused on the Oculus Device gave nearly no results at all, so we decided to widen the search by replacing “Oculus Rift” with “Head Mounted Display”. The results are interesting and will be discussed later on, although the search has also provided some solutions, which are more in the field of Augmented Reality [58] (AR) rather than VR.

After examining the following databases: Web of Knowledge, Google Scholar, and Scopus, an in-depth exploration of the field was carried out by referring to the Scopus results.

As far as the search on “Immersive Virtual Reality Education” is concerned, the number of published papers decreases with the years: 54 in 2013, 37 in 2014 and 2 in 2015. This is probably

because the search has been made at the end of 2014. Two papers have not yet been published but are due in 2015. Several works in 2014 have probably not yet been uploaded on the databases.
Figure 1 shows that a large number of the 93 papers have been written in the United States and in the United Kingdom. None of the other nations has more than 10 papers in the whole period considered.

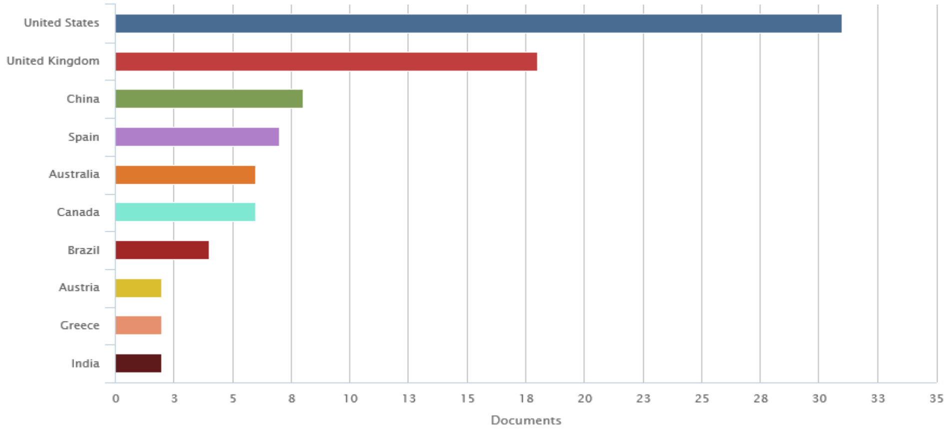

Figure 1. "Immersive Virtual Reality Education" - number of papers per country of publication

Figure 2 reports the distribution of the selected papers in different subject areas. The Scopus database reports a majority of papers in the Computer Science area: more than 60%. Many papers refer to more than one subject area, and Computer Science has been added to a large percentage of them since all the reported works refer to computer based programs or environments.

Nevertheless, when actually reading the papers, a significant number is related to medical area. In the following graphics, in fact, we can see nearly 12% related to medicine, but then there is another 3.2% in neuroscience, 3.2% in nurse training. Furthermore, another 5% is represented in the "Other" section referring to psychology, dentistry, health professions, etc.

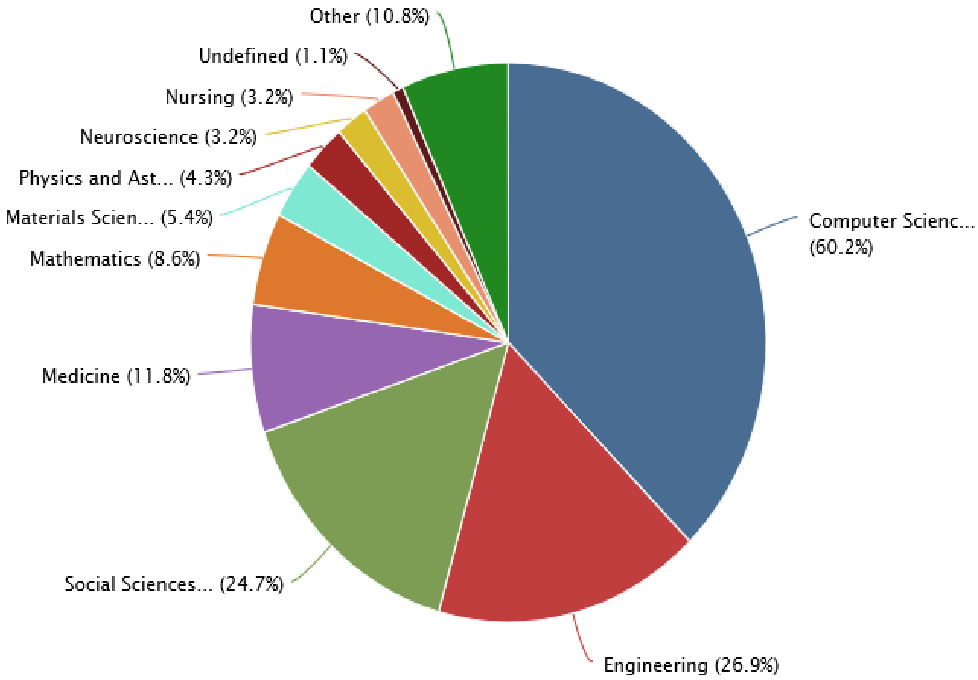

Figure 2. "Immersive Virtual Reality Education" - number of papers per subject area

The search on "Oculus Rift Education" only found three papers. One of the paper refers only to the engineering subject area, while the other two both refer to Computer Science and one other subject (mathematics and social science). Due to the very small number of results, we did not analyse this data from any other point of view. The very limited output of our search is probably because Oculus Rift is a commercial product that has only been on the market for a very short time.

"Head Mounted Display Education" produced only 18 results, 10 referred to 2013 and 8 to 2014. As stated earlier, since several papers published in 2014 may not have been introduced into the database yet, the numbers show that there is probably a slight increase in publications with time.

As shown in Figure 3, most papers have been published in the United States, and a relevant number in Germany. It has to be noticed that there are no papers at all in the UK. This is rathetr interesting since in the previous search, the United Kingdom showed a relevant interest in Immersive Virtual Reality, while the same search gave no results for Germany.

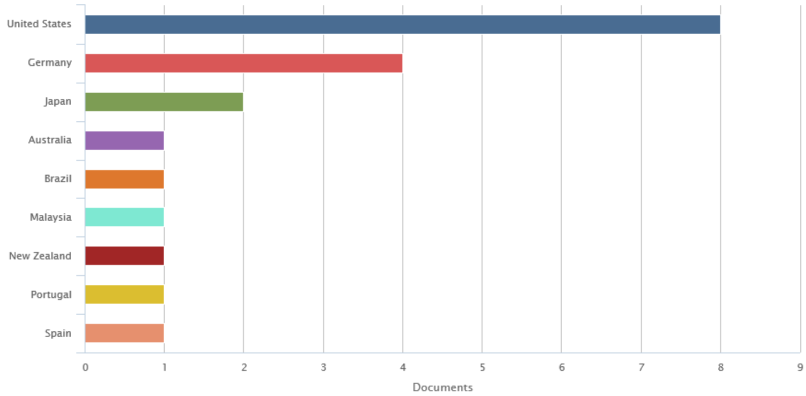

Figure 3. "Head Mounted Display Education" - number of papers per country of publication

Looking at Figure 4, the most common subject is Computer Science, and a significant number of papers referring to the medical subjects has been found: adding the ones that appear also under different subject areas, more than 22% of the selectyed papers were somehow related to medical issues.

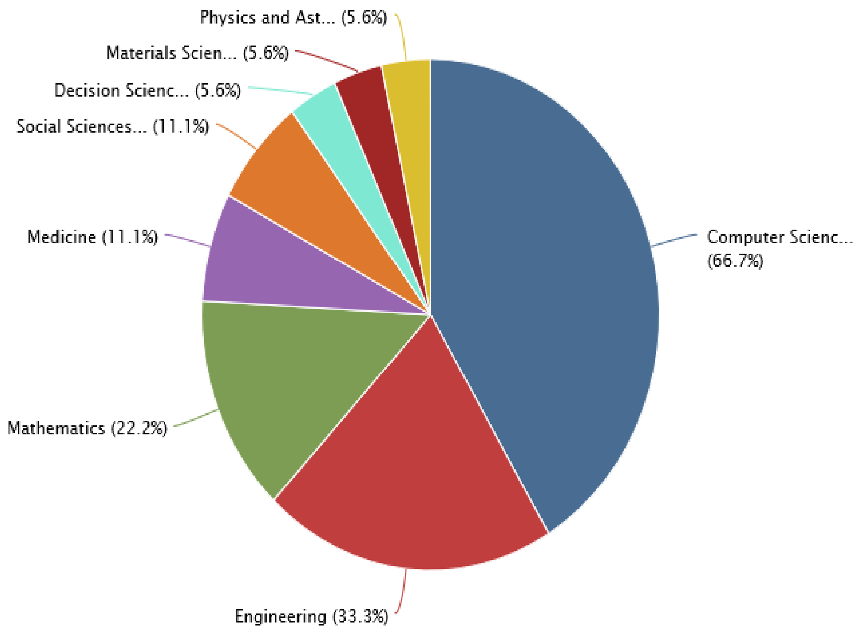

Figure 4. "Head Mounted Display Education" - number of papers per subject area

III. DISCUSSION OF THE RESULTS

3.1 Target Population Addressed

The reading the selected papers, showed that a relevant number of them refers to university or pre- university learning, with particular attention to the teaching of scientific subjects (physics, astronomy, chemistry, etc.). Several examples of such applications will be reported further on in this paper.

Another area in which VR appears to be widely used is adult training. This is particularly true in some specific areas, as it will be described later on. VR and AR offer the possibility to move safely around dangerous places, learning to cope with our emotions while experimenting the best solutions while far away from the real dangers.

There is very little referred to younger elementary students; we only found a paper about a project for teaching science to children between the age of 10 and 12 [11], one about a Virtual Art museum also aimed at children [12]. One reason for the very limited use of VR with younger children is probably because they are still growing and 3D vision, as well as hand-eye coordination and balance are still under development. As a matter of facts, the Oculus Rift “health and safety warnings” include a recommendation according to which children under 13 should not use the device.

As far as disabled are concerned, few studies have been found. Standen et al. [13] conducted an interesting review on the use of VR for the rehabilitation of people with intellectual disabilities, dating back to 2005. According to our search, very little seems to have been done since then. Matsentidou and Poullis [14] investigate the use of a CAVE based system for the education of children with mild autism while Dimitropoulou’s paper reviews the use of technological applications for the education of children with autism, also providing a set of examples [15]. An augmented reality system uses a HMD to train developmentally disabled people to serve food in a restaurant [16].

As far as other disabilities are concerned, we only found one paper about an application aimed at hearing impaired students in a science lab where the use of smart glasses for augmented reality allows them to see explanations in sign language without having to move their heads from the ongoing experiment [17].

3.2 Areas Addressed

Most of the selected papers refer to the area of education; they report on specific applications that have been implemented with a specific educational or training objective. These can be divided into two main groups: those aimed at adult vocational training and those that refer to high school and university education.

VR is often used in vocational training aimed at adult workers in all those areas in which the real situation may not be employed for practice due to lack of access to it or because it is highly dangerous. Examples are an immersive learning environment to teach the US army soldiers basic corrosion prevention and control knowledge [18] and a CAVE based system for teaching Mandarin [19]. Other papers analyse the impact on learners of training while immerse in an authentic environment, for example, Bastiaens et al. [20] report several VR based experiments made in training situations for supply chain workers using different devices. Rahimian at al. [21] reports the use of VR for the professional training of Architecture Engineering Construction specialists.

At high school level, not many experiences have been reported. We found some solutions that use a HMD, e.g. a system to help teachers in class management [22] or a haptic-augmented simulation in physics [23]. A 3D interactive virtual chemistry lab is also reported [24].

Many papers refer to university level education; here we are going to report some of them just to give a feeling of the ongoing activities. In a university Chinese class, the traditional projector has been replaced with HMDs increasing motivation and control of the students over the lesson [25]. An intelligent learning environment has been developed and experimented in several subjects of a Computer Science degree [26]. A VR immersive environment is reported in support of the design of architectural spatial experiences [27]. A VR system populated with avatars offers a training place for interpreting students [28]. A VR application visually represents neutrino data, aimed at both students and researchers [29] while another VR system based on CAVE system offers the possibility to experiment the effects of relativity [30].

Referring to both university education and adult training, the results show a significant percentage of papers reporting applications in the medical fields. Here, VR has been widely used at very different levels. Starting from the nurse education in a collaborative immersive system [31], medical training in a virtual hospital [32], medical professional training [33], a simulated caries removal exercise dental students [34], a surgical education system that uses a HMD and finger tracking to show the practitioners the exact movements of the expert's fingers during surgery [35]. A survey on the use of VR in medical training and education reports the use of VR in support of communication between medical staff, surgical simulations, pain management, several kinds of therapies and rehabilitation interventions [36]. Furthermore, VR is also used for directly on the patients both for educational purposes (e.g. an adult's oral hygiene education [37] or general health knowledge for adult healthcare training [38]) and for rehabilitation purposes (e.g. a VR based therapy for vestibular problems [39] or breathing exercises for people with Chronic Obstructive Pulmonary Disease [40]). Moreover, VR can also foster the doctor-patient communication while supporting remote monitoring [41].

Some of the selected papers are related to research activities referred to computer science and in particular VR devices, tools and solutions. The feeling of being somewhere real when you are in VR is well known to researchers, and is referred to as "presence," [42] and it most distinguishes VR from 3D on a screen [43]. The technical requirements that the VR devices need to have in order to generate the immersive effect have been analysed by Abrash [44]. A study on the perception of the environment while using a HMD with AR suggests that the real environment is not perceived well and there are social issues due to the technology worn on the body, but the system seems to enhance a better orientation ability and spatial awareness [45]. Other papers are related to CAVE based environments: Kenyon presents a new high resolution CAVE [46] while Leigh et al. describe a cylinder based CAVE [47]. Nan et al. study an alternative interface based on hand movement to be used in a CAVE system for design [48].

Results show also that VR can play a significant role in research activities, giving the possibility to visualize and simulate events that are not perceivable in real life. In medical research, VR allows not only the visualization, but also the possibility to move through neural tissue [49]. A CAVE VR system used for the visualization of the magnetic fields in the solar system [50]. A study shows how reducing a person's height resulted in more negative views of the self in comparison with other people and increased levels of paranoia [51] and another demonstrated how the perception of out body changes the way we play drums [52].

3.3 Motivations For The Use Of VR

From the reading of the papers, as we have seen, we argue that the main motivation for VR use is that it gives the opportunity to live and experiment those situations that "cannot be accessed physically".

This limit may be due to different kinds of reasons:

- *Time problems*: travelling in time allows students to experiment different historical periods [53].
- *Physical inaccessibility*: e.g. exploring the solar system by freely moving around planets [54].
- *Limits due to a dangerous situation*: for example training fire fighters on the decision making process in a situation in which the physical and psychological stresses are analogous to live firefighting situations [55].
- *Ethic problems*: for example, performing a serious surgery by non-experts as is the case with neurosurgery [56].

IV. CONCLUSIONS

A literature review has been conducted about the use of Immersive VR and HMD in education. Immersive VR can offer great advantages for learning: it allows a direct feeling of objects and events that are physically out of our reach, it supports training in a safe environment avoiding potential real dangers and, thanks to the game approach, it increases the learner's involvement and motivation while widening the range of learning styles supported. Results show how most papers report experiments in high education or adult training. Very little has been reported on younger children and in the field of disability.

Since immersive VR can interfere with the cognitive and physical development of children, its use with this audience has to be limited. We did not find any paper reporting experiments with children under the age of 10, and only a few between 10 and 17. Starting from middle school, VR could actually give some advantages by allowing a physical exploration of objects that are not accessible in reality, helping the learners to understand and memorize them better. Nevertheless, the constant presence of a teacher to mediate and regulate the use of the VR tools is needed and the VR system should be used only for limited span of time. Experiments could be carried out to verify these hypotheses.

Disabled people represent a population where immersive VR can really make the difference, especially now that the first affordable HMDs have appeared on the market. In particular, intellectually impaired people can really take advantage of such an approach. Learning in a virtual environment that reproduces the real one can minimize the problems related to learning transfer. As Standen et al. [13] state, learning transfer seems not to be a problem in the experiences reported. However, an extensive study to verify whether the transfer is actually easier with an immersive VR approach compared to traditional ones is not yet available.

Reference Text and Citations

[1] Howard-Jones, P., Ott, M., van Leeuwen, T., & De Smedt, B., 2014, *The potential relevance of cognitive neuroscience for the development and use of technology-enhanced learning*, Learning, Media and Technology, (ahead-of-print), pp. 1-21.

[2] Jennett, C., Cox, A. L., Cairns, P., Dhoparee, S., Epps, A., Tijs, T., & Walton, A., 2008, *Measuring and defining the experience of immersion in games*, International journal of human-computer studies, 66(9), pp. 641-661.

[3] Robertson, G., G., Card, S., K., & Mackinlay, J., 1993, *Three views of virtual reality: nonimmersive virtual reality*. Computer, 26(2), p. 81.

[4] Ott, M., & Pozzi, F., 2008, *ICT and Cultural Heritage Education: Which Added Value?*, In Emerging Technologies and Information Systems for the Knowledge Society, pp. 131-138, Springer Berlin Heidelberg.

[5] Classen, C., 1997, *Foundations for an anthropology of the senses*, International Social Science Journal, 49(153), pp. 401-412.

[6] Basu, A., & Johnsen, K., 2014, March, *Ubiquitous virtual reality 'To-Go'*, In Virtual Reality (VR), 2014, iEEE, pp. 161-162, IEEE.

[7] Roussou, M., 2004, *Learning by doing and learning through play: an exploration of interactivity in virtual environments for children,* Computers in Entertainment, CIE, 2(1), p. 10.

[8] Garris, R., Ahlers, R., & Driskell, J., E., 2002, *Games, motivation, and learning: A research and practice model*, Simulation & gaming, 33(4), pp. 441-467.

[9] Ott, M., & Tavella, M., 2009, *A contribution to the understanding of what makes young students genuinely engaged in computer-based learning task*, Procedia-Social and Behavioral Sciences, 1(1), pp. 184-188.

[10] Leite, W. L., Svinicki, M., & Shi, Y., 2010, *Attempted validation of the scores of the VARK: Learning styles inventory with multitrait–multimethod confirmatory factor analysis models*, Educational and Psychological Measurement, 70(2), pp. 323-339.

[11] Eleftheria, C., A., Charikleia, P., Iason, C., G., Athanasios, T., & Dimitrios, T., 2013, July, *An innovative augmented reality educational platform using Gamification to enhance lifelong learning and cultural education*, In Information, Intelligence, Systems and Applications (IISA), 2013 Fourth International Conference on, pp. 1-5, IEEE.

[12] Huang, Y., C., & Han, S., R., 2014, *An Immersive Virtual Reality Museum via Second Life*, In HCI International 2014-Posters' Extended Abstracts, pp. 579-584, Springer International Publishing.

[13] Standen, P., J., & Brown, D., J., 2005, *Virtual reality in the rehabilitation of people with intellectual disabilities: review*, Cyberpsychology & behavior, 8(3), pp. 272-282.

[14] Matsentidou, S., & Poullis, C., 2014, *Immersive visualizations in a VR cave environment for the training and enhancement of social skills for children with autism*, Paper presented at the VISAPP 2014 - Proceedings of the 9th International Conference on Computer Vision Theory and Applications, 3, pp. 230-236.

[15] Dimitropoulou, K., & Rekoutis, P., 2012, *THE USE OF THE LATEST TECHNOLOGICAL APPLICATIONS IN THE EDUCATION OF STUDENTS WITH AUTISM SPECTRUM DISORDERS*, INTED2012 Proceedings, pp. 2331-2338.

[16] Tae-Young, K., I., M., 2013, *A Situational Training System for Developmentally Disabled People Based on Augmented Reality*, IEICE TRANSACTIONS on Information and Systems, 96(7), pp. 1561-1564.

[17] Jones, M., Lawler, M., J., Hintz, E., Bench, N., Mangrubang, F., & Trullender, M., 2014, June, *Head mounted displays and deaf children: Facilitating Sign Language in Challenging Learning Environments*, In Proceedings of the 2014 conference on Interaction design and children, pp. 317-320, ACM.

[18] Webster, R., D., 2014, *Corrosion Prevention and Control Training in an Immersive Virtual Learning Environment*, CORROSION, 2014.

[19] Chang, B., Sheldon, L., Si, M., & Hand, A., 2012, *Foreign language learning in immersive virtual environments*, In IS&T/SPIE Electronic Imaging, pp. 828902-828902, International Society for Optics and Photonics.
[20] Bastiaens, T., Wood, L., C., & Reiners, T., 2014, *New landscapes and new eyes: The role of virtual world design for supply chain education*, Ubiquitous Learning: An International Journal.
[21] Rahimian, F., P., Arciszewski, T., & Goulding, J., S., 2014, *Successful education for AEC professionals: case study of applying immersive game-like virtual reality interfaces*, Visualization in Engineering, 2(1), p. 4.
[22] Silva, M., Freitas, D., Neto, E., Lins, C., Teichrieb, V., & Teixeira, J., M., 2014, *Glassist: Using augmented reality on google glass as an aid to classroom management*, Paper presented at the Proceedings - 2014 16th Symposium on Virtual and Augmented Reality, *SVR 2014,* pp. 37-44.
[23] Civelek, T., Ucar, E., Ustunel, H., & Aydın, M., K., 2014, *Effects of a Haptic Augmented Simulation on K-12 Students' Achievement and their Attitudes towards Physics*, Eurasia Journal of Mathematics, Science & Technology Education, 10(6), pp. 565-574.
[24] Ali, N., Ullah, S., Alam, A., & Rafique, J., *3D Interactive Virtual Chemistry Laboratory for Simulation of High School Experiments*.
[25] Du, X., 2014, *Design and Evaluation of a Learning Assistant System with Optical Head-Mounted Display (OHMD),* Doctoral dissertation, Carleton University Ottawa.
[26] Griol, D., Molina, J., M., & Callejas, Z., 2014, *An approach to develop intelligent learning environments by means of immersive virtual worlds*, Journal of Ambient Intelligence and Smart Environments, 6(2), pp. 237-255.
[27] Antonieta, Â., 2014, *Immersive Simulation of Architectural Spatial Experiences,* Blucher Design Proceedings, 1(7), pp. 495-499.
[28] Braun, S., & Slater, C., 2014, *Populating a 3D virtual learning environment for interpreting students with bilingual dialogues to support situated learning in an institutional context*, The Interpreter and Translator Trainer, 8(3), pp. 469-485.
[29] Izatt, E., Scholberg, K., & Kopper, R., 2014, March, *Neutrino-KAVE: An immersive visualization and fitting tool for neutrino physics education*, In Virtual Reality (VR), 2014 iEEE, pp. 83-84, IEEE.
[30] Sidharth, B., G., Michelini, M., & Santi, L., (Eds.), 2014, *Frontiers of Fundamental Physics and Physics Education Research,* Springer.
[31] Green, J., Wyllie, A., & Jackson, D., 2013, *Virtual worlds: A new frontier for nurse education?*, Collegian.
[32] Kleven, N., F., 2014, *Virtual University hospital as an arena for medical training and health education*.
[33] Ma, M., Jain, L., C., & Anderson, P., (Eds.), 2014, *Virtual, Augmented Reality and Serious Games for Healthcare 1,* Springer, Berlin.
[34] Eve, E., J., Koo, S., Alshihri, A., A., Cormier, J., Kozhenikov, M., Donoff, R., B., & Karimbux, N., Y., 2014, *Performance of Dental Students Versus Prosthodontics Residents on a 3D Immersive Haptic Simulator,* Journal of dental education, 78(4), pp. 630-637.
[35] Yoshida, S., Kihara, K., Takeshita, H., & Fujii, Y., 2014, *Instructive head-mounted display system: pointing device using a vision-based finger tracking technique applied to surgical education*, Videosurgery and Other Miniinvasive Techniques, 9(3), p. 449.
[36] Pensieri, C., & Pennacchini, M., 2014, *Overview: Virtual Reality in Medicine*, Journal For Virtual Worlds Research, 7(1).
[37] Rodrigues, H. F., Machado, L., S., & Valença, A., M., G., 2014, *Applying Haptic Systems in Serious Games: A Game for Adult's Oral Hygiene Education*, SBC, 5(1), p. 17.
[38] De Ribaupierre, S., Kapralos, B., Haji, F., Stroulia, E., Dubrowski, A., & Eagleson, R., 2014, *Healthcare Training Enhancement Through Virtual Reality and Serious Games*, In Virtual, Augmented Reality and Serious Games for Healthcare 1, pp. 9-27, Springer, Berlin, Heidelberg.
[39] Alahmari, K., A., Sparto, P., J., Marchetti, G., F., Redfern, M., S., Furman, J., M., & Whitney, S., L., 2014, *Comparison of Virtual Reality Based Therapy With Customized Vestibular Physical Therapy for the Treatment of Vestibular Disorders*, Neural Systems and Rehabilitation Engineering, IEEE Transactions on, 22(2), pp. 389-399.
[40] Qin, Y., Vincent, C., J., Bianchi-Berthouze, N., & Shi, Y., 2014, April, *AirFlow: designing immersive breathing training games for COPD*, In CHI'14 Extended Abstracts on Human Factors in Computing Systems, pp. 2419-2424, ACM.
[41] He, Y., Zhang, Z., Nan, X., Zhang, N., Guo, F., Rosales, E., & Guan, L., 2014, May, *vConnect: Connect the real world to the virtual world*, In Computational Intelligence and Virtual Environments for Measurement Systems and Applications (CIVEMSA), 2014 IEEE International Conference on, pp. 30-35, IEEE.
[42] Ninaus, M., Kober, S. E., Friedrich, E., V., Dunwell, I., Freitas, S,. D., Arnab, S., Ott, M., Kravcik, M., Lim, T., Louchart, S., Bellotti, F., Hannemann, A., Thin, A., Berta, R., Wood, G., & Neuper, C., 2014, *Neurophysiological methods for monitoring brain activity in serious games and virtual environments: a review*, International Journal of Technology Enhanced Learning, 6(1), pp. 78-103.
[43] Schuemie, M., J., Van Der Straaten, P., Krijn, M., & Van Der Mast, C., A., 2001, *Research on presence in virtual reality: A survey*, CyberPsychology & Behavior, 4(2), pp. 183-201.
[44] Abrash, M., 2014, *What VR could, should, and almost certainly will be within two years*, Steam Dev Days.
[45] Hofmann, S., & Mosemghvdlishvili, L., 2014, *Perceiving spaces through digital augmentation: An exploratory study of navigational augmented reality apps,* Mobile Media & Communication, 2(3), pp. 265-280.
[46] Kenyon, A., Van Rosendale, J., Fulcomer, S., & Laidlaw, D., 2014, March, *The design of a retinal resolution fully immersive VR display,* In Virtual Reality (VR), 2014 iEEE, pp. 89-90, IEEE.
[47] Febretti, A., Nishimoto, A., Thigpen, T., Talandis, J., Long, L., Pirtle, J., D., & Leigh, J., 2013, March, *CAVE2: a hybrid reality environment for immersive simulation and information analysis,* In IS&T/SPIE Electronic Imaging, pp. 864903-864903, International Society for Optics and Photonics.

[48] Nan, X., Zhang, Z., Zhang, N., Guo, F., He, Y., & Guan, L., 2014, *vDesign: a CAVE-based virtual design environment using hand interactions*, Journal on Multimodal User Interfaces, 8(4), pp. 367-379.

[49] Morehead, M., Jones, Q., Blatt, J., Holcomb, P., Schultz, J., DeFanti, T., & Spirou, G., A., 2014, March, *Poster: BrainTrek-An immersive environment for investigating neuronal tissue,* In 3D User Interfaces (3DUI), 2014 IEEE Symposium on, pp. 157-158, IEEE.

[50] Kageyama, A., 2013, December*, Keynote talk 1: Simulations and visualizations of magnetic fields in nature*, In System Integration (SII), 2013 IEEE/SICE International Symposium on, p. 1, IEEE.

[51] Freeman, D., Evans, N., Lister, R., Antley, A., Dunn, G., & Slater, M., 2014, *Height, social comparison, and paranoia: An immersive virtual reality experimental study*, Psychiatry Research, 218(3), pp. 348-352.

[52] Kilteni, K., Bergstrom, I., & Slater, M., 2013, *Drumming in immersive virtual reality: the body shapes the way we play,* Visualization and Computer Graphics, IEEE Transactions on, 19(4), pp. 597-605.

[53] Roussou, M., 2004, June, *Examining young learners' activity within interactive virtual environments*, In Proceedings of the 2004 conference on Interaction design and children: building a community, pp. 167-168, ACM.

[54] Detlefsen, J., 2014, *The Cosmic Perspective: Teaching Middle-School Children Astronomy Using Ego-Centric Virtual Reality*.

[55] Williams-Bell, F., M., Kapralos, B., Hogue, A., Murphy, B., M., & Weckman, E., J., *Using Serious Games and Virtual Simulation for Training in the Fire Service: A Review*, Fire Technology, pp. 1-32.

[56] Liu, Y., 2014, July, *Virtual neurosurgical education for image-guided deep brain stimulation neurosurgery,* In Audio, Language and Image Processing (ICALIP), 2014 International Conference on, pp. 623-626, IEEE.

[57] http://www.google.com/patents/US3050870

[58] Augmented Reality is defined as a view of a physical, real-world environment whose elements are integrated with computer-generated sensory input.