IMMERSIVE 360° VIDEO FOR FORENSIC EDUCATION

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DECLARATION

I declare that this manuscript does not contain any material submitted previously for the award of any other degree or diploma at any university or other tertiary institution. Furthermore, to the best of my knowledge, it does not contain any material previously published or written by another individual, except where due references has been made in the text. Finally, I declare that all reported experimentations performed in this research were carried out by myself, except that any contribution by others, with whom I have worked is explicitly acknowledged.

Signed: Cassina TAWHAI

Dated:13 July 2017

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GLOSSARY: The following terms are extensively used throughout this thesis:

Virtual Reality (VR): A three-dimensional, interactive, computer generated environment. These environments can be models of real or imaginary worlds. Conceptualization of complex or abstract systems is made possible by representing their components as symbols that give powerful sensory cues, related in some way to their meaning (Steuer, 1992).

Presence: A subjective phenomenon such as the sensation of being in a virtual environment (*Hodgkinson, 2016*)

Immersion: Immersion is the subjective impression that one is participating in a comprehensive, realistic experience (Dede, 2009)

Head-Mounted Display (HMD): Devices that are fitted over the head (Slater, 2009).

Part 1

A Literature Review on the use of Immersive 360° Virtual Reality Video for Forensic Education.

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ABSTRACT

Throughout the globe, training in the investigation of forensic crime scene work is a vital part of the overall training process within Police Academies and forensic programs throughout the world. However, the exposure of trainee forensic officers to real life scenes, by instructors, is minimal due to the delicate nature of information presented within them and the overall difficulty of Forensic investigations. Virtual Reality (VR) is computer technology utilising headsets, to produce lifelike imageries, sounds and perceptions simulating physical presence inside a virtual setting to a user. The user is able to look around the virtual world and often interact with virtual landscapes or objects. VR headsets are head-mounted goggles with a screen in front of the eyes (Burdea & Coffet 2003). The use of VR varies widely from personal gaming to classroom learning. Uses also include computerised tools that are used solely online. The current use of VR within Forensic Science is that it is used widely in several capacities that include the training and examination of new forensic officers. However, there is minimal review and authentication of the efficiency of VR use for the teaching of forensic investigation. This is surprising, as the VR field has experienced rapid expansion in the educating of many varying fields over the past few years. Even though VR could enhance forensic training by offering another, perhaps more versatile, engaging way of learning, no devoted VR application has yet been commercially implemented for forensic examination education. Research into VR is a fairly young field, however the technology and use of it is still rapidly growing and the improvement of interactive tools is inevitably having an impact on all facets of learning and teaching.

This review accounts for the advantages possible by using Immersive 360° with use of VR viewing for forensic education. This will be accomplished by exhaustively reviewing current scientific literature on Virtual Reality and the elements that contribute to the experience. Current VR in education, forensic education and the limits of the current methods, concluding with briefly summarizing and outlining any potential research possibilities that will further the knowledge and capability of using Immersive 360° with use of VR viewing for forensic education.

Keywords: *forensic examination; virtual reality; immersive; training; virtual learning environment*

SECTION 1 VIRTUAL REALITY (VR) IN GENERAL

Virtual Reality (VR) is computer technology utilising headsets, to produce lifelike imageries, sounds and perceptions simulating physical presence inside a virtual setting to a user. The user is able to look around the virtual world and often interact with virtual landscapes or objects. VR headsets are head-mounted goggles with a screen in front of the eyes (Burdea & Coffet 2003).

Not unlike describing many other fields of study, explaining VR can be complicated. Put simply, the purpose of VR technology is for use in an array of applications that enable the user to experience an environment and learn about a topic in a controlled, safe manner (Roussou, 2000, Nooriafshar, Williams & Maraseni, 2004). When considering the flexibility, cost, duplicability, reusability, experimental and environmental control that VRs carry all provide advantages over ‘analogue’ approaches. Other advantages include the ease that adaptations can be made to the environment and research designs. These advantages make them a decidedly suitable and exciting tool for social scientific exploration. Providing they are designed and created realistically enough, digital VEs can function as an addition to the real-world physical environment (van Gelder, Otte & Luciano, 2014).

For these reasons, VR is often employed as a type of teaching (Baus & Bouchard, 2014). VR allows the opportunity for users to experience environments that otherwise would not be available to them due to the factors of time, distance, size, and safety (Roussou, 2000, Baus & Bouchard, 2014). These factors assist in reducing training costs compared to non-VR trainings (Bowman & McMahan, 2007, Roussou 2000 and Baus & Bouchard 2014) and allow training on topics associated with often hostile environments such as mines and battlefields, or very specialized environments such as cockpits and those environments not readily accessible such as tourist destinations (Webster, 2014, Baus & Bouchard, 2014). VR training offers a degree of realism which, inside the classroom, is simply not possible to achieve, as well as offering higher flexibility with the ability of going beyond the physical locality of the real-life environment (Roussou, 2000, Baus & Bouchard, 2014). Examples of the earliest available VR technologies include: Morton Heilig's Sensorama, which in 1962 received U.S. Patent #3,050,870 (Heilig, 1962). This experience was an immersive 3D that contained colour, motion, aromas, stereo sound, wind effects and also had a vibrating seat (Turri 2014; https://www.engadget.com/2014/02/16/morton-heiligs-sensorama-simulator/, Webster, 2014). During that same decade came some of the first real consumer-grade VR hardware. These included the DataGlove (Zimmerman, 1989) and the PowerGlove (Eglowstein, 1990) both created for Nintendo Home Entertainment. Also, it was around this time that VR and its possibilities began to be noticed within the different professional trades and also noticed within the public (Webster, 2014). Fast-forwarding to today, VR developers and researchers still have many major tasks to consider. The literature herein will discuss the fact that learning is of a greater degree when a student is fully immersed and this immersion occurs at its best when viewing occurs through a Head-Mounted Device (HMD) (Rolland & Hua, 2005).Therefore, a major aspect to consider is the fact that HMDs with low latency, that are lightweight, purchasable at a low cost, offer a wide field of view, are user friendly, readily available at a consumer grade with high resolution do not yet fully exist. There are commercially available HMD such as the Oculus Rift by Oculus VR™ (http://www.oculusvr.com/) which have been developed into a more user-friendly product and is light weight, wireless, and portable, conferring a better display resolution and a superior display type than its predecessors and the Samsung VR by Samsung that also utilizes Oculus technology. Both these products each have their own pros and cons as discussed in the article http://newatlas.com/oculus-rift-vs-gear-vr-comparison-2016/45163 however, the technology is still young, as stated, and there are many changes that will occur in the future as more research is carried out. There is an overall agreement throughout the literature that the use of VR can have strong motivational influence on the field of education (Roussou, 2000, Bricken, 1991).

1.1 APLICATIONS FOR VIRTUAL REALITY

VR technologies have matured as development continues to increase enough to be able to extend research from scientific and military realms into multidisciplinary areas including art, health care, engineering, communication, entertainment, education and psychology (Roussou, 2000, Krijn, 2004, Baus & Bouchard, 2014). Due to this extended research on VR technologies, applications vary immensely including but not limited to:

Museum VR displays and computer-generated interactive experiences allow visitors to travel through space and time without ever stepping out of the building (Roussou & Efraimoglou, 1999, Roussou, 2000). Architects design dream homes and take the client on a virtual tours (Nooriafshar, Williams & Maraseni, 2004). Military/Defense fields use VR to simulate mission preparation, rehearsal and tactics practice, interacting with simulated smoke and fire without lives and property being put at risk (Tate, Sibert & King, 1997). In the Medical field, there are many areas utilizing this technology, however, to mention just a few that include but are definitely not limited to the use in training skills, prioritising of resources and identifying high-risk patients for treatment are achieved by using VR systems (Vincent, Sherstyuk, Burgess, & Connolly, 2008); as well as the training in the interventions for the management of pain (Maani **et al**., 2008). In the field of Technology Education, VR is used for simulating Industry, transportation, manufacturing and energy training (Padiotis & Mikropoulos, 2010).

1.2 IMMERSION

The notion of immersive virtual reality (IVR) was established in the late 80s (Nooriafshar, Williams & Maraseni, 2004). Originally used as a laboratory-based notion, the technology of IVR has been present for approximately 40 years, and has progressed over the past 20 years into being used as affordable, practical, and useful systems (Slater 2009). Immersion is one of the exclusive attributes of immersive VR that can lead to an increased level of learning outcomes and processes. Immersion denotes to the actual conformation of the interface and IVR is characteristically attained by operators wearing a head- mounted display (HMD) covered in detail in 1.4 (van Gelder, Otte & Luciano, 2014) A definition of immersion by Slater (2009) explains that by altering your sense of place and the non- invasive altering of our own body sense we go beyond the restrictions of physical reality. This altered feeling is also referred to in the literature as spatial immersion (Jennett **et al**., 2008).

An Immersive environment should be able to break the connection between where we think we are and where we are actually located (Sanchez-Vives & Slater, 2005). An ideal Immersion VR system typically consists of a set of displays corresponding to visual, audio, tactile factors and a tracking system (Slater, 2009). The actual immersion level then depends on a number of factors including how many senses are stimulated, the number of interactions and how involved they are (Slater **et al**, 2009). The level of immersion corresponds directly to the quality and quantity of the stimuli engaged to mimic the setting (Sanchez- Vives and Slater, 2005). From the exterior, the level of immersion also depends on the system's ability to isolate the user from stimuli coming from the real world, such as external noise or room lights which are foreign to the Virtual Environment (VE). To maximize breaking away from the real-world, Immersion VR commonly uses HMD and position trackers placing the operator inside a VE. This sense of inclusion created within the virtual world has a strong personal effect (Heeter, 1992). Ma and Zheng (2011) follow these rules to distinguish an immersive VR; being that it projects the optical setting into a HMD or large projection surface that encases the user thus filling the operator’s field of sight completely.

The operator’s experience in the VE is affected by the level of immersion. Three main notions are then used to ascertain the degree of the operator’s experience being 1) the sensation of presence 2) the degree of reality and 3) the degree of realism felt. Bricken (1991) reports on how three hundred partakers in Autodesk's cyberspace ranked the most exciting feature of their experience as that of being immersed inside the VR world. The VR world seems to account for head movement in a familiar way, and also in a manner which separates self from world. In simple terms; once immersed the world may stay unmoving but you have the sensation of moving (Heeter, 1992).

1.3 PRESENCE

In the paper written by Mikropoulos & Strouboulis (2004) they state that “Presence is the main attribute, the defining experience for VR”, it denotes a mental state that imitates physical, emotional and rational engagement with the VE (van Gelder, Otte & Luciano, 2014). Presence as a perception is not exclusive to VR: watching a play or a movie, looking at a painting, listening to music or reading literature can prompt the feelings associated with presence (Nash et al., 2000). The degree of presence relates directly to the moment both the amount of the operator’s expectations and the actual experience of the VE converge (Baños **et al**., 2000). Therefore, if a virtual stimulus meets the operator’s expectations, it is expected to be evaluated as realistic. The degree of reality denotes the level the operator feels the immersion as realistic in reaction to the stimuli within the VE (Baños et al., 2000, Baus & Bouchard, 2014). Slater (2009) defines presence in VR as the degree that operators react realistically when in a VE; these responses included both behavioral and emotional responses. Basically, 'presence' denotes to the sensation of feeling and behaving, as if we are actually within the virtual world visible on the screen or display.

In the papers by Sanchez-Vives & Slater (2005) and again in Slater (2009) it was proposed that while numerous definitions of presence have been attempted, presence is a multipart feeling made up of several different dimensions: 1) feeling of really being in the VE corresponds to personal presence; as opposed to in the real world room where the immersion is taking place, VR research focus has been on producing personal presence by mimicking the variety and strength of stimuli to the human senses as closely as possible so as to believe they are receiving in the natural world 2) feeling that the VE appears to recognize the operator by responding to their movements is the environmental presence, and 3) feeling as though not alone in the VE refers to the social presence (Heeter, 1992). Slater (2009) goes on to state that a system that can be similar to that of the physical world can actually give the operator the illusion that they are physically present inside the VE. The foundation for the notion of presence is the sensation of actually being there.

1.4 HEAD MOUNTED DISPLAY

The literature reviewed in this section focuses on HMD design and the applications of use. HMD are devices that are fitted over the head. The spectacles/goggles are attached in close proximity to the operators’ eyes, the images to the right and left are continuously updated through head tracking. This ensures that they are updated with respect to the underlying virtual environment according to the head movements of the operator (Slater, 2009). In designing HMDs, the challenge has been to design them with optics and headsets that are both light and ergonomic. To accomplish the feeling of really being present all five of our senses should be stimulated. The virtual world can easily produce complete immersion with use of HMD or other sorts of VR glasses, headphones are also quite often used (Jennett **et al**., 2008).

Recent applications for the use of HMD include medical, manufacturing, engineering and education although military applications previously dominated the HMD market for a number of decades. Discussions for advancing HMD have been driven by the restrictions of current HMDs, now designers are focusing on the improvement of head-mounted projection displays (HMPDs) and designing multifocal planes HMDs, eye-tracking enabled HMDs, and occlusion displays (Rolland & Hua, 2005). Another underlying trait of HMD is that when viewing with these devices the operator is unable to see their own body (Sanchez-Vives and Slater, 2005).

Ivan Sutherland pioneered the first graphics-driven HMD in the 1960s. HMD has been used within military applications referred to as helmet-mounted displays; this display is attached to their helmet. (Calhoun et al., 2005 , Rolland & Hua, 2005).In the 1960s the U.S. Army flew a helmet-mounted detection system on the Cobra helicopter, the Navy then shot missiles using HMDs. After this, the U.S. Army deployed the Integrated Helmet and Display Sighting System (IHADSS) on the AH-64 Apache helicopter (Rolland & Hua, 2005).

Levy, Michael et al (1998) discuss another complex example of the use of HMD in electronical imaging throughout endoscopic and microneurosurgical operations. This occurred through designing a stereoscopic HMD weighing just 900 g that has the ability to display 24-bit images and has a video graphics array of 640 × 480 pixel resolution. The use of stereoscopic images during surgery by the primary surgical assistant and ancillary personnel are possible due to the fact the stereoscopic recording and play system is interchangeable with typical video display resolutions including the home systems. The innovative model HMD allows the examining team to stereoscopically visualize the operating field, contains vocal control, image-in-image and stereoscopic recording abilities. The results included significant benefits being reported about the visualization with the HMD and the idea was well accepted by operators.

Nowadays, commercial products such as Oculus Rift and other products that are under currently exploration offer decent virtual simulation at reasonable prices; this makes the use of these systems possible in the area of training and education. In the past; major complications of using HMDs included the fact that 1) the devices were typically very costly and were not very widely spread and 2) due to mismatch between the users head movements and of the corresponding alteration in the scene their characteristics often caused a sensation of aversion (Jennett **et al**., 2008).

SECTION 2 VIRTUAL REALITY FOR EDUCATION

Within this section, the focus for the literature was on VR in education as doing a search for 360° immersive VR in education came up with no peer reviewed articles; the articles that do come up present making 3D presentations seem 360o. On the actual topic of 360° immersive VR in education there are, however, numerous internet articles available including https://virtualrealityforeducation.com/google- cardboard-vr-videos/science-vr-apps/https://virtualrealitypop.com/top-educational-virtual-reality-experiences ae323d04951ehttp://splash.abc.net.au/newsandarticles/blog/-/b/2202320/augmented-reality-virtual-reality-and-360-degree-video-in-education and there is also an app created http://demo.thinglink.com/vr-edu. This initial information proves this is an area that is on the rise and definitely beginning to be implemented into many areas. However, as there are no peer reviewed articles the reviewed literature to follow discusses how VR is assisting education with the available platforms readily on the market or currently being developed. While reviewing the literature around VR for education we found that there is much need for more experimental research to be carried out concerning the benefits of VR-based instruction versus traditional instruction.

When comparing several studies on VR based instruction there was an overwhelming agreement that VR confers a positive effect on learning results. Bricken (1990) informs us the use of VR for educational purposes began around 1990, these initial examples mostly argued the potential worth of VR as an educational device. Both Jia **et al**., (2012) and Mikropoulos **et al**., (2003) discuss the fact that most evaluations of VR for use in education have looked at factors such as immersion, engagement, presence, usability or motivation. Or conversely, have looked at issues including motion sickness, cognitive workload and after effects. Both support the fact that the ability to be able to support the notion that VR and VLEs can provide educational benefit needs to be further researched.

The main benefit of VR established is that the learning environments are easily transferable across diverse educational fields. Within the literature focus was paid on 3 studies, that of Taylor and Disinger (1997), Koepnick **et al** (2010) and Mehryar Nooriafshar **et al** (2004) that look into the use of VR in education.

Taylor and Disinger (1997) conducted an empirical survey study that was one of the first covering the recognition of VR within education, especially that of environmental education. Three hypotheses were proposed by the authors including: 1) As a teaching tool; what is the current acceptance level in environmental education of the use of VR by the subjects educators, 2) In the field of environmental education what are appearing to be the greatest roles and most valuable applications for the use of VR implementation and lastly 3) regarding the use of VR for education of environment : which areas ought to be considered in the field of environmental education in order for VR technology to become an operative tool? The sample used for the survey included 400 environmental educators and 40 programmers and developers of VR. Feedback was returned in the form of 192 completed surveys. Taylor and Disinger then used chi-square tests and descriptive statistics to evaluate the statistics. Feedback from surveys conveyed findings that presented VR as an acceptable educational tool in the eyes of environmental educators and appreciation that a VLE is able to provide students/trainees with practices not possible to experience within the current ways of teaching.

Koepnick **et al** (2010) created the RIST system (Radiological Immersive Survey Training system). RIST utilises a lifelike, real-time sheltering model centered on a ray casting that mimics radiological hazards from multiple causes. This system allows operators to test surveying the hazard utilising the virtual demos of the equipment and the world. Members of the survey group are prevented from joining in a response to a real hazard if their observed accumulated exposures to radiation reaches the allowable annual limit as they are then at the risk of being overexposed. Therefore, the use of VR training can ease concerns of exposure. In general, the use of VR training has shown to be an effective method in the training of stressful hazards. The use of VR training involves little set up time, is effortlessly repeatable and has improved the consistency and accuracy of the simulation. Another major benefit of the VR training is that other than being hazardous, radiation clean-up is also very costly; therefore training and cleaning costs are reduced.

Mehryar Nooriafshar **et al** (2004) carried out research to explore the potential learning effectiveness of VLE on the topic of basic human anatomy. Using the VR multimedia, students from Nursing and Business backgrounds sat a tutorial on areas related to basic human anatomy. Each student was interviewed at the conclusion of the tutorial and asked to offer feedback and/or comments. From the feedback from both groups of students it was possible to conclude that VR multimedia could improve education as it provides realistic imagery, ease of learning and graphic features very close to that of the real world. The students could immerse themselves in the virtual environment and interact with the setting and articles within it in a 'real like' manner. Statistical tests in the form of Weighted Average Indices and t-tests were carried out based on the feedback which also revealed the VR multimedia is a decidedly favored way of learning and teaching evident by a very high Weighted Average Indices, supported also by the t- tests results and favorable interview comments.

SECTION 3 LEARNING

The literature focus for this section is concentrated on learning as a general attainment of knowledge. The material that is decided to be taught through VR techniques to the operator is received through interactions with active and passive media. Learning has been defined in the literature by Ragan **et al**. (2012, p. 302) as "a complex mental activity involving perceiving new information from external stimuli, relating the new information with previously learned information and storing the new information in memory". This definition aligns perfectly with one of the major research areas dedicated to educational VR, which is finding out which components of VR are most influential to learning (such as immersion and presence, reviewed above).To date, the focus of the bulk of VEs that have been researched and created for use as educational tools has been to do with the formal science and natural science fields. (Mikropoulos **et al**., 2003). Mikropoulos **et al** (2003) believes that VE must include detailed learning goals, induce learning results and teaching outcomes, include educational scenarios that are cohesive and induce images with educational meaning in order for the technique to become an item that can be used for educational use. Here on in, multiple articles will be compared that have achieved results through use of VR in the realm of learning.

Ragan et al., 2012 carried out several experiments; their hypothesis for their first experiment was to question if better performance would result in the areas of factual learning and sequence memorization if the operator is provided with better support strategies for spatial memorization, and if clear memorization sequence steps are provided that associate directly with the given landmarks. In this experiment they sampled 32 university students and staff members with ages ranging from 18 to 57. Data was collected on observations, spatial aptitude tests, system logs and interviews. The data collected was analyzed using ANOVA, blended descriptive statistics, two-tailed Spearman correlation and three-way log linear analysis. The results revealed that operators performance in learning tasks were affected by the strategies used to complete the tasks, as well as the spatial presentations viewed. The hypothesis for their second experiment progressed to investigating cognitive processing at a higher level. Their hypothesis tested if structural memory and processing could be offset using spatial locations within a VE. In this experiment on engineering students the sample size was 24 with ages ranging from 18-22. Data was collected in the form of evaluations of performance, a Questionnaire, test on mental workload and exit interviews. The data collected was analysed using ANOVA as well as blended descriptive statistics. The results revealed when utilising spatial layout supports throughout the critical- thinking events within a VE, there was no decrease in mental workload or any enhancement in performance.

Trindade et al. (2002) also carried out a study testing the area of learning, with the creation of Virtual Water VE, which was carried out in the study field of microscopic concepts. The hypothesis of this experiment was to deduce whether greater benefit from the use of VR occurred with students possessing developed comprehension abilities and spatial reasoning. The two questions investigated were 1) in what way do students that possess high spatial aptitudes but do not possess strong backgrounds in chemistry and physics, respond to VEs both using stereoscopic visualization and without it 2) with spatial aptitude does the developed conceptual understanding vary with use of VR? Sample size utilized was that of 20 freshman university undergraduates from the chemistry, physics, and engineering faculties. The Provas de Avaliação da Realização Cognitiva (PARC) multiple-choice feedback form measured spatial aptitude. Dependent variables concerning conceptual comprehension and motivation were measured by use of led interviews and questionnaires. The data was analyzed using the Wilcoxon test and descriptive statistics. The three important findings were 1) students that already possess greater conceptual understanding have greater spatial aptitudes when using VEs, 2) The ability VR possesses to visually present circumstances that cannot be seen otherwise is a main strength and 3) Adding substance to theoretical models is an ability that VR possesses.

Mikropoulos **et al**. (2003) added to the literature with the creation of a VLE for teaching biology. The study investigated whether a VLE could be a successful tool in plant cell biology and support teaching and learning of the photosynthesis process and to explore the opinions of teachers toward the use of VR. Their hypothesis was based on the following research questions 1) what is the opinion of teachers concerning VLEs and VR and 2) for plant cell biology when using the VLE what is the influence on learning results? The sample size used was that of 37 primary school teachers located in Greece. No other study could be found that contained a sample of teachers as contributors. The data was collected in the form of questionnaires both pre- and post, that contained the categories defined as learning of plant cells and photosynthesis, demographics and attitudes and the questions were in the form of both open and closed ended questions. The data was analysed by using descriptive statistics. The results were 1) a positive teacher attitude concerning VLEs and the feeling that VR-based teaching tools could assist learning in a number of ways, safety in the learning environment and interactivity being its strongest features and 2) Information assembly within the VR must be strictly related to the study topic and involve specific instructive objectives and educational tasks; the context being motivating and attractive is not enough.

Padiotis and Mikropoulos (2010) carried out a study that shows the diversity of the learning abilities when using VR. They created a VR milk production line with importance given to pasteurization. Superscape VRT software was used, the objects included were designed not symbolically but realistically and specific consideration given to the likelihood of altering particular variables of the virtual processes and also consideration given to the operators interactions which occurred through free navigation with virtual objects. The results revealed that the number of questions not attempted or answered incorrectly was decreased to a large degree, thus proving a VR learning experience to be a great benefit for pupils at the level of unistructural and prestructural knowledge. Wittenberg (1995) created a research idea hypothesising that students would learn to control lab equipment with greater efficacy within a VR environment than they do in the real world lab environment. The paper continues on to discuss the improvement in the quality of work and on the fact VR does not utilise factory equipment that is expensive for the training purposes so there is a real reduction in training cost when implementing VR-based learning. Wittenberg concluded that his study demonstrates that VR training accomplishes enhanced results over real world training.

The final article found was that of Wang (2012) whom found that "Learning depends more than the transmission of knowledge; it also requires the ability of an educator to engage students to be immersed in a meaningful activity so that they can internalize the knowledge received" when completing their study on undergraduate students. Their study contained a sample size of 36 undergraduate students. Data was collected in the form of a pre-test questionnaire concerning the attitudes toward VR, demographics and computer-related skills and a post-test was also collected containing open-ended questions for comments. The findings revealed that 1) students moved from a passive to active learning state with the use of VLE, their attentiveness to absorb information was also improved and 2) those partakers that are not adapted to modern learning get the most benefits from the use of VLE.

3.1 LONG-TERM RETENTION

There is little research that seems to have been carried out on the use of VR and long-term retention. It has been highlighted in the literature that more emphasis is required to be employed on discovering the factor of long-term retention and this area needs further research carried out in concern of the use of VR for educational purposes (Ragan **et al**., 2010, Trindade **et al**., 2002, Waller **et al**., 1998).

Kontogeorgiou **et al**., 2008 created the VLE "The Quantum Atom" to assist learning the concepts and principles needed when defining an atom conferring to Quantum Mechanics (QM) standards. This topic is difficult to comprehend for students of all education levels and ages. After interactions with the VLE Students' sense of presence and acquired learning results were tested. Two months later they then tested for long-term retention of sense of presence and cognitive content. A sample size of 38 first year students from the University of Ioannina Primary Education Department participated in the study. The data was collected in the forms of questionnaire for entry, exit and retention followed by controlled interviews. The data was analysed by utilizing descriptive statistics. The results revealed that there was a greater sense of presence inside the VLE by the students when they used stereoscopic glasses and also revealed that the acquired learning results were positive. Concerning retention the major findings were two months later the mental images were still present that had been created during the interactions within the VLE and 2) regarding sense of presence the participants still believed they had experienced a solid sense of actually being there.

Jia **et al**., (2012) presented a study on their VLE, evaluating both immediate and long-term responses through testing the operator's opinions of self-adeptness and observed VE adeptness, through the testing of operator's performance and knowledge acquired and through the testing of the operator's improvement of practical or motor skills to evaluate the efficiency and effectiveness VE. Jia **et al** believed that the evaluation of VE training effectiveness and efficiency concerning a single criterion is nearly impossible due to the complexity of VR and it being at such an elevated level. Their study focused on six hypotheses 1) the outcomes of the tasks performed with self-efficacy will have a positively result, 2) perceived VE efficacy will improve due to the self-efficacy improvement, 3) with perceived VR efficacy improved task results will improve, 4) task results, recognition/recollection and performance retention checks will all show a positive relation, 5) there will be no direct connection perceived VE efficacy and memory and 6) there will be no direct connection self-efficacy and memory. Their sample size included 76 volunteers aged 18 to 45 from varied backgrounds. The data was collected for measuring the affective results in the form of interview and questionnaire, for measuring the skill- based learning results data was collected in the form of software generated log files that recorded the time operators took to complete each designated task, errors in efficacy or answer and the operators actions within VE, lastly to measure cognitive learning outcomes data was collected in the form a memory test. To examine long-term retention these were redistributed one to two months later. The data was analysed utilizing four different methods including Cronbach's alpha, Factor analysis, Regression analysis and Pearson's correlation. The results revealed that there was moderate to high degree of recognition and recollection even though only 18 retention exams were received.

The final literature review for this section is of a study carried out by Brelsford (1993); a very early case of using VR to educate in the subject of physics. This piece of literature is from a conference proceeding not from that of a peer-reviewed journal. The study's purpose was to deliver a beneficial comparative assessment in terms of long term retention of lecture-oriented/teacher-based instruction and VR-based presentations. The hypothesis was 'are school room practices, such as VR, superior to the modern class teaching experiences?' The sample size was 14 students, each in four groups of 2 differing education levels being junior high and university, one group from each education level would receive information via VR and the other would not. Data was collected with a 50 multiple-choice questions pre-test. An unexpected and unannounced test for long-term retention that consisted of 50 multiple choice physics computation and knowledge questions was held after an interval of four-weeks. The data was analysed utilizing ANOVA and descriptive statistical analysis. The results revealed that VR based learning is actually greater then modern lecture-based learning.

SECTION 4 FORENSICS TRAINING AND EDUCATION

In reviewing the literature there are a number of areas within the forensic field that already utilize some form of virtual training. The focus when searching for articles was virtual training in forensics not focusing on 360^{o} or immersive to be able to receive a broader view of how this type of education is accepted and being utilized within the field. We have chosen to attempt to review one article from each discipline within the forensics field found that currently employs VR training of any kind.

Brueckner **et al** (2008) discussed how the demand for training in the field of digital forensics is large and growing; currently training in the field of digital forensics is principally conducted with the modern style of online coursework or lectured in the classroom. Before carrying out their research they were unaware of anything similar to CYber DEfenSe Trainer (CYDEST) that could deliver preset training and evaluation using comprehensive live scenarios. Brueckner discusses CYDEST; which is a VR platform that achieves a high amount of realism by virtualizing the systems and networks that students are tasked to investigate or defend, rather than simulating them. Their research demonstrates CYDEST as a means for training forensics within an educational setting. CYDEST utilises virtualization to model networks and complex attacks upon them, the prototype solves the technical issues of having to control these models within manual training scenarios. It provides passive and active observation of the performances of students' and provides infrastructure for defining scenarios. They carried out a field test utilizing CYDEST. The sample size was eighteen undergraduate students from the University of New Orleans that were enrolled in the forensics course in the winter of 2008. To carry out the assignment, two 2-hour time slots were given to seven teams of 2–3 students each. Each team concluded the assignment in varying amounts of time; within the time teams accomplished the discovery from the 8 evidence files of between 4 and 7. All teams successfully acquitted at least one other user and realized the inside attacker. Given the time restrictions all teams performed adequately however no team understood all of the scenario's distinctions. Data was collected in the form of questionnaires, filled out by the students, providing feedback on both the scenario and the CYDEST framework. The feedback received, in relation to CYDEST, included thoughts on the application performance and thoughts for refining the operator interface, particularly the Instant Messaging IM system and notebook. They noted that creating high-quality and realistic forensic scenarios is difficult and general solutions are required because the feedback received in relation to the scenario included the facts that there were timestamp inconsistencies and footprints had been left while the scene was being set up to be photographed. The results revealed that the realism and automation of CYDEST, combined with its internet availability, provides the delivery of vital training while decreasing workload on instructors.

Minhua **et al**, (2010) discusses VR simulation not for training, but in relation to recreating scenes for use in the court room to educate the judge and jurors. This is classified as Augmented Reality (AR); being the combination of real-world and VR content. Virtual humans or items are overlaid over real items or into video material in real time. Once the reproduction is made, an AR operator can wear transparent goggles, in which they are able to view the real world with the pictures projected on top. In the forensic process this begins with modelling 3D humans and items based on photos and measurements, animations of the reproductions then occur in order to recreate the incidents concerned or the crime scene. The research carried out by Minhua **et al**, (2010) investigates forensic 3D animation. The paper identifies several technologies that have the possibility to be applied to or those which are already beginning to be used for forensic visualization. These technologies include dynamic simulation, motion tracking, natural language visualization, computer vision and AI. They go onto discuss which areas within forensics these computer technologies may provide benefit to and carry on to analyse the process of forensic visualization VR applications within forensic animation, including murder reconstruction, pathological visualization and shooting case briefing tools. AR Applications within forensics include the mimicking of road traffic accidents where virtual vehicles are merged into footage of the real scene and crime scenes that are augmented where 3D models of suspect, victim, or missing weapon are all merged into the real crime scene for presentation as evidence. Reconstructions of the following incident also occurs; homicides, bombings and accidents of varying severity. Advantages of AR visualization use within forensics are that costs are reduced and time is saved due to the higher immersion by using real-world features, thus reducing the amount of time required to carry out

3D modelling. There comes with AR the issue of generating bias from viewing only one scenario. This carries the difficulty of admission of animation into the courtroom as individuals are five times more probable to recollect what they have seen or heard rather than what they have only heard; they are then also twice as likely to be swayed if the case presented is supported by visual aids, AR could also be utilized during the forensic investigation procedure to examine and eradicate any presented hypothesis. Overall, VR ⁄ AR animation confers the capacity to communicate extremely difficult, three-dimensional and sequenced evidential facts concerning event scenes whilst bringing about improved accuracy or quicker speed in the investigation side of forensic processes, therefore decreasing the expenses involved. The results of this research revealed that it is acknowledged that high Level of detail (LOD) animation involving the use of human characters, could be of assistance for the investigation of crime scenes but, because of problems with admissibility, only had limited courtrooms use. Ebert et al (2014) carried out a similar study researching the use of VR also for providing information in court.

Drakou & Lanitis (2016) created a 3D environment, where the operator must apply the knowledge they have acquired in the game. There are three cases to solve and multiple topics are covered during each case in relation to the forensic investigations processes followed. The operator plays the game without any direction of a virtual teacher, the operator acts like a real policeman and attains new awareness about forensic investigation processes as the game advances. The operator has more concentration and immersion in the game. The actions the operator has to experience are created from real actions that take place at forensics departments. By experiencing these actions within the game the operator gains awareness about the real-life procedures that must be adhered to. The hypothesis of the research was whether or not a dedicated gaming platform could be used for educational training that is similar to the on previously created. The sample size was 28 volunteer users and a specialist being from the Nicosia Forensic Department, Cyprus. Ages ranged from 11 to 65 years old. The data was collected in the form of two questionnaires. The initial questionnaire focused on topics relating to procedures used in the Forensic Department laboratories of the local Police Stations during their forensic examinations such as the processes involved in the of collecting of suspect fingerprints and collection of prints from murder weapons, requirement of fingerprint matching, the process of evidence recording, blood analysis and blood matching. The questionnaire consisted of nine questions requiring true/false answers. Questionnaire one was a requirement of continuation and once completed the volunteer progressed to play the game so as to assist assessment of any knowledge gained as a direct result of playing the game. Questionnaire two consisted of 14 questions to evaluate the operators' experience of the game, the genuineness of the processes the game presented when comparing to that of those a real policeman must adhere to in the Forensic Department laboratories of the local Police Stations and lastly relating to the overall operators experience was there any educational value of the game. Additional to the data collect by questionnaire, a specialist from the Nicosia Forensic Department, Cyprus, conducted an interview with a chain of open questions, prior to leading the interviews the specialist had opportunity to play the game. The resulting opinion of the specialist, after conducting the interviews, was that this game could be used in the in the form of an assessment for a lesson for the local police academy and that it for visitors in the Forensic Department laboratories in Cyprus the game could be used as part of an educational experience to check the visitors knowledge.

Kanable (2012) wrote an article revealing that in 2009 for the first time; the National Institute of Justice awarded the Law Enforcement Innovation Center (LEIC) a two-year grant in the area of Forensic Science Training Development and Delivery. The joint efforts of University of Tennessee (UT) and National Forensic Science Technology Center (NFSTC) creating the Investigator-Virtual Reality earned the Award of Best Collaboration at the 2012 BizTech Innovation Summit Awards & Expo. In addition to joining with the (NFSTC), LEIC also united with Advanced Interactive Systems to create a VR education tool called Investigator-Virtual Reality (I-VR). The reproductions assist pupils to practice the learned theories. NFSTC, in partnership with the (UT), LEIC and with the assistance of Brian Cochran, a detective for 11 years and a graduate of UT's National Forensic Academy, are making VR crime scene training available to state and local law enforcement professionals. Current National Forensic Academy (NFA) programs were collected, evaluated and transformed into storyboards to generate virtual crime scenes and lessons and subjects covered comprised of: Management of the crime scene, photography, footwear impressions, collecting of DNA and processing of latent prints. Those that benefit from I-VR would include those who want to become forensic practitioners or investigators of crime scenes such as Entry-level law enforcement personnel. Seasoned investigators can also use the training as a refresher. The processing of a crime scene must be done correctly and I-VR training covers the essentials of managing a crime scene and the requirements when processing one such as searching for evidence and evidence identification, scene security and properly documenting, packaging, collecting and preserving the evidence as well a how to photograph the evidence. I-VR is an online 10-week, in-house program for training crime scene investigators and is offered twice a year and includes hands-on exercises and lab work. Students work with a virtual trainer throughout the online teaching. Students come to be virtual crime scene investigators collecting evidence and documenting a simulated case as the lessons are completed. Previously, for law enforcement online teaching involved a PowerPoint demonstration with commentary, I-VR is the first scenario-driven, avatar-based training of its kind. The avatar depicts graphically that of a teacher. Experts on subject matter from UT evaluated and tested the plan of the teaching platform. They also provided advice on photography, crime scene management, fingerprints, DNA, mapping and sketching. The virtual exercises were in the form of three components: 1) Fundamentals of managing a crime scene: oblique lighting, narrative writing, evidence recording, evidence marking, scene photography and evidence sketching. 2) Evidence processing on site: this was avatar-led instruction and virtual demonstration of tools and 3) Practicing independently the use of tools demonstrated in 2, evidence detection, evidence collection, evidence lifting. Simulated scenarios were created which comprised of an assault and a burgled apartment. The training is estimated to take 8 to 20 hours; students are assisted with navigation through the training via tutorials however those personnel that enjoy video game playing may be more adept in the virtual environment than those personnel who don’t. There are multiple choice quizzes during the units and a practical evaluation is completed at the conclusion of the course. Students wishing to increase their results are able to repeat the practical evaluation. A student evaluation of the teaching was also carried out by a member of the Kansas Bureau of Investigation, Crime Scene Response team leader and senior special agent

Cory Latham, whom was also an expert on subject matter. His findings were that the attention to detail within the virtual environment was impressive; he responds that the teachings was rewarding and fun especially the avatar interaction and the first responder officer briefing. I-VR increases a pupil's capacity for making judgements on a crime scene. What should they do first? How should they process this piece of evidence? Which samples are priorities to send to the laboratory? These are problems pupils must decide for themselves, in addition to those skills just mentioned I-VR also improves a pupil's abilities to correctly identify evidence and document a crime scene. It was found that this type of training reduces costs and minimizes the loss of working hours due to investigators having to travel away from their departments to receive training, especially with more than 400 participants registered for the course within ten months, which included participants such as first responders, law enforcement officers, field training officers, crime scene investigators, veterans and rookies. Enabling students to work at their own place of employment on the training or in fact anywhere, they are able to put the training down and return to it later which is not possible to do with a mock crime scene.

SECTION 5 POSSIBLE DRAWBACKS TO IMMERSIVE CURRENT 3D VIRTUAL REALITY TRAINING AND THE NEED TO LOOK TO 360^0

This section of the literature review focuses on the difficulty of creating the 'realness' provided by the current 3D immersive VR techniques. As reviewed earlier in sections 1.2 and 1.3, respectively, 'the greater the feel of immersion and presence the greater the information retained by the operator'. 360^{o} capture not covered by literature in this section as it does not require construction therefore is already real.

Roussou, (2000) discusses that before the introduction of virtual technologies into scholastic settings, a number of concerns must firstly be addressed. Learning environments that are interactive must provide the theoretical and visual standards required for the learning purpose, they must take the physical setting of the working space into account, and they must be well-designed and manageable to its planned group of learners. Roussou goes on to discuss that the technology should be non-obtrusive, should be planned to "disappear" during the practice and should lend focus to the educational experience. It is also noted that VR technology will be set up in significantly less quantities than those of personal computers. Roussou discusses that the increase in detail and interactivity of a 3D environment, in turn, results in decrease in performance and this decrease then creates a less realistic experience. Roussou goes on to then explain the importance of utilizing a content expert for the construction of any sound within the environment and when designing interactive and virtual environments to ensure they are complete environments. When planning an interactive virtual learning environment, whether with a 3D or 360o presentation, some of the problems vital to be addressed include having ample seating, good lines of sight and fields of view and being comfortable and ergonomic when viewing is for extended periods. The interface of an interactive experience must be simple and easy to learn and use, it should be manageable by an extensive variety of skill levels and require almost no training on how to use it. (Roussou, 2000).

Other areas that also Roussou noted need to be addressed are the cost, fragility uniqueness and size of VLEs. Two examples of these that are used consistently are that of CAVE Automatic Virtual Environment (CAVE®) (Cruz-Neira, Sandin & DeFanti, 1993) wherein students wear special stereo glasses that are lightweight and allow unobtrusive visualization of both the real and virtual worlds whilst using a hand-held device that is light-weight for interaction (Padiotis & Mikropoulos, 2010) and that of the ImmersaDesk™ which resembles a drafting table consisting of a rear- projected screen that is tilted at an angle of 45-degrees (Padiotis & Mikropoulos, 2010). Rousosu et al (1999) within their study of Narrative Immersive Constructionist / Collaborative Environment (NICE); a VLE designed for children acknowledges a number of design flaws with 3D VLE designing. Limitations included the design of the navigation hand held device as this created discomfort to young operators due to having to use both hands to simultaneously press the joystick and reach the buttons and at the same time. Another observed flaw was that despite the use of glass-ties, the stereo glasses were too large for the children's' heads and continuously fell off, therefore the child attempted to hold the glasses on with one hand (disabling their ability to correctly use the hand held device) or just take them off. These combined flaws created operator fatigue and reduced the motivational level therefore creating a decrease in the learning capacity because both the hand held device and the stereo glasses create the atmosphere of the virtual experience.

Other than the flaws with equipment Padiotis and Mikropoulos (2010) found that only the drivers were focused on the task and the other children within the VLE became distracted by the 3D imagery and movement going on. They also found that the individual differences of drivers correlated to their abilities of being able interact with the 3D environment. These individual differences could be explained as two types: Type 1) those that pursued their own goals and seemingly did quite well and 2) those that tried to listen to the other members of their group and ended up disoriented and confused. Padiotis and Mikropoulos then went to discuss that these two types of differences could be directly related to the individual child's independence level. Padiotis and Mikropoulos performed another test with a concept map testing for orientation. In initial planning, on paper the students created altered approaches for planting and the test was to see how the children would implement these approaches in VR. The results of this test revealed that although the children endeavored to stick to their plan due to the case studies being more focused, the children were not successful at completing the task at hand with the exemption of only one child in the initial study.

SECTION 6 CONCLUSION

According to the findings of our literature review, the contribution of VR to the field of Forensic Science is inevitable and necessary. VR learning environments warrant further research in many areas especially, as discussed, those areas pertaining to long term retention and issues with 3D VLE use. VE content if not designed correctly can break the suspension and then create a disbelief in the Virtual landscapes, objects being presented. 3D uses avatars that must be consistent and fit in the interactive and visual design of VE. Even a slightly wrong object in the design will create a possible source of disruption then disbelief; and for VR to be successful it must be believable. Immersive VR can provide strong learning tools and a typical learning experience that involves this technology must be brief, controlled and highly structured. It is well established throughout this review that any learning goal using VR technology must be important, must be hard and must be reasonably enriched by the addition of immersive VR training.

The use of VR with 360^0 immersive HMD may result in improved efficiency and safety of training, 360^0 capture is absolutely real life, HMD is comfortable, reliable and allows for an excellent field of view and accessibility to a real-life crime scene they would otherwise not be able to access. When comparing the current used 3D VLE technologies and modern classroom lecturing, the costs that make incorporating large VLEs into dwindling school budgets can be very difficult coupled with issues of usability and educator training, and VLE maintenance presents important drawbacks for the educational use of the current used VR technologies. The need to find a simpler, cheaper, less problematic and hard to design way of delivering an immersive VR experience is something that is worthy of researching. However the overall opinion of VR of all types in education is that when used alongside normal class room lessons the technique can increase the learner's motivation and involvement and there is constantly a wider range of learning styles supported.

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Part 2

MANUSCRIPT

IMMERSIVE 360° VIDEO FOR FORENSIC EDUCATION

IMMERSIVE 360° VIDEO FOR FORENSIC EDUCATION

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ABSTRACT

Technical skills for forensic crime scene investigation must be acquired within a competency-based curriculum, beginning in the lecture theatre, followed by laboratory demonstrations and completed with mock scenes training. The setup of mock scenes requires time, effort, funds, availability of space and trainers. Furthermore, the access to the scene may be possible to only a few students at the same time, and often that will be the only access they will ever have to the scene for their training. Our objective was to develop a 360° recording of a crime scene that will be viewed through a Virtual Reality Headset to assist in the learning abilities of Forensics Students. The recording of the scene will incur only in a single cost, time and effort for the set up, but the student will have access to the virtual scene and the connected training (audio information) any time the student will need. Implementation of this type of technology as a training tool enables students to feel they are within a scene without actually being physically at a real scene.

Following setting up a forensic crime scene, then recording the scene investigation using a 360*fly* camera, and uploading the finished video online (private), the immersive video has been submitted to a cohort of 10 forensic students to review. The review was in the form of a questionnaire. All sections of the questionnaire revealed with Weighted Average Index, a score for all four questions that was greater than 0.76; indicating that Virtual Reality (VR) training would be something they would find beneficial when implemented as a learning alternative on top of the usual lectures and practical work.

However, more research is required to record satisfactory lessons and one disadvantage clearly defined was the quality of the VR headsets (VRH). Preliminary results suggest that the VR gear goggles merit more attention as a potential and that the viability of inexpensive but highly immersive VR goggles would significantly improve cost effectiveness and increase memory retention and interest from students.

Keywor*ds:* *forensic examination; virtual reality; immersive; training; virtual learning environment*

INTRODUCTION

Within law enforcement academies as well as for forensic science/professional practice students, training in the investigation of forensic crime scenes is a vital part of the overall education process. Due to the delicate nature of the information presented within crime scenes, and the overall difficulty of forensic investigations, the exposure trainee forensic officers get in real life scenes, by instructors, is minimal (Horswell, 2004). Virtual reality (VR) can assist in immersing students inside these difficult worlds that offer unique educational experiences. *Virtual Reality is a* three-dimensional, interactive, computer generated environment that can be models of real or imaginary worlds. Conceptualization of complex or abstract systems is made possible by representing their components as symbols that give powerful sensory cues, related in some way to their meaning (Steuer, 1992).

Forensic students as well as law enforcement in training can learn standard or complex procedures without worrying about harming objects, humans or animals in the process (Hilty et al., 2009). Currently, in law enforcement training VR is widely used in several capacities, including in the training and examination of new forensic officers. VR is often employed as a type of teaching (Baus & Bouchard, 2014) allowing the opportunity for users to experience environments that otherwise would not be available to them due to the factors of time, distance, size, and safety (Roussou, 2000, Baus and Bouchard, 2014). These factors assist in reducing training costs compared to non-VR trainings (Bowman & McMahan, 2007, Roussou 2000 and Baus & Bouchard 2014) and allow training on topics associated with often hostile and irrepetable environments (Webster, 2014, Baus & Bouchard, 2014).

Retention is increased significantly when students are exposed to more than one instructional media (Sulbaran et al., 2000). Although most students are visual learners, the instructional environment is mostly loaded with lectures, which can have a negative impact on the instructional environment (Sulbaran et al., 2000). It is also important to realize that "Instructional aids do not ensure an improvement in academic achievement" (Sulbaran et al., 2000). Even though VR could enhance forensic training by offering another, perhaps more versatile and more engaging way of learning, to date no devoted VR application for forensic examination education has been commercially implemented. Research into VR is a fairly young field, however the technology and use of it is still rapidly growing and the improvement of interactive tools is inevitably having an impact on all facets of learning and teaching (Dede, 2009). VR training offers a degree of realism which inside the classroom is simply not possible to achieve, as well as offering higher flexibility with the ability of going beyond the physical locality of the real-life environment (Roussou, 2000, Baus & Bouchard, 2014).

Progressing from the currently used graphically designed and 3D overlaid methods; this research aims to assess whether viewing a 360° recording of a crime scene through VRH, and feeling as though they are personally within the crime scene will provide a positive educational tool for forensic students.

The background of VR can be complicated to describe, not unlike many other fields of study. VR has been used to enhance domain-specific learning, which relates to memory and the conceptual organization of material (Hilty et al., 2006). VR use is currently utilized within education in the form of 3D presentation. The use of VR technology is within applications as it enables users to experience an environment and learn more about a topic in a controlled, safe manner (Roussou, 2000, Nooriafshar, Williams & Maraseni, 2004). Advantages that VR carries over other types of 'analogue' approaches include the flexibility, cost, duplicability, and reusability, experimental and environmental control. The difference between utilizing 360° capture and 3D overlay are that other technical necessities are required to produce a 3D representation, including having to realise that adaptations need be made to the environment and research designs. However, providing a 3D presentation is designed and created realistically enough, they function as an addition to the real-world physical environment (van Gelder, Otte & Luciano, 2014).

There are however technical issues that can occur with the 3D overlay technique that can disrupt the immersive nature that the VR function is aiming to achieve.

Fast-forwarding to today, VR developers and researchers are now aware that a greater degree of learning is acquired when a student is fully immersed, and this immersion occurs at its best when viewing occurs through a Head-Mounted Device (HMD) (Rolland & Hua, 2005).Therefore, a major aspect to consider is the fact that HMDs with low latency, that are lightweight, purchasable at a low cost, offer a wide field of view and are user friendly, are used when accessing the VR material. The technology surrounding HMDs is still young and there are many changes that will occur in the future as more research is carried out.

WHY THE NEED FOR CHANGE?

The difficulty with the current styles of alternate education available in the field of forensics is creating the 'realness' provided by the current 3D immersive VR techniques. 360^{o} capture does not require construction, therefore is already real.

Learning environments that are interactive must provide the theoretical and visual standards required for the learning purpose, they must take the physical setting of the working space into account, and they must be well-designed and manageable to its planned group of learners (Roussou, 2000). The technology should be non-obtrusive, should be planned to "disappear" during the practice and should lend focus to the educational experience.

Increase in detail and interactivity of a 3D environment, in turn, results in decrease in performance, and this decrease then creates a less realistic experience (Roussou, 2000). The interface of an interactive experience must be simple and easy to learn and use, it should be manageable by an extensive variety of skill levels and require almost no training on how to use it. (Roussou, 2000). Other areas that should be addressed include the cost, fragility uniqueness and size of VLEs. A number of design flaws with 3D VLE designs have been discussed within the literature, including design of navigational hand held devices and stereo glasses being too large and continuously falling off (Padiotis and Mikropoulos, 2010). These combined flaws created operator fatigue and reduced motivational levels therefore creating a decrease in the learning capacity as both the hand held device and the stereo glasses create the atmosphere of the virtual experience. Distraction can be created by the 3D imagery and movement going on, and individual differences of drivers correlated to their abilities of being able interact with the 3D environment (Padiotis and Mikropoulos, 2010).

There are currently few immersive educational opportunities available for training forensics officers, and they all utilize 3D presentation either with or without the use of avatar to complete assigned tasks. One such method is the Cyber Defense Trainer (CYDEST); which is a VR platform that achieves a high amount of realism by virtualizing the systems and networks that students are tasked to investigate or defend, rather than simulating them (Brueckner et al, 2008).

M. Drakou and A. Lanitis (2016) created a 3D environment, where the operator must apply the knowledge they have acquired in the game. There are three cases to solve and multiple topics are covered during each case in relation to the forensic investigations processes followed. The operator plays the game without any direction of a virtual teacher, the operator acts like a real police officer and attains new awareness about forensic investigation processes as the game advances.

National Forensic Science Technology Center (NFSTC), Law Enforcement Innovation Center (LEIC) and Advanced Interactive Systems, correlated to create a VR education tool called Investigator-Virtual Reality (I-VR). The reproductions assist pupils to practice the learned theories Current NFA programs were collected, evaluated and transformed into storyboards to generate virtual crime scenes and lessons. Subjects covered comprised of: Management of the Crime Scene, Photography, Footwear Impressions, Collecting of DNA and Processing of Latent Prints (Kanable, 2009).

WHAT VR EDUCATION CAN OFFER FORENSIC TRAINING

There is an overall agreement throughout the literature that the use of VR can have strong motivational influence on the field of education (Roussou, 2000, Bricken, 1991). To be successful in creating long term retention and a good learning capacity it is also known that presence (Mikropoulos & Strouboulis, 2004, Baños et al., 2000, Baus & Bouchard, 2014) and users to experience environments that otherwise would not be available to them due to the factors of time, distance, size, and safety (Roussou, 2000, Baus and Bouchard, 2014). These factors assist in reducing training costs compared to non-VR trainings (Bowman & McMahan, 2007, Roussou 2000 and Baus & Bouchard 2014) and allow training on topics associated with often hostile environments (Webster, 2014, Baus & Bouchard, 2014).

AIM OF THIS RESEARCH

With this research we hypothesis that creating a 360° recording of a crime scene with the *360fly* device and viewing as an Immersive Virtual Reality experience will be an acceptable alternative type of learning tool with in the field of Forensics. To be able to view the video through the Samsung Gear VR model headset the recorded video must first be downloaded from the camera to the paired Samsung S7 edge mobile device, this device can be connected to the front of the Samsung Gear VR model headset to view the presentation video. It is also hypothesized that this type of learning will be a less expensive, less complicated style of immersive learning, therefore both cost and time effective, as well as increase learning.

MATERIALS AND METHOD

SET UP OF SCENE

Within a laboratory at Murdoch University a mock scene was created (Figure 1-4) with the deceased being a clothed plastic mannequin that had been stabbed. Blood used was expired greyhound blood acquired from the veterinary department of Murdoch University Western Australia, and a number of evidence types to collect including bloody shoe impressions, hair, DNA, dead flies and live fly larvae. The total time needed for the set up was 45 minutes.

Figure 1. Overview of crime scene

Figure 2. Close up of injured area

Figure 3. Overview of impressions collection

Figure 4. Correct PPE

RECORDING OF SCENE

The scene was recorded using a 360*fly®* camera (Figure 5) paired to a Samsung Galaxy S7 edge (Figure 6); capture was made of the scene walkthrough and then collection of the evidence types. The camera used in the research is commercially available and was primarily selected because of its compact size and ease of use that made it ideal for testing.

Correct Personal Protection Equipment (PPE) was used throughout and gloves were changed in accordance to how a real scene would occur. All usual crime scene documentation was also carried out and verbally explained throughout the recording. The total time needed for the recording was 12 hours in total over 2 days.

Figure 5. 360*fly®* camera

Figure 6. 360*fly® app* on Samsung Galaxy S7 edge

UPLOADING THE SCENE RECORDING

To upload the recording to a format able to be used by the VR headset, it must be first be downloaded from the camera (Figure 7) onto the paired Samsung phone, this required use of internet. From this point, to be able to view the recording through the Gear VRH the recording was exported from the phone (Figure 8) then uploaded onto YouTube and a playlist was created in sequential order to view in correct order without going in and out of videos. This task was carried out at the library of Murdoch University for the speed of the internet download and upload capability. This ran at 1.98Mbps(247.5 KB.sec transfer rate) and 2.33Mbps (291.3 KB/sec transfer rate) consecutively (speedtest.att.com).

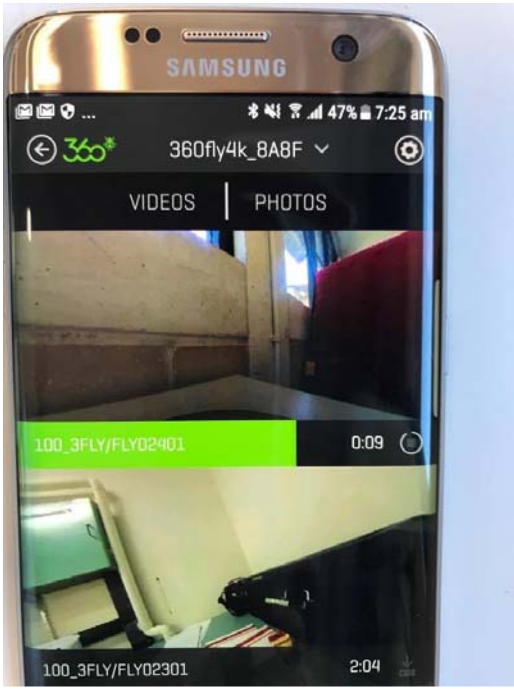

Figure 7. Downloading from camera

Figure 8. Exporting from phone to YouTube

APPROACHING PARTICIPANTS

An overview of the project was presented to undergraduates within the forensics field during a lecture requesting for volunteers. An advertising post was placed on the Facebook Murdoch Forensic Students page, to gauge interested people. Once an email of interest was received, an information letter and consent form was provided for students to return if still willing to participate further. A viewing date was then arranged at a convenient on campus location. To be able to allow volunteers to view the video and participate in a questionnaire a submission was first placed with the University Ethical Committee which was subsequently accepted in order to proceed appropriately.

VIEWING OF THE FINAL VIDEO BY VOLUNTEERS

A large number (18) Forensic Students from Murdoch University, Western Australia responded interest in participating as a viewing volunteer. However, only ten volunteers assisted in the study. The volunteers were first shown a short trial video that contained blood to assess suitably with viewing blood or motion sickness, and to explain how to access the required videos on the headset menu. Upon proving suitability the volunteers then viewed the captured crime scene assessment video.

To view the 360^{o} presentation the Samsung Gear VR (Figures 9, 10) headset was selected, this is a HMD without built-in display, used together with a smartphone as a main image source and thus possible to use without any cables. The Gear VR has an in-built touchpad on the side, for some limited interaction with the virtual environment. The display is a single screen. The headset is lightweight, making them more comfortable for long use. The parameters of the device are presented in the Table 1. Following the requirements stated in the ethics, volunteers filled in a form regarding their suitability, were seated and verbally walked through how to access the video on the HMD; they then viewed a sample video to further assess suitability. Furthering this once viewing had occurred of the crime scene volunteers were offered water and chocolate while they completed their questionnaire and were free to sit for any period of time needed to adjust to the real world again. They were then provided information that the Medical Center was available, free of charge, if they felt any type of motion sickness later and were offered a chocolate and water.

Figure 9. Phone attached to the Gear VR headset

Figure 10. Volunteer whilst viewing

Table 1. Selected parameters of the Samsung Gear VR

Product Specification Platform	Android
Display	5"1’ 2560x1440 60 Hz LCD
Resolution	1280x1440 per eye
Low-persistence	No
Optics	One aspheric acrylic lens per eye (7X)
Interaxial distance	55 ~ 71 mm
Tracking	3 DOF angular
Tracking latency	<20ms
End-to-end latency	50-60ms
FOV	96°H
Sensors	Accelerator, Gyrometer, Geomagnetic, Proximity

PRESENTING THE QUESTIONAIRRE

Once volunteers had viewed the video they were requested to complete a short questionnaire (Table 2) containing four 1-5 answer questions and one open ended answer section to provide any feedback regarding possible comments and improvements.

Table 2 Questionairre provided to volunteers

Question	***Negative/ no 1***	***2***	***Nuetral 3***	***4***	***Extremely Good/ yes 5***
How would you rate the overall 360º immersive experience?					
Did you find the narrative easy to follow?					
Did you find this educational?					
Would you be interested in this type of learning?					
Please comment any improvements you would recommend to make the experience more pleasant/educational for you.					

RESULTS

SCENE RECORDING

8 scenes were successfully recorded. This included a detailed scene walkthrough and collection of 6 evidence types, with detailed vocal instruction along the way and a detailed scene wrap up. Upon reviewing the recording of the scenes it became evident that visual instruction would have been better with the camera positioned differently, however all volunteers still understood via the vocal instruction what was happening.

UPLOADING FROM 360° CAMERA THROUGH TO UPLOADING TO YOUTUBE

The videos recorded were successfully downloaded from the camera to the paired phone and then successfully uploaded onto YouTube (Figure 11). Even with the improved speed of using a community shared internet the uploading of the YouTube videos took considerable time, the longest being the finale video of 9 minutes, taking 2 hours to upload. The videos were placed in a playlist in sequential order of occurring within the scene; this enabled the viewing day to run smoothly. The video began with a scene walkthrough, scene cordoning, collection of DNA from bench top, collection of shoe impression photographic evidence, collection of hair from jacket, live larvae and dead flies, and finally the lab coat with a detailed end of scene description.

Figure 11. View of scene recording from YouTube through the phone screen

VOLUNTEER VIEWING

10 Students of Murdoch University currently enrolled in Forensics courses participated to the viewing stage of the video. It was required that the Students must be domestically enrolled as this allowed for them to receive free medical assistance in the event they felt any ill ease. This stage was carried out in an office within Murdoch University, South Street campus, within the Medical Centre hours, if by chance anyone suffered badly from blood sight or motion sickness. These students were provided with a Gear VR headset paired to a Samsung S7 mobile phone so that the presentation of video and truly 360º presentation would be possible. In other words, an almost real (virtual) presentation of the real objects was presented to these students. Hence, the learners were able to interact both mentally and physically with the learning materials. They followed verbal directions and easily navigated from the Gear VR menu through to having a video displayed in full VR by using the mouse pad to click menu links within the virtual world provided with the headset on.

PARTICIPANT FEEDBACK

The effectiveness of this visual lesson was measured via a short questionnaire. The students were invited to rank their views on a 5 point (Likert) scale for the following 4 different factors:

1. How would you rate the overall 360^{o} immersive experience?

2. Did you find the narrative easy to follow?

3. Did you find this educational?

4. Would you be interested in this type of learning?

The research instrument consisted of:

- an organised VR video;
- a structured Questionnaire; and
- a feedback section for other comments.

The view rankings within each of the 4 questions were then used to create a calculation of Weighted Average Index (WAI).

The frequencies of responses of students were recorded in excel program by giving the highest weight of one (5/5 =1) to the 'extremely good' and 0.8 (4/5 = 0.8) weight to the 'good' and so on to 0.2 (1/5 = 0.2).

RESULTS AND DISCUSSION

Statistical analysis has revealed that an overwhelming number of students strongly agree with the following factors. See Table 3 for details.

Table 3: Frequency Distribution and WAI of Factors (1-4) provided by Students

Question score	Rating	Narrative	Educational	Interest
Extremely good	1(10.0)	8(80.0)	7(70.0)	5(50.0)
Good	6(60.0)	1(10.0)	3(30.0)	5(50.0)
Neutral	3(30.0)	1(10.0)	0	0
Not so good	0	0	0	0
Negative	0	0	0	0
Total no student	10(100)	10(100)	10(100)	10(100)
WAI	0.76	0.94	0.94	0.9

Note: percentages are within the brackets

The Weighted Average Index (WAI) value on all four factors are larger than 0.76. This illustrates that on average, students, are in between close to *agree* or above *strongly agree* choices on all learning factors. In fact, the Overall Weighted Average Index value is 0.885 which is very close to one. Hence, it reveals that the general significance of this method is rated very high in the terms of students' learning experience.

The WAI values of the two factors, "*Did you find the narrative easy to follow?"* and *"Did you find this educational?"* are equal and are the highest among the other responses (0.94 for both factors). This shows that the VR Immersion Method is more important to students for those two factors. The "would you be *interested in this type of learning?'* scored very close to 1 (0.9) also indicating that students rate this of high importance.

The WAI value of the *overall 360^o immersive experience* directly correlates to feedback given in the written section information to follow.

The final question in the feedback form was an open section for Students' to comment on their feelings for improvement or provide general feedback. From the findings of this section we were able to discern that because the virtual reality 360^o recording provided detailed capture on recoding and collecting within a crime scene.

The following statements are some of the comments made by students with regard to the virtual reality viewing:

- The technology is amazing and would potentially be a useful tool at a forensic crime scene. The only improvement I would recommend is the quality of the camera.
- Requires clearer video and higher resolution.
- Overall loved it and found it quite informative. Was a bit blurry.
- The videos contain a lot of information and is very good for educational. Needs improving the quality of videos and less shaking around.
- Really good learning tool for future. Did feel like part of the crime scene. Perhaps improve quality of goggles and move around a bit slower.

Finally, it was interesting to observe some of the students who were completely immersed and reached out to the air in front to click something which was really empty space as they needed to click the mouse pad on side of the head set.

DISCUSSION

TRAINING WITHIN THE FORENSICS FIELD

At the forefront of every discipline is the need for the employee to be trained to a level of confidence. This is also true for Forensic Crime Scene Examination (CSE). The crime scene is measured by many to be the most important characteristic of a criminal investigation. High-quality and valuable evidence that assist in leading to the correct and just judicial results can only occur if the scene is handled skillfully and efficiently (Robertson, 2009). According to

Stanley 2004, the attitudes, skills and knowledge of Crime Scene Examiners (CSEs) can be of huge impact within a criminal investigation. The crime scene is where forensic science begins and a critical element hinges on the quality of criminal investigations. Ineffectively managed scenes lead to poor evidence recovery or documenting and with these come the risk of wrongful convictions (Kelty **et al**., 2012). Several individual skill sets have been identified for top performance in CSE: these include at the top; knowledge, professionalism, effective communication, cognitive abilities, and stress management (Kelty **et al**., 2012). The National Academy of Sciences committee concluded that numerous problems in the collecting of evidence at crime scenes could have been mistakes resulting from lack of experience or training and too much haste of the crime scene personnel (National Academy of Sciences 2009, Kelty **et al**., 2012).

Good CSEs have an understanding of two manners where their findings fit into the criminal justice process. These include the probative value and the admissibility of evidence as well as how they can improve the criminal investigation process. Good CSEs are known among the police and their peers as having comprehensive scientific understanding that supports their work, and are respected highly due to this acquired knowledge (Kelty **et al**., 2012). From this knowledge it is important to realize that lectures and mock scene work is not enough for a new cadet or officer to be able to amply assist in investigations and some alternative real life experience should be implemented to improve the balance of knowledge (Kelty **et al**., 2012).

CURRENT EDUCATION IN FORENSICS

Most of the prominent books available detail procedural aspects of 'processing a scene' and the order in which tasks should be accomplished (Pepper 2010). For example, in Horswell's book it was eminent that two features of efficient crime scene processing include scene security/ control and guaranteeing the constant flow of pertinent material between CSEs and investigators (Horswell 2004). In such books what is commonly not conferred is the type of communication skills required to work effectively in difficult circumstances or manage crime scenes, or the type of assessment is undertaken to conclude what material is related and what is unnecessary (Kelty **et al**., 2012). High CSE performers tend to collect the correct items to analyse and then collect them the correct way therefore produce greater quality evidence outcomes (Kelty **et al**., 2012).

Beside classroom lectures and mock scene work, the alternatives to learning with any type of real world feel (or VR) currently all run on the 3D method. 360^{o} capture is still a very new field of educating and not yet peer reviewed. Therefore to establish why a new way of utilizing VR equipment in education should be investigated we will discuss some of the differences between the 2 methods. To begin with we explore the fact that creating a 3D world takes a lot of input, time and costs. Firstly there is the importance of utilizing a content expert when developing a 3D platform to assist with the construction of any sound within the environment and when designing interactive and virtual environments to ensure they are complete environments (Roussos). Disadvantages to such environments include cost, time to construct, and the inability to (sometimes) mimic real conditions (Hilty et al., 2006). These are costs that are not associated with the production of a 360° presentation as these videos are recorded in real time.

To contrast the ease of recording in real time a 360° recording of a crime scene to the complex development of the current 3D models, we look at the development process of just one currently use educational model. To begin there is a creation of 3D models represented by Virtual Reality Modeling Language (VRML) from geographic information system (GIS) or computer-aided design (CAD) data; and secondly interaction with the VRML worlds. In the creation of the models, Pavan (Sulbaran **et al**., 2000) and VirtualGIS (Hilty **et al**., 2006) are two typical examples.

Pavan is a VRML compiler and project management system for the GIS, MapInfo can be used to create comprehensive VR worlds, with navigable 3D models generated from data held in the MapInfo app. The resulting models can be represented by VRML and viewed interactively in the most recent versions of Web Browsers. VirtualGIS is an add-on application of 3D visualization and analysis, and has similar functions to Pavan. Once this creation is successfully completed then the second step of integration with the VRML worlds needs to be carried out, Moore et al., 1999 illustrated how to interact with the VRML worlds via a 2D Java interface. This virtual interface permits an operator to travel between viewpoints, select the required view, and extract from the model any locational data. The prototype (Raper **et al**., 1999) offers a connection between an operator-browsable virtual world and a map, and the viewpoint in the virtual world can be shown on the linked map. This prototype was developed by the Visual

Basic language with the Map Objects components in combination with the Sense 8 VRML plugin.

Another virtual interface provided by Brown (1999) employs both the Java external author interface (EAI) approach and script nodes to interact with VRML worlds. This includes actions such as hanging an image layer over a landscape VRML model and probing a VRML world. Rather than 3D modeling of spatial objects in the natural world like buildings, the design of GeoVR, is proposed to discover a suitable method for interactively producing 3D VRML models from 2D GIS data, as well as providing a user-friendly interface for interacting with the GIS data on the Internet through a tight coupling of Internet GIS with VRML. The development of these systems would be high cost and need expert technicians to design. When compared to creating a real life real time once only 360º recording that can be viewed independently by students forever; the cost, time and initializing factors are stand out.

Areas of Virtual Realty training that assist in successful learning

When planning an interactive virtual learning environment, whether with a 3D or 360º presentation, some of the problems vital to be addressed include having ample seating, good lines of sight and fields of view, being comfortable and ergonomic when viewing is for extended periods (Roussos, 2000). To access any VR presentation, the user is presented the view as captured by the camera. When the camera is positioned in a regular, human-like place, the immersion makes sense to the body’s senses and the viewing practice has an accepted sensation, disassociations such as physical balance are not affected. However, when the camera observations are not human-like, this can create coordination complications (Hodgkinson, 2016). In VR, successful presence occurs when the viewer is viscerally conveyed to another world – the immersion is with the full "world" (Hodgkinson, 2016). VR is typically experienced through the Internet, goggles, or room-sized simulation. Artificial intelligence systems and position-tracking software are often used (Hilty **et al**., 2006).

RECORDING WITH THE 360*FLY®* CAMERA

In considering the technical aspects of creating and using 360-degree video, the most critical shortfall was the difficulty students experienced in identifying small details (George, 2016). For example the students were aware there were maggots on the lab coat but when viewing the video could only see a black dot. The 360-degree video provided clear benefits to the students by being able to immersive experience the crime scene. The 360*fly®* camera records high definition video, but this is a misleading description as once the video is stretched and wrapped around 360 degrees, the actual resolution is much lower, approximate quality 360p (George, 2016). To have a real HD 360^{o} video, the native resolution of the video must be 4k, preferably 8k. Nevertheless, another drawback of the 360*fly®* camera is the 120° blind spot in the perspective perpendicularly under the camera (nadir), which limits the vertical height location of the camera to evade a large blind spot. However, YouTube and most VR viewers currently only support 4k, or less, 360-degree videos (George, 2016).

Qualities of the Head Mounted Displays for viewing

A major feedback response from the questionnaire was that the quality of the image coming through the goggles could have been better. Previous studies have shown that using the low-cost HMD which have optical limitations, the quality of the image observed through the goggles was not of clear quality; this is due to the fact that there is only one image source, to improve the image the creation of stereo pairs must be performed manually. The users also paid attention to a phenomenon of hazy lenses in Gear VR – it frequently happens spontaneously if the goggles are removed and put back on (Buńa et al., 2015). They do not have an integrated solution for tracking user's head in space similarly to the professional HMDs), but they allow tracking of orientation by built-in accelerometers. There is no complex optics – just single lenses, which introduces certain image deformations, which need to be compensated using software means. There are already studies being carried out that improve these issues.

Buńa et al., 2015 describes a study that is already using additional programming work to improve the quality of the vision through the gear VR goggles. These included adjustment of display resolutions, menu for the users, and adjustment of the devices' orientation sensors for communication with the application and allowing some movement-based interaction. These adjustments included Stereoscopic image generation and orientation tracking. However, for this study the Gear VR solution seemed to be an optimal product to use, with the device mass lower than the professional HMD, resolution and FOV acceptably high with additional advantage of wireless communication with the base PC, it deemed suitable for a pioneer study (Buńa et al., 2015).

The Samsung Gear VR is a newer solution, being a result of cooperation between Samsung and Oculus VR companies. Its display device is an Android smartphone Samsung Galaxy S7, which is also used as a processing center and image source in typical scenarios of operation. The Gear VR device is intended to keep the smartphone on user's head and display the image properly through integrated lenses (Buńa et al., 2015). The device is considerably light. It does not have interchangeable lenses, but it has a simple possibility of image sharpness adjustment (by a rotary knob), which can partially compensate for potential sight impairment of its user. It also has integrated orientation sensors with better parameters than the accelerometer built in the smartphone. By default, the device only allows to determine the distance to the nearest obstacle by the user through use of the camera, with no extra possibilities (Buńa et al., 2015).

Choosing where to complete the downloading and uploading of the videos

The uploading to YouTube took a substantial amount of time and this was very dependent on the internet strength available at the download venue – the internet speed at place of residence was download Mbps of 3.87 and upload of Mbps 0.39 which was very slow compared to that available within the university grounds. Therefore it is essential to ensure when creating this type of educational technique that good internet speed is available to support the large size of the *fly®* camera videos created.

In addition, to the positive feedback received from this study other controlled studies have shown that virtual reality training is valid and reliable and in some cases superior to traditional methods of learning (Kelty **et al.**, 2012).

CONCLUSION

Training of a CSE to a high and confident standard is imperative not just to ensure the correct verdict is found in court but also in ensuring that all evidence is found and then actually allowed to be presented in court without any chance of it being jeopardized by poor standards. When a good CSE arrive at a scene they appear to instill confidence in the other investigators. Poor CSEs gain a reputation as being unreliable and unable to be depended on. With poor CSEs in attendance, investigators overwhelmingly believe they have no confidence that the scene will be processed well and feel they cannot leave the CSEs "unmanaged." This can lead to tensions and conflicts that create difficulties for crime scene management.

In many parts of the world crime scene work still remains outside the scope of formal quality assurance, accreditation schemes, or other forms of regulation. However, even if procedures are properly documented, properly followed, and techniques properly applied, does this assure high-quality and highly effective outcomes at the crime scene? Accreditation should assure that broadly speaking the 'right things' are done and to a good technical standard

Given the importance of forensic simulation for training and recertification, this video represents an important step forward in student being able to feel they are on scene and see and hear all instructions fully without the dangers of contaminating a scene or fighting for space amongst a class of other students. Innovations, like changing how a lesson is presented to a student, requires careful assessment of how they fit within the current programming with regard to pros and cons of implementation. With the advances in technology, this tool could have an active teaching role in the education of the near future.

We have developed a real time augmented, virtual reality for Forensic education. The Gear VR platform creates a virtual reality environment using stereoscopic, dynamic 360^{o} rendering, following scene walkthrough, evidence collection through to handing over the scene. To assess the interest level to students and realism of the virtual/augmented reality platform, we designed a video that is sectional and designated to each section of the particular mock crime scene for students to follow the correct procedure of these parts of an investigation correctly. The video accurately reproduces the part-task experience of investigating a crime scene. Feedback from students correlates with the belief that this type of lesson will be well suited as an addition to the current educational types available to Forensic students in the future.

Additional research would be beneficial in the areas pertaining to the view wear of the presentation to ensure a clearer view be available.

DECLARATION

This research has been approved by the Murdoch Ethic Committee number 2017/031. This research was also carried out without any known conflict with any other study.

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