THE USE OF VIRTUAL REALITY IN EDUCATION AND LEARNING: A CASE STUDY FOR TEACHING CRIME SCENE INVESTIGATION

Andrew Cardwell[1], John Murray[1], Ruth Croxton[2], Beth Nurse[2]

School of Computer Science[1], School of Chemistry[2]
University of Lincoln, UK
LN6 7TS

Abstract

This paper presents a novel way of using Virtual Reality technology in teaching Crime Scene Investigation techniques to students studying Forensic Science at the University of Lincoln. As part of interdisciplinary collaboration, this paper looks at how technologies and skills from one discipline can be used to support students and teaching in another. The system presented in this paper seeks to utilise VR technology for teaching CSI. This paper presents the developmental methodology of the VR:CSI application along with results and analysis from Forensic Science students on the applicability of the system. Indeed, the results show us that Virtual Reality could become an effective mechanism for delivering interactive teaching and educational experiences to students, overcoming resource allocation and access issues that could be found with more traditional practices.

Keywords: Virtual Reality, Education, Crime Scene Investigation, VR, CSI.

1 INTRODUCTION

The University of Lincoln's School of Chemistry delivers a Forensic Science module in Crime Scene Investigation (CSI). This is delivered via lectures and lab sessions, which lead into practical assessments carried out in a dedicated Crime Scene House located 5km from the main university campus, where mock crime scenes are created for the students. This facility is used to both train and assess the students in CSI techniques, to ensure effective learning has been carried out. Due to student numbers on the module and limited availability of the Crime Scene House, coupled with its location, this can pose a problem in terms of pedagogical support and learning for the students.

In order for a student to use the facilities at the crime scene house, they first need to ensure the house is available for when they require access. Due to the size of the house, it is only available for a small number of students at any one time. Students then need to arrange travel to be able to physically get to the crime scene house for access. This in itself is not the main problem, and indeed is something that is faces by many students every day, having to find access to facilities and travelling to university. However, for students to gain maximum benefit for learning and training of CSI techniques, it is important that the crime scene being used is ‘novel’ to the student and as such needs to be set up previously by someone other than the students. This incurs a large cost in terms of resource allocation, and restricts the number of scenarios that can be played out at any one time at the house.

These limitations can result in students not receiving as much practice time as the programme team, students and lecturers might prefer. Additionally, the set-up is limited, not only by the time available for set-up but also by the *types* of crimes that can be re-created in such an environment. For example, blood stains on walls and upholstery would incur a cost both financial and in time for ‘clean up’; windows and doors cannot just be smashed or damaged at random; the types of furniture and equipment in the house would be costly to continually change; most importantly and the largest problematic factor is the physical design of the building and room, these cannot be altered at all for any scenarios and as such clearly provides limitations to what can be performed and achieved in the available Crime Scene House. To address these limitations and provide a flexible and dynamic solution we propose the use of a Virtual Reality (VR) Crime Scene Investigation simulator.

Virtual Reality (VR) with its photo realistic and immersive qualities can provide students with an environment where skills can be honed and developed without these real-world restrictions, consequences or limitations. VR can be an ideal technology to be used in teaching subjects that have inherent difficulties being delivered in a static classroom based environment. In the case study presented in this paper, we use the HTC Vive [1] system; this technology allows users’ movements to be tracked, accurately and responsively; allowing the recreation of practical activities in a virtual environment without the constrains imposed by physical constructs. The system presented in this paper demonstrates how requirements and workload for lecturers can be greatly reduced as configuration of the crime scene can be achieved via software rather than setting up physical space. This allows for a much richer and dynamic environment to be created, that can be auto generated by a computer algorithm.

This paper presents a system designed to teach students Crime Scene Investigation techniques and processes using this Virtual Reality technology. The goal is to provide a platform that gives students the ability to engage in practical CSI learning, in a rich and stimulating environment, like what would be experienced in practical workshops and traditional lessons.

2 LITERATURE REVIEW

As VR becomes more readily available with lower costs, the potential use of VR in other areas of practical teaching such as surgical education has now become feasible. There are many areas where the use of VR could be beneficial. These areas are often expensive or dangerous to teach in a traditional manner. For example, firefighting is incredibly difficult to replicate in a safe environment and has associated risks. Flaim Trainer is a VR system which can be used to train firefighters. It includes a fireman's jacket and real hose which can "accurately represent heat, jet reaction and step-up forces, along with sound and visuals, to immerse a trainee in a real house, car, boat or aircraft fire" [2]. Flaim Trainer aims to provide firefighting trainees with realistic training scenarios in a safe synthetic environment, improving preparation before live fire training is undertaken in a similar way to this project being aimed at preparing students for the real crime scene house assessment. Flaim Trainer is very flexible and can be setup to take place in a number of different scenarios which could not be done in real life, showing the great value VR can bring to a project such as this.

Social Virtual Worlds such as second life [3] are increasingly being used in education as tools to deliver interactive educational material, roughly three quarters of UK universities were estimated to be actively developing or using Second Life in 2008 [4]. A virtual world is a computer-based, simulated multi-media environment, usually running over the internet, and designed so that users can '*inhabit'* and interact via their own avatars [5]. Second life has many education projects that are used in educational institutes, for example Texas A&M University and Florida Institute of Technology are explored how Second Life can facilitate and enhance the learning process through teaching chemistry, both through traditional lab sessions and virtual labs where users in Second Life complete the same tasks. "*The students using the replicated lab in Second Life had better retention of information than the students only using the physical lab*" [6-7].

They found that students using Second Life required significantly less time to complete experiments and that it could pose as a legitimate alternative to traditional methods. Second Life hosts a dedicated education page [8] which contains resources for educators to use along with a wide list of all the educational projects available such as cardiac auscultation training that allows visitors to test their skills at identifying the sounds of different types of heart murmurs, based on sound files from McGill University's Virtual Stethoscope project. This demonstrates the important impact that technology-led learning can having on student education and development, showing a clear need to develop technology enhanced learning where possible.

Merchant et al [9] investigated the effectiveness of VR based learning on students in higher education. It suggests "games show higher learning gains than simulations and virtual worlds" [9]. These findings are interesting and link to the concepts of Flow and Immersion which are typically present in video games, showing the importance of these factors for a VR system and how it can affect learning outcomes. They also found that with serious simulations not games "*if students were repeatedly measured it deteriorates their learning outcome gains*" [9]. This would suggest having dynamically changing scenarios where students can develop skills rather than a set course of objectives to complete as this would become boring.

Csikszentmihalyi [10] investigated positive gameplay experiences and how to quantify them. In particular, they look at the idea of "Flow". Flow is described as the process of optimal experience, "*the state in which individuals are so involved in an activity that nothing else seems to matter*" [10]. Flow is comprised of eight components: clear goals; high degree of concentration; a loss of the feeling of self-consciousness (sense of serenity); distorted sense of time; direct and immediate feedback; balance between ability level and challenge; sense of personal control; intrinsically rewarding. Flow also requires three conditions that must be met to achieve a state of Flow: one must be involved in an activity with a clear set of goals and progress; the task must have clear and immediate feedback; one must have a good balance between the perceived challenge and their own perceived skills to complete the task. The balance between skill and challenge is what creates the state of flow. Figure 1 visualises the balance that must be achieved to reach the state of Flow.

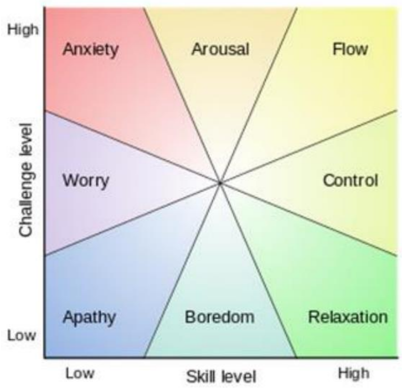

Figure 1. States of Flow based on Csikszentmihalyi, 1997.

Flow can be applied to education, Csikszentmihalyi states that enabling the mind to concentrate on a set of challenging assignments that stretch one's skills leads to Flow. Csikszentmihalyi found that the principles of the Montessori Method of education [11] is suited for continuous flow opportunities for students. The Montessori Method of education is based on the principles that "*children and developing adults engage in psychological self-construction by means of interaction with their environments*" [11]. Montessori's method calls for free activity within a "*prepared environment*", meaning an educational environment tailored to meet the needs of the student. The student is free to direct their learning within the environment according to their inner psychological directives. This freedom within the environment sets up opportunities for Flow to occur which leads to optimal development. Csikszentmihalyi states that "*higher education succeeds or fails in terms of motivation, not cognitive transfer of information. It succeeds if it instills in students a willingness to pursue knowledge*" [12]. The Montessori Method could be applied to allow students pursuit of knowledge within a purpose-built environment, increasing opportunities of Flow for optimal learning similar to the Crime Scene House where students direct themselves.

Recent research into Immersive VR found most use was in higher education or adult training, with the main reasons for using VR being limitations such as time, health & safety and ethical problems particularly surrounding military and medical tools [13]. Ott and Freina conducted a literature review and found that "*in education. Immersive VR can offer great advantages for learning: it allows a direct feeling of objects and events that are physically out of our reach, it supports training in a safe environment avoiding potential real dangers and, thanks to the game approach, it increases the learner's involvement and motivation while widening the range of learning styles supported*" [13]. The VR setup can have a big impact on Immersion and Presence. Botella reported more emotional reactions when a high-quality head-mounted display (HMD) was used compared with a medium system. Studies also found that more sophisticated systems create a higher sense of Presence compared to other systems [14]. This shows the importance of the technology quality for creating higher Immersion and sense of Presence.

Presence is a popular research area linked with VR which is under debate and has differing definitions. The most widely accepted definition for Presence defines it as a psychological sense of being in a virtual environment, using factors believed to underlie presence (control, sensory, distraction, realism) [15]. Another definition claims that "when the environment responds to the user's actions in a way which is perceived as lawful, presence is more likely to occur." [16]. The sense of Presence is an important feeling in VR and relates heavily to the users' sense of realism. For example, Witmer and Singer created a questionnaire measuring Presence. They found that the naturalness of the interactions with the virtual environments and how much they mimic real-world experiences affected how much Presence is reported. This indicates that realism is the key for creating a feeling of Presence in VR. Presence can allow for a more immersive and realistic experience, research into exposure theory finds that there is an association between Presence and emotional experience in VR. Presence is found to be a necessary mediator that allows real emotions to be activated [17]. This indicates the importance of Presence in VR for creating a realistic experience. Recent research found that "greater immersion of a VR system increases presence, particularly in emotionally neutral VR scenarios" [18]. This demonstrates the link between Presence and realism and how it can be used to create a sense of Presence in an emotionally neutral scene.

3 METHODOLOGY

3.1 Requirements

To ensure development of the CSI Simulator meets with the requirements and needs of not only the students, but the learning outcomes of the module it was necessary to ensure that a full requirements gathering stage was carried out.

Once the CSI module had been fully explained it was imperative that the limitations and capabilities of VR were discussed, as the CSI module team had limited knowledge of VR. This led to discussion of the types of evidence that would be appropriate in a VR system such as 'fibres' being too small and fiddly for VR and including how complex procedures would be represented in VR. Due to the capabilities of VR the CSI module team were impressed with the range of actions that could be achieved in areas that the Crime Scene House was limited in, such as blood splatter and broken glass.

The learning outcomes for the CSI tool and how this tied in with the CSI module learning outcomes were discussed. It was decided that for the purpose of this prototype the aim should be to recreate the Crime Scene House to be used as a tool for students to practice in preparation for the assignment. The system will be used to re-create basic burglary scenarios that involve all the evidence types that the clients identified as important to the education of students.

Table 1 contains the refined User Stories that were gathered during the requirements stage of the iterative software development lifecycle model. This table was updated during the development of the project and was changed according to the tasks completed to reflect the appropriate priority of each task. These tasks covered all the requirements and features that the clients wanted implemented in the system.

Table 1. User Stories gathered from the CSI module delivery team.

User Story	Priority (1-10)	Risk (1-10)	Resources (Hours)
Teleport system so that users can navigate VR	10	2	2
Interactive house where crime scenes can be mocked up	10	5	60
Ability to interact with objects within the house	10	8	30
Realistic Crime Scene scenarios based on real crimes	8	4	4
The Ability to use camera to take long, mid and close photos	7	6	10
The ability to add Scene Markers to the scene	7	4	5
The ability to add a Scale Ruler to the scene to measure evidence	5	4	5
The Ability to Collect blood sample from any blood within the scene	5	2	2.5
The ability to create Foot wear impressions within the scene	5	4	8
The ability to dust for Finger prints within the scene	5	2	2.5
The ability to Collect objects within the scene as evidence	5	6	2.5
Scenario briefing given to students before entering the scene	4	2	2
The ability to collect tool marks using gel mould	5	7	5

During the requirements gathering stage the CSI practitioner provided user stories of all the crime scene equipment and methods that would be needed. Each of the mechanics that are outlined below should be familiar to students, covering the main evidence types that are appropriate for generic CSI in the scenario. The information gathered included great levels of detail and multiple steps to recovering each type of evidence.

List of all CSI related mechanics:
• Camera
• Scene Markers
• Scale Ruler
• Bloodswab

• Footwear impressions
• Dust for Fingerprints
• Collect object as evidence
• Tool Marks
• Torch

The list of CSI procedures and tools above each contain multiple sets and processes. For example, for collection of blood the first step would be a KM test to confirm it is blood, then wet or dry swabs would be used depending on the scenario and finally the evidence would be bagged and labelled. This is accurate to what the students would be required to do in a real CSI scenario and all the correct methods and procedures are taught to students through lab sessions. This means that the forensic students should know the correct procedure. However, after discussions with the clients about the aim of the project it was decided that the point of the project is not to test participant's knowledge of complex procedures, but rather to practice a full run through of a crime scene looking at things such as: dynamic risk assessment, prioritisation of evidence and correct evidence collection order.

3.2 Development

The CSI VR Simulator was developed in Unity, this is a 3D games engine that has support for the HTC Vive VR system and therefore supported the tools and hardware being used for the study.

The first iteration of the development involved creating the 'crime scene house'. The literature suggests realism is an influencing factor on Immersion which can be linked with the learning effectiveness of a system and tied to Flow. To support this and create a photo-realistic scene, one of the main benefits of Unity for development is the asset store where professional assets can be purchased. Investigation into the asset store found a suitable realistic housing asset package that allowed the creation of realistic housing, see figures 2-3.

The use of this asset greatly improved the aesthetics of the project. However, this asset package was not perfect as the house was required to be interactive for VR. This meant that all the doors, windows, cupboards and drawers had to be animated using Blender, ready to be imported into Unity. Figure 4 shows an example of some of the tools and evidence types that were modelled and textured from scratch for the project including: Fingerprint brush, scene marker, scale ruler, torch, glass shards, footwear impression, bloodswab and a glove.


Figure 2 (left) – Realistic Housing asset package (Not-Lonely, 2015)

Figure 3 (right) – Downstairs lounge area.

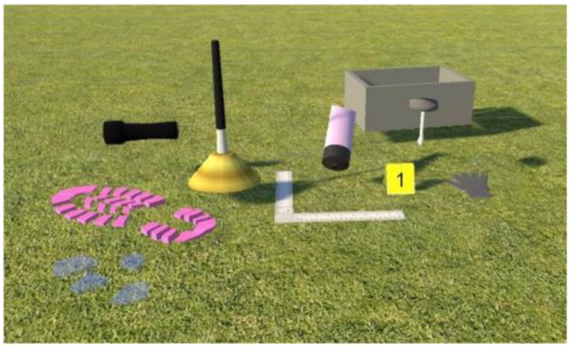

Figure 4 – Tools created for the VR CSI Simulator for evidence gathering.

3.3 Study Design

In the study, the Forensic Science students will be assessed on their CSI skills and techniques that have been delivered in lectures and lab sessions. The students are assessed using a marking scheme which is also used at the Crime Scene House. The first part of the assessment is not in VR and requires students to recite the Personal Protective Equipment (PPE) order. Students are graded out of 6 for this as it forms a major part of their practical assignments on the programme.

The controls and buttons for the VR technology are then explained to the participant to ensure they understand all the controls and how the hardware works using head and hand controller tracking. After everything is explained to the participant and they are ready to proceed, they put on the HTC Vive headset and are given the controllers.

This next stage is particularly important for novice VR users and will require guidance and teaching of CSI techniques if the student has not yet learnt the techniques from lectures or labs. As the student enters the VR environment they will be presented with a practice area or tutorial area that will take them through all the mechanics of the system. This area allows participants to familiarise themselves with the controls and interact with the environment practising the CSI techniques they will use in the real scene. The researcher may want to help guide the students through each area to accompany the text. Once the participant is happy with all the controls and interaction methods they can proceed to the real VR crime scene.

Students entered the house where the crime scene was set up. During this time they are to treat it like a real crime scene and explain all of their justifications throughout. The forensic students who participated were marked on the criteria outlined below to give detailed feedback about where they can improve. Throughout the study if the students are unsure the researcher will help by asking questions and prompting when necessary and getting students to engage in the material finding the balance between challenge and enjoyment.

Marking Criteria for within the VR environment itself

- Verbalised dynamic risk assessment throughout
- Scene walkthrough conducted
- Location Point of Entry
- Photography - long, mid and close
- Evidence markers used
- All evidence located and documented
- All evidence recovered in sequential order
- Maintained accurate and comprehensive verbal records throughout

3.4 Questionnaire

The study has two different groups of participants with different expectations or prior knowledge of the system (experienced Forensic Students / new Forensic Students). It is for this reason that it is appropriate for two different questionnaires to separate the data and ask specific questions appropriate to the type of participant. For space purposes, only the experience Forensic Student questionnaire is presented here.

The purpose of the questionnaire is to investigate the effectiveness of VR in education through the CSI tool that has been created. The questions provided aim to give insight and further understanding into how the project performed and whether the project succeeded in reaching its goal. The questionnaires were designed to be as simple as possible whilst gathering all the desired information so as to not over complicate the results and giving participants clear concise questions as much as possible. The questionnaire is shown in Table 2 below.

Table 2. Experienced Forensic Student Questionnaire

Forensic Student Questionnaire	Question Type
Gender	Multiple Choice
Age	Multiple Choice
Have you used VR before?	Multiple Choice
What mark did you receive after completing the Crime Scene Simulation?	Numerical Value
I found the visual content of the virtual environment to be realistic	Likert Scale 1-5

I felt a sense of immersion within the virtual environment	Likert Scale 1-5
I felt I could reuse techniques that I learnt on the previous tasks in later tasks	Likert Scale 1-5
Have you participated in the Crime Scene House training?	Multiple Choice
I feel the project offered an experience representative of a real crime scene scenario	Likert Scale 1-5
I feel that I have learnt about the application and execution of crime scene investigation techniques	Likert Scale 1-5
I feel this project was beneficial to my learning and practice of crime scene investigation	Likert Scale 1-5
I would use this resource if it was offered to me	Likert Scale 1-5
What did you like about the project and how would you improve the project?	Open

3.5 The Developed System

Below are a series of images that show the evidence markers, and trace evidence within the CSI VR Simulation, these are shown in Figure 5. Figure 6 shows students at the physical Crime Scene House and students using the CSI VR System.

Figure 5 – Several Scenes from the CSI VR Simulator, showing several elements of trace evidence and evidence collection.

4 RESULTS

Over the course of the study a total of 28 participants completed the study, 9 students from the Forensic Science programme and 19 non-Forensic students who also attended the university studying different programmes. All the participants attend higher education and volunteered to participate in the study. The demographics were balanced with 14 male and 14 female participants with similarly split usage of VR experience. This was very positive for the study and helped to represent a wide range of demographics from within higher education, both on Forensic Science and multiple other programmes.

The mean of the results questions was: 15.11 and the standard deviation (STD): 2.64313. The coefficient of variation was also calculated and multiplied by 100 to be represented as a percentage 17.5%. Using this data we can see that only two of the values fall outside of 1 deviation from the mean at the bottom and top end. The results represent a classic bell curve as seen in Figure 7. However, these results are from grades based out of 20, this means that all the participants got over 50% and were in the higher end of the marks. This is as expected as all the participants are enrolled on the Forensic Science programme and had completed for are currently studying the CSI module.

Figure 6 – Students at the physical CSI House (left), Student using the CSI VR Simulator (right)

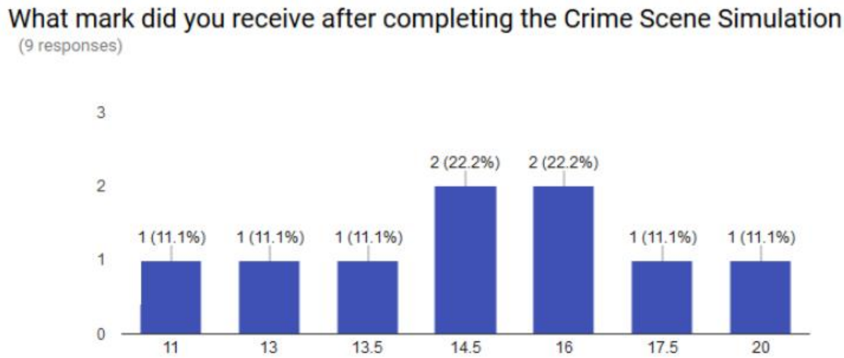

Figure 7 – Results for the grades of all Forensic participants.

The forensic students were asked if they would use the resource if offered to them again, as seen in Figure 8. All the students strongly agreed that they would use the system again. This is highly positive and indicates the students both enjoyed their experience and valued it highly enough to return after using the system for 45 minutes already.

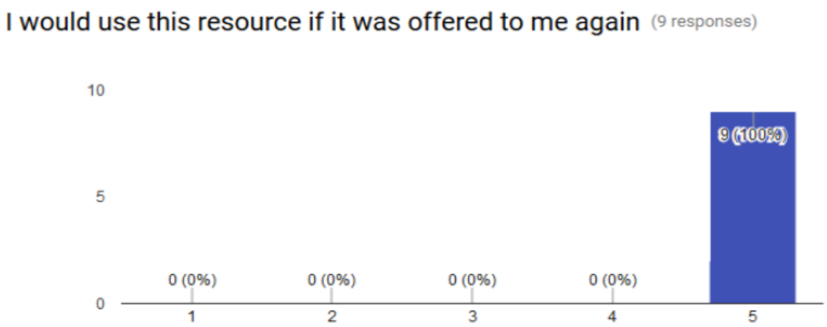

Figure 8 – Response rate to using the system in future.

The next questions were asked to both groups and use a Likert scale to measure the response from Disagree:1 to Agree:5. These questions being analysed can be found in Figure 9. The questions relate to the visual content of the system as well as immersion. The results show that the majority of the participants answered in the agree column for both questions with only 2 neutral responses. This data is as expected in the hypothesis that the visual quality of the application is directly linked and can be used to increase the sense of immersion within a virtual environment. The open feedback section on the questionnaire received 12 responses specifically praising the realism of the project, in particular the house, for example "*Really liked the realism of the house and evidence. Not really anything to improve*".

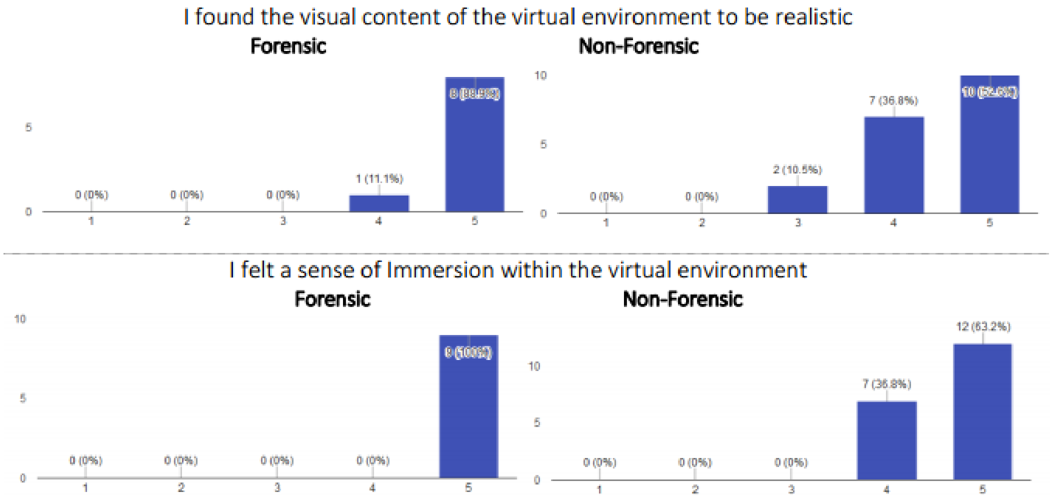

Figure 9 – Results from questions regarding visual content and immersion.

5 CONCLUSIONS

Overall the study proved to be a success, with findings supporting the hypothesis made in the project. Investigation into whether realism and Immersion are linked found that the use of realism can be used to create an Immersive experience. This was found in the literature review and the results reciprocate the findings. However, the Immersion that users felt may not have occurred just from realism. With the feedback from students there was a focus on the realistic assets as well as the factor of using new technology impressing participants perhaps.

Investigation into use of the system with forensic students saw that more experienced users gained an overall higher average mark, however this was a small test size and is not conclusive. The feedback from forensic students also had more positive responses which could be due to more interest in the subject matter and interest in learning the material. Both groups of participants thought that the tool was a useful learning tool that taught them about CSI methods and procedures. This is a great success aligning with other literature that shows VR being used in education successfully. However, the presence of a researcher may have affected this as the researcher can engage with the student and get them critically thinking. If the system was to be used alone it would not be as effective. One interesting unexpected discovery was the enthusiasm and enjoyment that non-forensic participants had for the project. They particularly liked the realism of the project and gameplay aspects so this could be an exciting new way to draw in new students for a higher education programme. It can be used to effectively experience a realistic CSI environment cheaply and safely where an instructor can easily teach and engage students in CSI procedures.

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