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CrashEd – A live immersive, learning experience embedding STEM subjects in a realistic, interactive crime scene

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Interactive experiences are rapidly becoming popular via the surge of 'escape rooms'; part game and part theatre, the 'escape' experience is exploding globally, having gone from zero offered at the outset of 2010 to at least 2800 different experiences available worldwide today. CrashEd is an interactive learning experience that parallels many of the attractions of an escape room – it incorporates a staged, realistic 'crime scene' and invites participants to work together to gather forensic evidence and question a witness in order to solve a crime, all whilst competing against a ticking clock. An animation can enhance reality and engage with cognitive processes to help learning; in CrashEd, it is the last piece of the jigsaw that consolidates the students' incremental acquisition of knowledge to tie together the pieces of evidence, identify a suspect and ultimately solve the crime. This article presents the background to CrashEd and an overview of how a timely placed animation at the end of an educational experience can enhance learning. The lessons learned, from delivering bespoke versions of the experience to different demographic groups, are discussed. The article will consider the successes and challenges raised by the collaborative project, future developments and potential wider implications of the development of CrashEd.

Keywords: animations; avatars; connectivism; higher education

Introduction

Unfortunately, a crime scene might be found anywhere. This includes the home, the workplace and anywhere within our towns, cities or on our transport systems. According to figures issued by the Office for National Statistics (ONS), there were approximately 7.8 million crimes committed against households and adults (aged 16 and over), in the year ending June 2014 (ONS 2015). Whilst this figure, according to the ONS, represented a decrease in crime overall at the time, records for individuals killed or seriously injured on our roads revealed a 4% rise for the same period (Department of Transport 2014).

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Fuelled by media reports of the tragic events caused by the impact of crime and their secondary representation within TV drama and documentary, society now has a largely voyeuristic relationship with crime and its investigation. According to Chermak (1994), Greer (2009) and Hall (1973), amongst others, contemporary media content has seen an expansion from the lexical to a more visual interpretation of criminal behaviours and the investigative procedures employed by enforcement agencies to reduce them. It is therefore perhaps unsurprising that, like the generation before them, young people have a fascination with crime.

As a catalyst for learning, texts, codes and conventions representing the content of popular crime drama, have for a number of years been increasingly employed in studies of English, Drama and Media at GCSE and A Level. There is even a suggestion that as a result of the number of TV programmes such as CSI (Crime Scene Investigation), there is the potential for influencing legal procedures. Whilst the 'CSI effect' is as yet unproven, research does however indicate that there is an association between the levels of audience viewing and increased expectations of evidence types and an appreciation of scientific evidence.

The evidence provided by Maeder and Corbett (2015) amongst others suggests that the interest in crime reflected in the media reinforces the potential for it to be used as a tool for education. This is where the idea of using a 'real' crime scene as a hook to engage young people in science, technology, engineering and maths (STEM) subjects was initially conceived.

In collaboration with police from the East Midlands Serious Collision Investigation Unit (EMSCIU), De Montfort University (DMU) has applied a range of specialist knowledge to create an exciting project that has exposed hundreds of young people to STEM subjects. Raising aspirations in STEM careers is a major priority in UK education, with a focus on young people from disadvantaged backgrounds. To capture the imagination and develop an interest, academic staff from forensic science, maths, physics and criminology developed an interactive learning experience, showcasing STEM subjects in a hands-on car crash scenario.

Another step towards the improvement of student engagement is the provision of clear, immediate feedback. Our crime scene scenario concludes with an animated film that illustrates the cause of the accident – texting while driving, which immediately confirms the students' success or otherwise in solving the crime.

In 2015, the police provided a crashed car, along with film and data of the crash, to enhance the realism. CrashEd has since become part of DMU's popular Open Day programme and has been delivered to hundreds of Year 8–12 pupils as part of the university outreach initiative, both on and off campus. The 'experience', whilst similar in basic concept every time it is delivered, has to be tailored to suit the particular age, background and demographic of each student group involved. There have also been a number of additional variables including duration and order of each sub-activity, number of pieces of evidence to collect and analyse, level of understanding of mathematics required to interpret data and size of group. Many lessons have been learned as a result of delivering CrashEd in subtle but significant variations. This article first presents the background to the development of the collaborative CrashEd project and describes the core crime scene scenario that has been developed so far. The successes and challenges raised by repeatedly adapting the same core experience for a variety of different audiences will be discussed, followed by a summary of lessons learned. The glue that holds the CrashEd experience together is the timely presentation of a tailored animation after pupils/students have analysed evidence and formulated their own theories and attempted to solve the crime. The article therefore secondly explores the use of such animations, in particular as part of an immersive, interactive educational experience.

Development of an interactive educational experience

CrashEd was first delivered by DMU in April 2014 at an event organised by TeenTech, a UK company that engages teenagers with STEM careers. Police officers from EMSCIU consulted on the forensic details, and support from Leicester College Artistic Make-Up and Special Effects students further enhanced the realism of the scene. The university supplied a partly dismantled car that had been used in another project, to enhance the realism of the crash scene. Arriving at the site of the crash, students were asked to apply basic investigation skills, using tools from science, maths and physics to solve a crime. Their challenges included questioning a witness, measuring skid marks to calculate speed and collating additional forensic evidence to identify the cause of the crash. In addition to showing how STEM subjects can be used in exciting, practical applications and in potential future careers, CrashEd also incorporated a public safety message.

CrashEd was delivered to 350 students in Leicestershire schools in 2014. This included 60 Year 8 pupils from black and minority ethnic backgrounds who had been identified as potentially disengaged – 85% of whom said they were interested in attending university in post-event feedback. Feedback from pupils and teachers has been unanimously positive.

In 2015, CrashEd was delivered to over 200 students in schools across the East Midlands and 100 and 66 students in Staffordshire. This included 36 Year 8 gifted and talented mathematics pupils from 15 state schools in Leicester as well as under-represented and potentially disengaged groups such as 'looked after children', travellers and young carers.

The first scenario that was developed as part of the project concept centred around the networks, contacts and resources to hand. The use of a partly dismantled car and contacts with local crash investigators led to the development of a car crash scenario, but has led the way to the proposal and early development of many other scenarios, as described below.

Car crash scenario

The basic premise of the 'live experience' centres about the discovery of skid marks, which appear to be associated with a crashed car and a possible victim of crime. Our victim of the 'crash' appears to be very badly injured and is represented by a realistic manikin. In order to investigate the scene and engage with the exercise, student participants are initially asked to prepare by dressing in forensic overalls, shoe covers and gloves. They are told that they will be presented with a crime scene and it is their task to preserve the scene, gather the evidence and formulate a theory. A number of elements are then introduced to the students.

At the scene, the students have to apply STEM-based skills and knowledge in order to measure the skid marks to calculate the speed of the vehicle prior to the collision. Observation and logic is subsequently applied to additional evidence found at the scene to enable them to piece together a theory about what actually happened and why. This is supported by the analysis of additional forensic evidence that is to be found at the scene.

Students are supported in their investigations by academic specialists who facilitate their collection of important evidence, such as fibres, hairs and pollen from within the car, and who demonstrate new skills that can then be applied to further evidential materials such as a bag of suspected counterfeit money from the car boot. At each stage, students consolidate their learning by completing worksheets. The students also have an opportunity to question a witness. The duration of interview time and amount of information the witness reveals can also be tailored according to the age of the student group. At the end of the exercise, students are debriefed and asked to discuss their findings before being shown an animated account of events leading up to the crash which reveals the cause of the accident – texting while driving.

Development of other crime scene scenarios

The CrashEd team secured internal University Teaching Innovation Project funding to further enhance the resource by purchasing specialist equipment for blood pattern analysis, forensic photography and image analysis, access to forensic databases for identification of counterfeit money and video animation projects. Most recently, the team acquired a realistic manikin that can incorporate special-effects blood, wounds and fingerprints. This will enable the development of further crime scene scenarios, utilizing the University Crime House. Furthermore, EMSCIU and the university are employing 360-degree filming using state-of-the-art equipment to develop online resources, making the resource available permanently, both as an academic resource and for community outreach. This is especially important as since the demise of AimHigher it is essential that sustainable outreach resources are developed.

Using an animation to enhance learning

Interacting as a network

In the car crash scenario described above, an animated film finally shows the cause of the accident – texting while driving. An animation can enhance reality and engage with cognitive processes to help learning, and in our project, this is the last piece of the jigsaw that embeds the students' incremental acquisition of knowledge to tie together the pieces of evidence, identify a suspect and ultimately solve the crime. Ainsworth's six different levels of explanation that can and should be evoked to understand learning with animation (Ainsworth 2008) are explored as part of this article, namely (1) expressive, (2) cognitive, motor and perceptual, (3) affective and motivational, (4) strategic, (5) metacognitive and (6) rhetorical.

It has proven especially effective as a way to enthuse and motivate pupils identified as disengaged from education and demonstrates the importance of connective knowledge requiring an interaction. Downes (2007) posed 'Is the knowledge being produced the product of an interaction between the members, or is it a (mere) aggregation of the members' perspectives?'. We have observed that a different type of knowledge is indeed produced when student learners interact as a network to solve a crime and concurs with one of Siemen's principle of connectivism (Siemens 2005), namely that the 'ability to see connections between fields, ideas, and concepts is a core skill'.

This engagement may also provide these disadvantaged learners with a further benefit if we consider Bourdieu's theory of social reproduction (Bourdieu 1977, 1984, 1986, 2004, 2005; Bourdieu and Passeron 1979; Bourdieu and Wacquant 1992) in that the 'capital' or 'social advantage' obtained by engagement with this process provides them with access to 'science capital' which, according to a research by Archer, Dewitt, and Willis (2014), is currently unevenly spread and affected by lack of equality and opportunity in education (Archer, Dewitt, and Willis 2014; Archer and Francis 2007).

Scenario-based learning

Gordon (2014) identified the need to develop alternative strategies and flexible pedagogies as part of an audit undertaken by the Higher Education Academy in 2014. Technology provides opportunities to enhance learning and to educate as well as entertain. Research by Deslauriers, Schelew, and Wieman (2011) supports the evidence that students will learn more in classes where there are interactive tools as opposed to the more traditional lecture structures. The active 'hands-on' real-life simulation learning processes, which are core to the principles of CrashEd, are based loosely on the concepts of situated learning theory (Lave and Wenger 1991). These state that situated or scenario-based learning (SBL) should take place in the environment in which it would normally be applied. Mariappan, Shih, and Schrader (2004) note the importance of an authentic context; whilst SBL generally reflects the improvement of performance in learning environments such as nursing, engineering or policing, when associated with scenarios such as those developed in CrashEd, it facilitates the engagement and authentic learning of non-practitioners (Evans and Taylor 2005).

Shaffer (2004a, 2004b, 2005) suggests that this type of learning may also be transposed to the virtual world where such simulations aligned to the interests of learners can promote collaborative practice and problem solving. Learners may use 'real tools' to address problems in what Shaffer notes is an epistemic frame within a pedagogical praxis.

The CrashEd simulations provide students with an opportunity to solve a complex problem in a realistic setting thereby encouraging an appreciation of a professional domain comprised of knowledge, skills and values associated with several crime-related professional or practical 'epistemologies'. Whilst Shaffer's work has focused principally on the development of opportunities to virtually develop professional epistemic frames, thus enhancing the skills and understanding of the practitioner, the success of CrashEd suggests that this pedagogical approach may be transferable and, indeed, cross a number of learning boundaries.

Carroll (2000) noted the benefits of the technological enhancement of scenarios to augment the potential for multiple levels of learner reflection and cognitive interaction. This is reinforced by research undertaken by Meyer and Moreno (2002) who found that graphical images produce visual and verbal mental representations which link and integrate prior knowledge in order to construct new knowledge.

'What if?' – Creating virtual scenarios that reinforce the learning experience

Throughout the development and generation of the virtual context for the CrashEd scenarios, one of the co-authors of this article (the developer of the technological component) was mindful of work by Fisher, Higgins, and Loveless (2006), Gee (2004), Plowman and Stephen (2005) and Shaffer (2005) who identified the potential for clusters of 'purposeful activity' when associated with digital technology, particularly if associated with creativity and the development of responses to 'what if?' questions as part of a problem-solving process.

The virtual scenarios thus needed to logically reflect the choice of possible actions that had subsequently resulted in and were at the heart of the crime scene. Responses to the, 'what if?' questions posed as part of the practical student engagement activities thus needed to have a resolution within the 'back story' which would be revealed to the students at the conclusion of the exercise. This information was manufactured and created as a film that not only provided the context to the incident under investigation but, in revealing the answers to the questions posed in the student crime scene investigation, reinforced the learning experience.

Development of the animation

The film, based on the back story, needed to reflect the possible motivation and other actions of the offender or offenders/victims in the planning and commission of the crime but, more importantly, to challenge the perceptions of those involved in the exercise as to who typically might or might not be capable of committing crime. As a result, the context revealed that those individuals who might stereotypically be perceived as offenders might not be responsible for the crime under investigation (Figure 1).

In addition to the development of a storyboard, which would logically plot the course of the crime, the actions and activities of the offenders were 'captured' by designing and developing a realistic community landscape in iClone software (Figure 2).

The avatar or virtual actor who represented the main protagonist in the film was designed to be physically similar in appearance to a member of the CrashEd team (Figure 3). By looking like a real actor in the simulation, associations could thus be made directly by students between the real actor (a lecturer in criminology who

Figure 1. Challenging stereotype perceptions of offenders.

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Figure 2. Design and development of a realistic community landscape in iClone software.

played the role of an unlikely offender), with the avatar whom they would later see on screen.

The car, which was the hub of the forensic and mathematical investigation in the exercise, and a collie dog, which provided some of the forensic evidence in the case, were also virtually recreated and reflected on screen in the consolidation movie and in reality, with both the real damaged motor vehicle and a physical representation of the dog (Figure 4).

It would have been impractical to use a real dog for the 'hands-on' element of the simulation because of health and safety issues, and so a realistic cuddly toy was purchased as the key forensic link between the offender and the crime scene. Even the police specialist who supported the exercise was represented as an avatar on screen.

In addition to the creation of the avatar movement and activity, 'live action' video film of the car crashing and other activities, which might have led the offenders towards the eventual crime scene, was edited and blended with the avatar-based materials (Figure 5).

The voices of the characters talking and planning the offence and subsequently arguing as the crime later began to go sour, and were scripted, developed and recorded in Audacity (Version 2.1.1 free online) software. This not only enabled changes to be made to the sound levels but also alterations to be made to the pitch and tone of the voice recording which could then be used to create both a male and female voice reflecting the gender of the films' two main actors.

The film was cut and edited in Movie Maker (a free Microsoft product), before the vocal element was re-introduced to ensure clarity of sound and enable the

Figure 3. The design and development of avatars (or virtual actors).

Figure 4. Virtual recreation of a real damaged motor vehicle and a physical representation of the dog.

introduction of background noises, such as a dog barking or glass breaking. Finally, a subtle musical soundtrack was threaded through the film to highlight events and tensions associated with actions on screen.

Discussion

Benefits

Research by Becker and Park (2011) revealed that there is evidence that integrative approaches to teaching STEM subjects had a positive effect on students learning experiences. Their research noted that, in particular, the effect was most profound at the elementary school stage. Integrated STEM approaches, defined by Sanders (2009) as 'those which explore teaching and learning between/amongst any two or more of the STEM subject areas, and/or between a STEM subject and one or more other school subjects', are additionally acknowledged by Sanders and others as being intrinsically linked to social sciences and humanities subjects which suggests that both academic and collective benefits are possible if the learning experience is appropriately managed before 'students make their exit from the 'STEM pipeline' (Sanders 2009).

As formerly highlighted, there are numerous nodes and connections within the project, each one vital for ensuring the project is a live and immersive educational experience for pupils and students alike. It is perhaps easiest to first outline the obvious benefits to those experiencing the car crash scenario. Benefits to pupils/students include the following:

Figure 5. Editing and blending of 'live action' video film with avatar-based materials.

- An interactive learning experience to engage and encourage student exploration
- Fun, interesting, inquisitive, relevant task
- Promotes teamwork
- Shows students how subject disciplines complement each other
- Illustrates how mathematical calculations and scientific principles are applied in 'real' jobs
- Introduces important ethical messages

To the education providers, the time invested has been considerable at times, but with such positive feedback its benefits to the university are noted:

- CrashEd has been recognised as an excellent widening participation/outreach tool and an innovative approach to education, and it has been nominated for an award.
- The project has been used on university open days and is currently used at Faculty open days for the BSc Mathematics and BSc Physics programmes.
- Publicity – CrashEd empowers all members of our scholarly community and illustrates the contribution universities can make to inspire the next generation to future STEM careers.
- Sustainability – Online CrashEd will be a cost-effective outreach tool.

Lastly, the benefits to society include the provision of novel opportunities/experiences to schools that they themselves cannot offer.

Successes, challenges and lessons learned

One of the key successes of the collaboration is the clear engagement of the pupils/students with learning. Altogether, this process supported a more psychological engagement with the process, as described by De Rosis *et al*. (2005), Matsumoto and Tokosumi (2005) and Morrison and Zemke (2005) as avatar empathy. This is apparent from verbal feedback from children, teachers, as well as testaments from the police, TeenTech and other agency organisers:

> This has not only inspired the students but has opened their eyes into a new world of science. This hands-on learning environment has enhanced the learning cycle and empowered the students. This multi-agency approach to learning has opened up a vast learning potential. (PC Tim O'Donnell, Forensic Collision Investigator/Motorcycle Instructor, East Midlands Serious Collision Investigation Unit, Leicestershire Police)

> It makes such a difference when high-quality, well-thought-through activities are run which are not only exciting and fun but also give students real insight into the relevance of work they are doing in the classroom and the possibilities open to them if they develop the right skills. The activity also underlined the way teamwork, attention to detail, tenacity, curiosity, critical thinking and leadership are just as important as pure academic knowledge. The students were buzzing with enthusiasm – essentially they'd spent 30 minutes in a highly creative maths lesson. (Maggie Philbin, CEO, TeenTech)

> One of the most popular experience days available on the 'Yes You Can' programme is the visit to X University, the practical, hands-on activity surrounding the car crash is one that readily appeals to the pupils. The activity brings together science, maths and

> criminology in an exciting package. The pupils discussion of and interest in careers around science and maths has increased, as has their interest in wanting to go to university – over 85 per cent of our pupils expressed a desire to go to university following the visits. (Gregory Smith, Kainé Management)

Whilst the current focus of this exercise has been to engage students with mathematics and the physical sciences, this form of active and virtual engagement additionally provides opportunities for the social sciences (Crisp 2012). A recent, more flexible, version of the scenario, which was tailored to the specific needs of a local college, also provided opportunities to engage with students about the moral dynamics of crime law and criminal justice and connect with elements of psychology and criminology. This blend of physical and virtual engagement thus endeavoured to operate in a similar way to games for change (Games for Change).

Challenges have been varied but centre on the following issues:

- Timing issues: Running events to tight schedules, sometimes having only a few minutes to set the scene for a group of pupils, before they are immersed in the experience and set to task, was perhaps the biggest frustration experienced by the educators. If too little time is assigned, the pupils/students do not get to experience the whole activity and therefore are unable to gather adequate evidence and formulate a theory to solve the crime. The length of time required depends on a number of factors including age, group size, background of students and any other factors that might affect their attention/interest.
- Communication issues: Owing to the large number of stakeholders in the project, there is an obvious need for clear communication between all parties, at all times, to ensure logistically that plans can come into fruition.
- Fit for purpose: This issue expands upon the timing problems of tailoring a scenario to suit a particular group. Without clear communication and timing, in addition to planning, if the scenario is not adapted to suit a particular age or demographic, the experience may not be a success. In particular, the level of mathematics required to complete a task has to be pitched appropriately in order to maintain student engagement with the activity.
- Funding issues: Complications with cross-faculty budgets.
- Staff availability: These events have to be blended with teaching availability and commitments to the ‘day job’.
- Currently, the focus is on STEM subjects alone. Whilst this is currently fit for purpose, recent opportunities for presenting the CrashEd concept in a roadshow format enabled opportunities for the social sciences and highlighted ‘morality tales’ and citizenship issues. This aspect is an important and valuable element of the student engagement.

In summary, the lessons learned from our experiences are vast (Bassford *et al.* 2015a, Bassford *et al.* 2015b) and can be categorised as follows:

- The crime scene is best divided into different activities – small groups can simultaneously gather evidence and then rotate around the scene similar to a ‘circus event’.
- There is an optimum group size for the activity, based upon the number of different activities within a crime scene. Depending on their age, seven students

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appears to be an ideal number to fully engage in a 'hands-on' experience. At a recent event for example, each group comprised approximately 11 students (or 44 in total) and this was not compatible with either the physical size of the scene or the activities involved.

- There is an optimum activity length, based upon predominantly the age of the participant. For disengaged and under-represented groups (travellers, young carers and 'looked after children'), activity length was 15 minutes per activity. It was noted that the group was keen to ask questions rather than to analyse. Pupils from a 'gifted and talented' group however engaged with lengthy and mathematically challenging activities up to 25 minutes in length.
- Pupils/students require very little information prior to commencing the activity. It is sufficient, for a crime scene scenario, to simply inform participants that they are about to enter a crime scene and that they are required to follow activity sheets.
- Clear activity sheets need to be prepared. The level, depth and quantity of mathematics included are crucial for facilitating the participants' gathering of evidence.

The future of CrashEd

In 2015, the academic team acquired university funding to adapt and enhance the scenario to develop a new, level 5, cross-faculty module on forensic investigation aimed at physics, mathematics and forensics undergraduates. More than 50% of current mathematics and physics first-year students have indicated they will choose to study this module. The new module involves the study of key elements of modern forensic investigation, including crime-scene processing, analytical techniques, laboratory skills, the principles of experimental design and the scientific analysis of data. With a focus on the use of mathematics and physics, students will also have the opportunity to gain hands-on experience of simulated crime scenes, learning about the role of the expert witness.

The translation of a single, focused activity lasting between 20 and 30 minutes into a 12-week module involves significant new material development; however, the ethos of the module will continue to focus on our innovative 'hands-on' crime-solving scenarios. This is because, with striking consistency, studies show that innovative, active, collaborative and constructivist instructional approaches shape learning more powerfully, in some forms by substantial margins, than do conventional lecture discussion and text-based approaches (Pascarella and Terenzini 2005).

Lastly, our project has enabled us to gather extensive verbal feedback from staff and students involved in the activities. However, given the typically short length that each student spends on an activity, it has not proven possible to gather significant quantitative data so far. This is notoriously difficult to do with an outreach activity and is a future aspect of our research for the CrashEd team to seize opportunities in future activities that will facilitate the collection of more comprehensive data to evaluate specific aspects of each activity.

Conclusions

CrashEd is an original approach to practical learning, as it provides a practical example of how to stimulate young minds to explore STEM subjects. It demonstrates the contribution universities can make by transferring existing skills and knowledge in an engaging format. Through the collaboration with TeenTech, this good practice is now being made available throughout the country. Our project has enabled us to develop bespoke scenarios, dependent upon pupil age and background, and many lessons have been learnt. CrashEd has proven especially effective as a way to enthuse and motivate pupils identified as disengaged from education, yet also has the scientific and moral depth and scope to engage talented STEM students and undergraduate students alike.

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