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Adopting the use of a legacy digital artefact in formal educational settings: opportunities and challenges

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Abstract

This paper explores how a legacy digital artefact can be adopted within formal education settings and looks at the pedagogical and other opportunities created by its use within primary and secondary classrooms. In particular, through a comparative case study of three schools in the UK, the paper investigates the potential of using a virtual 3D model of the 1938 British Empire Exhibition in formal educational settings and highlights a number of salient issues and challenges that emerged. As the data suggests, engagement with the model created opportunities for playful learning, facilitated motivation and collaboration, and enhanced student interest. However, participation was often compromised by barriers such as the wider pressures of the curriculum, assessment regimes and teacher time as well as technical inhibitors and limitations. In light of the above, the paper considers the range of actors and factors that influenced the experiences of teachers and students who engaged with the use of the 3D model and concludes by considering the implications of these findings.

Keywords: virtual 3D models; virtual 3D environments; schools; digital technologies; research data

Introduction

With digital technologies now forming an important feature of contemporary school activity, a range of tools exist which can be adopted to support teachers and students in their everyday teaching and learning practices. This paper explores how a legacy digital artefact can be adopted within formal education settings and can be used within primary and secondary classrooms. The artefact used in this research study was a virtual 3D model of the 1938 British Empire Exhibition (BEE) and this paper will now go on to discuss the potential and challenges of using such digital tools in formal educational settings.

Clearly, virtual environments (VEs) and 3D models have been used widely across various disciplines and levels of education since the 1990s (Dalgarno & Lee, 2010; Hew & Cheung, 2010; Mikropoulos & Natsis, 2011). For instance, Mikropoulos and Natsis (2011) reported in their review of 53 empirical studies that virtual 3D models and environments adopted across a range of school and higher education settings are predominantly used in the subject areas of science and mathematics as they are concerned with abstract concepts, experimental phenomena as well as spatial perception and orientation. At the same time they have also been used in the field of social sciences in order to 'provide real world case based environments, and enable context and content dependent knowledge construction' (ibid; 776).

The use of virtual 3D environments is seen to have potential learning benefits in both primary and secondary education since it can provide opportunities for rich learner engagement as well as the possibility to explore, manipulate and construct virtual objects (Dalgarno & Lee, 2010). The educational use of such 3D environments can also enhance motivation and student interest (Bouta, Retalis, & Paraskeva, 2012), facilitate creative interactions where students learn through active participation (Dawley & Dede, 2014) while they also allow for user-led innovation and co-production (Hunsinger & Krotoski, 2012). As such, experimenting and learning through 3D models can teach young people how to critique, improve and refine what they make resulting in the creation and sharing (across classrooms, schools, and communities) of highly personalised digital artefacts (Dawley & Dede, 2014).

To this end there are several examples in the literature that highlight the pedagogical potential of such technologies across a range of curriculum subject areas. For instance, the use of a 3D virtual environment that replicated the situations of a real life ecosystem was reported to be a valuable tool for environmental education at primary level as it provided students a significant cognitive advancement compared to that of a typical environmental class (Barbalios, Ioannidou, Tzionas, & Paraskeuopoulos, 2013). Within the context of foreign language learning 3D multi-user virtual worlds were seen to provide ‘a shared, realistic, and immersive space’ where students had the opportunity to explore and modify the world as well as interact with others and this appeared to increase their motivation for language learning (Ibanez et al., 2011, p. 2). Similarly, another study reported that a purpose-built 3D virtual environment used to teach Mathematics in Primary Education actively engaged the students’ interest and led to richer student interaction (Bouta et al., 2012). Other examples include designing a 3D environment that allowed senior high school earth science students to take a virtual field trip (Lin, Tutwiler, & Chang, 2011), using a multi-user virtual environment as a pedagogical vehicle in a middle school to solve problems around disease in a virtual town (Ketelhut, Nelson, Clarke, & Dede, 2010), stimulating motivation and creativity and facilitating imaginative writing at primary school level with the use of a virtual learning environment (Patera, Draper, & Naef, 2008).

Virtual 3D models and environments can take a range of shapes and forms and have attracted the attention of educators and developers alike. On one hand, ‘co-opting’ (Buchanan, 2013) the games and tools that students already use appears to be a particularly appealing prospect that has led to the adoption and re-purposing of commercial 3D games such as Minecraft (Hanghøj & Hautopp, 2016). On the other hand, the enthusiasm regarding the potential of virtual 3D models to support teaching and learning has led to the development of new virtual 3D tools designed to address particular educational needs (Dalgarno & Lee, 2010).

However, not all 3D models and environments are either co-opted from commercial off the shelf (COTS) games or developed specifically for a classroom purpose.

There are also virtual 3D models that have emerged as outcomes from Arts and Humanities research projects with the aim of visualizing historical buildings and sites and offering a richer, more nuanced understanding of a particular period. These can be defined as 'legacy digital artefacts' and can offer a great deal of potential for adaptation into formal educational contexts. For example, the value of 'enmeshed experiences' that bring together research and pedagogy are discussed in detail in Cobb and Croucher (2014). They assert that pedagogy 'emerges through its interaction with the assemblages of research and professional practice', particularly relevant to material culture (ibid. p.201).

As learning via virtual 3D models is gaining momentum and there is increasing enthusiasm regarding the educational potential of such tools, there is also an array of challenges and barriers that need to be considered. As discussed later in this paper, some of these relate to the availability and the cost of having robust hardware and internet connectivity, the pedagogical skills needed for creating relevant and meaningful tasks in virtual worlds and the time to plan and design these tasks (González, Santos, Vargas, Martín-Gutiérrez, & Orihuela, 2013; Kluge & Riley, 2008). Usability problems relating to user interface acquaintance and navigational effort have also been reported (Virvou & Katsionis, 2008).

Other issues frequently highlighted in the literature relate to virtual navigation and users, especially non expert ones 'getting lost' or having difficulties when looking for specific locations (Barbalios et al., 2013; Chittaro & Ranon, 2007; Ibanez et al., 2011). Furthermore, Merchant (2010, p. 147) reported how a 3D virtual world that was designed to support primary school literacy was not easily accommodated into classroom life as 'the use of space, disciplinary time and the regulation of activity institutionalised conventional approaches to literacy learning and teaching'.

The challenges and barriers above all remain relevant when considering legacy digital artefacts. For instance, Lackovic et al. (2015) reported that teachers' practices when using 2D and 3D heritage site visualisations depended on their confidence with both subject-specific and cross-curricular themes as well as their willingness to get outside the curricular comfort zone. There are also additional challenges to be considered for these types of digital artefacts and although they are typically publicly accessible online upon completion of the project, there is often little further public engagement and they are rarely used for educational purposes. As Jeffrey (2015, p. 145) argues 'expert forms of knowledge and/or professional priorities invariably inform digital visualisations, consequently, the resulting digital objects [can] fail to engage broader communities as a means of researching and representing the heritage'.

Furthermore, data originally produced for research purposes can exacerbate the existing issues surrounding teachers' confidence with the subject and complicate the many roles required of teachers when integrating digital learning tools in their classrooms (cf. Marklund & Taylor, 2015). The lack of existing standards and guidelines for teachers embracing the use of digital 3D environments is also noted as a factor which increases the laborious process of acquainting themselves and their students with such resources (ibid.). Therefore, while legacy 3D models hold great potential for creating the 'pedagogic assemblages' described by Cobb and Croucher (2014) and enabling engaging and meaningful learning within schools, these challenges cannot be ignored.

Despite the volume of research studies that explore the affordances of both off-the-shelf and educational 3D models, very few – if any– have looked at the potential of these legacy digital artefacts to be re-appropriated into educational settings. Little has changed since Lackovic and colleagues identified this issue in 2015 (2015). As such, this research study aims to address this gap by exploring the potential as well as the challenges of adopting legacy 3D models within formal educational settings. In particular the paper explores the following research questions:

- What are the pedagogical and other opportunities created when adopting the use of a legacy digital artefact within formal educational settings?
- What are the drivers and barriers for its successful use?

Context of the study

The study used a virtual 3D model of the British Empire Exhibition[1], an architectural six-month exhibition that took place at Bellahouston Park in Glasgow in 1938 [see Figure 1]. The original exhibition saw 13 million people visit its 104 principal buildings and statues, fountains and gardens, all but one of which were temporary. The exhibition included national industrial and cultural pavilions, for example many countries such as Canada and Ireland had national pavilions, but so also did industries such as the Coal industry and even specific companies such as ICI, the chemical industry giant. There was also a series of exhibition areas dedicated to broader themes such as gardening, highland village live and even abstract concepts such as 'Peace'. This 3D data was produced as part of a research project by The Glasgow School of Art in 2004-6. The dataset consisted of 3D models of over 100 buildings and structures, alongside the paths and water features, which comprised the Exhibition, placed in their correct relative positions within the topography of Bellahouston Park. The 3D data was accompanied by a rich digital collection of 2D and audiovisual data related to the Exhibition, such as source data for the 3D models, visitor photos, and contemporary reflections in the form of video interviews with people who attended the exhibition.

[1] http://empireexhibition.com/

As such, this legacy 3D model is rich in research data related to a material and cultural experience that no longer exists and appears to have strong potential for adaptation and re-use in educational contexts although this was not its original purpose. It was the diversity of the themes around the BEE project; national, architectural, industrial and social, as well as the ready availability of contextual and supplementary material (i.e. the large body of digitised archive material) in addition to the 3D model of the BEE site, that suggested it as an ideal candidate for teaching and learning.

With this in mind, a research project was developed entitled Research Engagement through Virtual Immersive Tools for Learning (REVISIT) which explored the potential of using this dataset for school-age teaching and learning.[2] For the purposes of this research study, the 3D model was delivered through VSim, free prototype software designed for educational interaction with 3D models (VSim, 2017)[3]. VSim allowed users to navigate using the 'wasd' control keys and freely explore the scene, similar to a first-person game. An avatar was not used but the graphical perspective was rendered from the viewpoint of the single player. No interaction was encoded into the 3D model; therefore, users could freely explore but not affect the 3D scene. Additionally, the resource only included the external features of the buildings. It was not possible for the students to go inside or if they did there was not detail, just an empty shell. At first, the virtual 3D model was presented to interested teachers in three schools and a two-hour training workshop was delivered by the research team. The VSim software and 3D

[2] http://blog.gsofasimvis.com/index.php/research/heritage/revisit/

[3] VSim was prototype software at the time the project was carried out developed at UCLA and funded by the National Endowment for the Humanities. V2 in now freely available from https://idre.ucla.edu/research/active-research/vsim.

scene was installed on the school's computers and the teachers were asked to organise teaching and learning activities of their choice drawing on the virtual 3D model and the digital archive and also support their students' with creating their own tours of the BEE collaboratively in small groups. Then the teachers and students engaged in the various teaching and learning activities and created in groups their own tour of the BEE. Selected tours created by the students as well as a range of other digital material and resources can be found on the project's website[4].

Figure 1 - A screenshot of the BEE virtual 3D model, as viewed through VSim

Research methodology

A multiple case-study approach (Yin, 2008) was adopted to address the research questions. This allowed the researchers to gain insight into the participants' experiences, practices and beliefs with respect to the use of the BEE virtual 3D model in the classroom. Qualitative data were collected from one primary and two secondary schools in the UK between February and December 2016. A more detailed description of the research cases can be found in Table 1. Data collection involved conducting class observations, semi-structured interviews with teachers and head teachers, and focus-group interviews with students. The interviews, which lasted between 30 to 60 minutes each and totalled around 15 hours, were audio recorded and then transcribed verbatim. For the purposes of this paper, a pseudonym was assigned to all schools and individual participants so as to guard their anonymity.

[4] http://blog.gsofasimvis.com/index.php/research/heritage/revisit/outputs/

Table 1. Summary of schools and participants.

For the analysis of the qualitative data collected for this study thematic content analysis was employed, described by Cohen, Manion and Morrison (2017, p. 674) as 'a strict and systematic set of procedures for the rigorous analysis, examination, replication, inference and verification of the contents of written data'. Analysis of the data required various layers of interpretation and coding. This involved initial readings of the interview transcripts and class observation field notes to familiarise oneself with the data. An open coding approach (Corbin & Strauss, 1990) was adopted in order to generate initial codes and themes. These themes were compared across the different research settings in order to identify recurring thematic patterns. These were then reviewed before the emerging themes were finalized.

Results

Implementation and use of the virtual 3D model

The schools were given the flexibility to use the virtual 3D model and the digital archive in any way that suited their circumstances without having to comply to particular guidelines or timescales imposed by the research team other than completing the project before the end of the research study. This resulted in three distinct case studies that were shaped and driven by the different attributes of the schools as well as the particular qualities and needs of the teachers and students that took part.

Within Young's Primary students worked on project-related activities over a two-month period. The teacher, Daniel, did not plan stand-alone lessons but allowed the theme of the 1938 BEE to run through different curriculum subject areas. This approach was often seen as adding a 'wow' factor to the everyday routine of the curriculum as well as 'a hook into a topic' since the students 'recognised the controls, they recognised the navigation and they were able to jump on board and be enthused about it' (Daniel, YP Y6 teacher).

In particular, the topic of the 1938 BEE was adopted to inform a range of learning activities such creating fact sheets for various countries who had pavilions at the exhibition; doing Algebra problems and looking at population scaling and rounding; producing 3D models of exhibition buildings; and exploring the virtual 3D model of the BEE and creating their own tours in groups. This 'theme' approach was considered to be extremely successful by both the class teacher and the Head:

> Because you can weave all the topics together it's so much easier [...] It's been the longest running theme I've known since I've been at this school and I think easily the most successful thing and it's down to preparation. (Daniel, Y6 teacher)

In the case of the Hall's Secondary the 1938 BEE was the focus of a 3-day cross-curricular creativity challenge designed for Year 9 students (n=106). Working in teams, students created various resources such as audio and video files, PowerPoint presentations and pictures of artefacts. These were then added to each team's virtual tour of the 3D model, which focused on particular buildings and themes. Seven teachers of History, Science, Maths, Music, Arts, Design and Technology, and ICT led the taught sessions and supported students with creating the resources. Working in groups of about 7-8 students within a limited amount of time resulted in delegating tasks to different members depending on their skills and experience. As such, only a few students from each group engaged with the 3D model and created a tour within VSim.

In the case of the Barrow Secondary the 3D model of the BEE was presented to S4 students (aged 14-15) during a lunch-time session and they were then invited to take part in an extracurricular club co-ordinated by a History and a Geography teacher. Seven female students signed up for the club and took part in the research study. Due to the Local Authority guidelines and restrictions it was not possible to install the software on the school's computer. As one teacher explained:

> We can't put software on the computer [....] In order to get the software put in the computer it would take us a long time to get it because it would have to put on across the whole city. We did ask for that but we were kind of put off. We don't have independence of that kind. (Malcolm, BS Head of Humanities).

In order to overcome this barrier a research project laptop was handed out to the teachers so that students could explore the virtual 3D model during lunch time and plan their tours which were then created at the The Glasgow School of Art's computer lab during pre-arranged visits. The approach taken at this school resulted in learners who had self-selected their participation in the study and were participating outside of a classroom context. As such, students were generally more interested in the technology, 3D model, and wider context for its own sake and less concerned about how it fitted in to their curricula. Their teachers noted the places where the BEE had direct ties to learning objectives, particularly in History and Geography (while also noting that in some cases the links felt slightly 'artificial') but emphasised the value of the 3D model as an experiential surrogate for a real, inaccessible event:

> I think it was the idea that there were images that they could link to a model of an actual event, I think that was quite interesting to them. (Malcolm, BS Head of Humanities)

Across the three schools the majority of the participants had no prior experience of using virtual 3D models within formal educational settings. Only a few students from Barrow Secondary had done 3D modelling the year before while a few of the Hall's Secondary students had used in the past 3D modelling and visualisation programmes such as SketchUp and SolidWorks. Outside a school context a large number of interviewees mentioned that they had explored 3D games such as Minecraft. The majority of participants from Young’s Primary and Hall’s Secondary were familiar with the ‘wasd’ control keys from playing games and they reported that they found the software easy to navigate once their teacher showed them 'the steps to get on it' (John, 11,YP). Then they ‘all worked in groups and got to explore it from there' (Liam, 10, YP) and ‘started messing around’ and ‘found out different things about it’ (Mustafa 11, YP).

Students demonstrated mixed views regarding the graphics. Some of them found them satisfactory and they reported that the model ‘looked good for its age’ (Yasin, 14, HS), whereas others felt that ‘it didn't seem that realistic, it was all very blocky’ (Peter, 13, HS). However, they agreed that it became difficult when the model was ‘jumpy’ or ‘laggy’ and became frustrated when the software crashed.

> It looked good but it kept lagging lots and sending you back to the position you'd been to a couple of minutes ago when you were moving around (Steve, 14, HS).

Technical problems were not uncommon due to the large size of the 3D scene and the computational demands running the software placed on the hardware within the school computer labs. In fact, these issues allowed a number of students to demonstrate a high level of maturity and understanding of technical limitations when interacting with 3D models. As put by Lennie, 11: ‘Sometime when I said it wasn't going smooth it might have been from the computers anyway not the program.’ Students also described how they would often get lost when exploring the model and they did not find the paper map particularly useful, as it was hard to read. Overall, students exhibited a positive reaction to the 3D virtual model, commenting on its realistic appearance, its ease of use and simple controls.

Opportunities for playful exploration and engagement

The majority of students that took part in the research study welcomed the break from their everyday teaching and learning routines and considered it as an often refreshing alternative to 'ordinary' lessons:

> They love the fact that they get to do a different activity, they are not sat in front of an interactive whiteboard, in front of a textbook and they are not being bored silly in a standard lesson. They like the freedom and it builds their maturity and it builds their teamwork which is fantastic. (Andrew, HS ICT teacher)

The game-like aspect of the 3D model appeared to appeal greatly to the majority of the participants. For instance, the younger students at Young's Primary were very excited when one of them discovered they could go down a slide in a small playground within the model as well as climb on the top of the Tait Tower. As one student explained, 'we went on it and then we stopped flying and we fell off the building, we just dropped all the way down' (Sumir 11).

Likewise, older students also commented positively on the gaming nature of the virtual 3D model:

> I liked the software quite a lot because you could see everything and you know […] I also liked when you walk around you can like change like fly mode and just go to the ground and in fast speed and I really enjoyed that. (James, 14, HS)

Furthermore, the opportunity to freely explore the reconstructed layout of the 1938 BEE was perceived as particularly positive by the students:

> I enjoyed the most about like you could just go anywhere, there was not boundaries, you could just explore everywhere, go on the top of the Tait tower, look all around the map and you could just feel, you could just imagine how it would be if you was there and many other people were there. (Owen, 10, YP)

Teachers also commended positively on the combination of familiar control keys and the gaming aspect of the 3D model navigation, e.g. the flying mode resonated well with the pupils' needs and experiences:

> I think the 'wasd' controls are something children use day in day out if they are gaming at home and so that brought that little bit reality and the fact that you could fly to the top of buildings it just made children feel like they were almost being naughty but in a constructive way. (Daniel, YP Y6 teacher)

Opportunities for learning

In the case of Young's Primary having the time and flexibility to explore the virtual 3D model at their own pace allowed them to engage in both independent as well as peer learning. According to the students in one of the focus groups:

> Olivia (11): I just learned the simple controls at first but then some people told me more about flying, how to go in fast mode-
> Louis (10): (interrupting) We were like interacting with each other and helping each other with stuff like that.

Furthermore, the students also talked about how engaging with the 1938 BEE supported their learning and they were particularly fascinated by the fact that the model was based on a real historical event that involved actual people visiting the site back in 1938:

> It's really impressive even though it's like 80 year ago or so they still know exactly what it looks like and they've got all the details right. (Mustafa, 11 YP)

The digital multimedia collection that accompanied the virtual 3D model was also seen as pertinent to the success of the project and its learning outcomes as it allowed the teacher to incorporate the archival material into the teaching and learning tasks and added another realistic dimension to the project:

> …photos and videos and interviews with people who were there, that made it real and allowed children to really access what the empire exhibition was about (Daniel, YP Y6 teacher).

Similarly the students commented positively on the different pictures, audio recordings and videos that were projected on the Interactive Whiteboard from the digital archive:

> That was the most important thing about it because well the programme shows us how they place looked like but the most important thing is information about it and what people thought about it. (Mahida, 11, YP)

In addition, the students welcomed the opportunity to create their own tours of the exhibition and they felt very proud of the 'end-product', the tour itself.

> We felt that without the tour I think it would be a bit boring cause all you could do is just go around in the Scottish buildings and do nothing with them. But making your own tour you could feel proud of what you'd done, it's an achievement. (Owen, 10, YP)

The majority of teachers from all schools recognised the relevance of the 3D virtual model to students' interests and described that it could offer opportunities for more engaging cross-curricular teaching and learning since 'it gets the kids to think outside the box' (Ralph, HS History teacher) and 'it takes them away from just reading through a textbook and listening to someone talking (Lucy, BS History teacher).

Additionally, it was recognised how engagement with the model offered opportunities for teamwork and independent learning while another perceived benefit was the good fit with the GSCE and A level Design and Technology curriculum as well the potential of the model to be used as a virtual exhibition space where students would work collaboratively to curate their digital artefacts:

> It's got scope for teamwork because then they could go off create work as teams and then actually put an exhibition together. The idea of curating work is quite an

> interesting one and something the students don't get the opportunity to do. (Lauren, HS Design teacher)

All in all, the teachers at large acknowledged the relevance of digital technology use in the classroom and how this resonated with students' interests and informal learning practices. However, one teacher also highlighted the risks associated with adopting more innovative practice that may deter teachers from getting involved in the use of such tools:

> I guess it's one of these things with innovation - everyone wants to be innovative and as soon as there is a bit of risk attached to that 'well, maybe I'll do it in the next year'. That's the sort of thing you have to struggle internally with as much as everything. (Ralph, HS History teacher)

Drivers and barriers

This section will now go on to identity the drivers as well as the barriers underpinning the use of a legacy digital artefact within formal educational settings. These will be jointly discussed since it was clear from the data analysis that a potential driver for one school often acted as a barrier for another.

In the case of Young's Primary the successful engagement with the BEE 3D model was interrelated with Daniel's enthusiasm and his ability to 'sell' the idea to the students as he explained that 'spinning a topic to the students is crucial'. He also invested a considerable amount of time in order to become familiar with using the model and creating tours as well as getting to know the various resources contained in the digital archive and designing relevant and meaningful tasks and activities in line with the Year 6 primary curriculum:

> After our initial meeting I went home and made an excel spreadsheet of all the objectives I think I could fit and where the links could be and cross -referenced

> them[...] I think it will leave a legacy of 'if you plan and prepare a theme can run for as long as you will allow it to'. (Daniel, YP Y6 teacher)

Indeed, individual and institutional time – or often the lack of it was a recurring issue raised in the interviews. Particularly within the context of the secondary schools, time constraints were reported as a major inhibitor that compromised engagement. In particular, schools' imposed timeframes combined with dominant assessment regimes and the pressure applied to teachers to produce tangible outcomes with regards to formal examinations was reflected in the limited time and effort that teachers and students were able to devote to the project. For these reasons, it was particularly difficult to find time within the curriculum to align teaching activities and this resulted in the separate creativity challenge or lunchtime club approaches adopted by the secondary schools.

> I think that [time] would definitely be an issue. We've started our GCSE course, for use to sacrifice 2-3 cycles worth of lessons that would have a knock-on effect on the actual day-to-day bread and butter business that we do (Collin, HS History teacher).

Another perceived enabler within primary school context was the flexibility of the primary curriculum that allowed them to adopt a theme-based approach as soon as the Year 6 class completed their scheduled test in May. In contrast, teacher and student practices within the secondary schools were clearly structured by protocols associated with wider imperatives of assessment regimes, outcomes and accountability.

Having the support of the Head teacher was also vital for the success of the project. In the case of Young's Primary the Head teacher not only allowed Daniel more flexibility with regard to adopting a theme-based approach to teaching the primary curriculum but she was also keen to see this cascade to other classes. As she argued:

> There is the academic side that they are learning the objectives fit for the national curriculum, fit for their age group but also their emotional intelligence is growing, their artistic, cultural intelligence is developing so they are becoming more rounded by doing the project theme (Catherine, YP head teacher).

However, the eagerness and support of a Head teacher appeared to be futile when not matched with equivalent teacher enthusiasm. Tellingly, in the case of Hall's Secondary some of the teachers expressed concerns regarding the potential of the tool and its relevance with regard to the school curriculum:

> Andrew: The difficulty is not getting them to use the software, it's the passion for the topic. (HS ICT teacher)
> Isaac: We've got to find a hook. If it was a 3D model of [our city], then obviously it would tie in beautifully. (HS Learning and Teaching Director)

These reservations demonstrate the difficulties in both persuading teachers who were unfamiliar with legacy research data of its curricular relevance, and for engaging those teachers in cases where a wide topic was not seen to easily tie in with existing lesson plans. They also reflected the findings above that teachers understood intuitively that cross-curricular topics needed to be 'spun' in order to successfully engage students. In the follow-up interview, similar sentiments were expressed indicating that exploring the potential of the 3D virtual model for cross-curricular teaching and learning was imposed by the senior management rather than based on the interest of the participating teachers:

> I feel as though in some ways it's a bit of a cart before the horse in that we are trying to find educational value for something that we wouldn't have normally chosen to look at rather than saying this is what we'd like to do educationally and what's the best way of doing it. (Isaac, HS Learning and Teaching Director)

Additionally, throughout the three diverse case studies various technical constraints were identified by teachers and students alike. In the case of Barrow Secondary it was not possible to install the software on the school’s computers due to the Local Authority guidelines and restrictions. Young’s Primary and Hall’s Secondary were equipped with fairly modern computer labs, however, one of the major challenges was that these were not adequate for running the VSim software and the virtual 3D model smoothly. The majority of students reported that they found the software ‘laggy’ and it often crashed.

Moreover, as VSim was still at the prototype stage, a range of technical glitches emerged when the students were creating the tours which sadly resulted in work getting lost and affected the students’ experience. This in turn led to frustration and disappointment for the students who were not able to complete their tour. As the primary school teacher described:

> The children differ in kind of mental strength and also in resilience and some children were like 'oh I have to start again' where others they were a little bit upset because they'd put work into it and that disappeared (Daniel, YP Y6 teacher).

Similar technical difficulties were present at Hall’s Secondary and these often discouraged pupils from persevering with the creation of the tour. As the ICT teacher reasoned:

> When you've lost your work once you go 'oh I've lost my work' when you've lost your work five times you go 'I can't be bothered, what's the point'. And they said that and that's a problem. (Andrew, HS ICT teacher)

In contrast, the students from Barrow Secondary who explored the virtual 3D model and created their tours at The Glasgow School of Art’s computer lab during pre-arranged visits did not face such technical issues and their experience was far more positive.

Desired features

When asked about the limitations of the 3D virtual model, or further features that were desired a large number of students suggested that the model would be more appealing if it had allowed for interaction and collaboration when navigating and exploring. This sense of social presence would have resonated more with their experiences with commercial video games which allowed them to play along with friends and include competitive elements and it would also increase collaboration. As these students explained:

> Stuart: Maybe if you added more people, if more than one person could be in each world with a friend.
> Peter: Maybe make something like when you are on with your friends and stuff you can save and make stuff yourself onto the, in the buildings. (HS Focus Group 2 interview)

Another suggestion was regarding familiarity with the software itself with some students suggesting a tutorial that 'pops up when you load the world and if you've played before you can have an option of skipping it but if you've never played it before you could use the tutorial to get an understanding' (Ben, 14, HS). However the majority of students from all schools proposed that simply ‘messing around’ was their preferred way of learning how to navigate and use the pedagogic tools within VSim, with one secondary student going so far as to say ‘you can't really teach it to people, it's more effective if people teach it to themselves when it comes to like technology and stuff.’ (Mandy, 14 BS)

Another issue that was often raised in the student interviews related to virtual navigation and users, especially ‘getting lost’ within the model. While they were provided with an image of a real map and key to the different buildings on the site that was used during the 1938 Exhibition, this did not prevent navigational difficulties. Suggestions included ‘adding a mini-map that lets you see where you are and navigate wherever you want would be useful’. (Adnan, 14, HS)

A further limitation of the 3D model highlighted across all schools was the fact that they could navigate around the various building but they could not go inside or if they did there was no detail, it was just an empty shell. As one teacher commented:

> I guess that's partly down to the idea that they can go around the model but they can't go inside it [...] I think that young people nowadays kind of almost expect to be able to do whatever they want online […] and when they can't do that and it's just the outsides, I think it intrigued them what it looked like inside (Malcolm, BS Head of Humanities).

Further suggestions included users having more power over settings such as the sensitivity and being allowed to add new pavilions to the model. These suggestions demonstrated students' experience with a range of broadly similar technologies, and their desire for advanced functionality as well as highly detailed and comprehensive 3D models. However, it also showed a lack of understanding of the distinction between the 3D model itself (the BEE scene) and its delivery mechanism (VSim). Students and teachers alike interpreted the tool as one program, and several made the assumption that the 3D scene was online.

Another issue was raised regarding the use of the digital collection of related material. Teachers noted the need for highly accessible and discoverable materials, pointing out that the huge number of files and folder structure could put students off: 'our pupils looked at it and went 'I'll go on Google and get my own [images]' (Andrew, HS ICT teacher). Finally, one teacher identified that the participating students struggled with the navigation keys and folder structures as they were more accustomed to using tablet devices compared to desktop or laptop computers:

> I think they are more used to tablets so when it comes to pressing buttons on a computer keyboard to move through a model I think they are confused by that […] So even just pressing the buttons to move your vision they struggled really with

> that [...] they are used to dragging and dropping, pressing their finger on it, I even saw one of them trying to do it instead of with the key. (Malcolm, BS Head of Humanities)

As well as identifying a strong desire across the three participating schools for the 3D model and software to be delivered on tablets, the REVISIT study presents evidence that the prevalence of mobile, touchscreen devices in both homes and (some) schools appears to have changed the technical capabilities of schoolchildren away from desktop input/output modes and into those more associated with tablets, phones, and gaming consoles. This creates a, possibly widening, disconnect between the digital skills children are assumed to have and those they actually possess, another critical factor when considering how legacy data, developed by and for adults in research settings, might be fruitfully adapted to use by younger learners.

Discussion

The results of this study provide insight into how a legacy virtual 3D model was used within formal educational settings. This section will now go on to discuss in more detail the range of benefits and opportunities that were highlighted as well as the underlying pedagogical, institutional and technical challenges that emerged and the implications these posed.

Pedagogical opportunities and implications

In line with other studies, the implementation of the 1938 BEE model across the three schools was seen not only to promote cognitive aspects of learning but also to enhance student interest (Bouta et al., 2012) as well as 'provide real world case based environments, and enable context and content dependent knowledge construction' (Mikropoulos & Natsis, 2011, p. 776). Similar to the findings of others the game-based nature of the virtual learning environment facilitated student motivation (Kim, Ke, & Paek, 2017) and 'novelty' and 'fun' were seen as significant factors in promoting student engagement (O'Rourke, Main, and Ellis 2013). Additionally, it allowed for creative interactions and facilitated learning through active participation and collaboration (Cho & Lim, 2017) while it also provided students with opportunities for user-led innovation and co-production (Hunsinger & Krotoski, 2012) such as when they created an original tour of the BEE within their groups. Last, as discussed in a different paper this game-based mode of learning facilitated the development of non-disciplinary key skills, such as creativity, collaboration, leadership and emotional intelligence (Abbott, Jeffrey, Gouseti, Burden, & Maxwell, 2017).

The game-like aspect of the 3D model also created opportunities for playful exploration and for engaging in peer and informal learning. Playful learning as conceptualised by Moyles (2010) relates to child- or adult-inspired or initiated learning experiences which allow for playful engagement and such opportunities were frequently observed. At the same time, practices of 'messing around' were also popular amongst students revealing a more intense engagement with the tool (Ito, Antin, Finn, Law, & Manion, 2010). Furthermore, the creation of personalised digital artefacts by the groups of students chimes in with the findings of Dawley and Dede (2014) and also relates to the popular 'Maker Movement' in education that promotes the creative production of artefacts and the sharing of these via physical and digital forums (Halverson & Sheridan, 2014).

However, the adoption of the BEE 3D virtual model was not always unproblematic and the participating teachers often struggled both with navigating the environment and also with creating meaningful and relevant activities for their students. The 3D model of BEE was perceived a means of enriching existing practice rather than transforming it and this is in line with Merchant's (2010) findings who reported that innovative teacher practices were limited by the current focus on standards and individual performance.

Last, the desire of students for the 3D model to be delivered and navigated on tablet devices relates to the changing nature of literacy or literacies in a digital age and the changing types of younger learners' engagement with technological tools. For instance, the portability of technologies such as smart phones and tablets as well as their 'graphic, sensory and multimedia affordances' are seen to be re-shaping children's experiences of literacy across a range of modes such as words, sounds and images (Sefton-Green, Marsh, Erstad, & Flewitt, 2016, p. 13). Additionally, this chimes with the literature that highlights the growing popularity and rapid uptake of tablets in formal educational settings (Herodotou, 2017; Roblin et al., 2018).

Institutional opportunities and implications

A range of institutional factors affected the re-use of the BEE 3D model across different educational settings and resulted in varying outcomes. First, teachers' preconceptions of how the virtual model could be used in their lessons were translated into classroom realities 'under the influence of powerful pedagogic and curriculum discourses' (Merchant, 2010, p. 137). In particular, the flexibility of the curriculum was indeed a prevalent theme that emerged as both a driver and a barrier depending on the school setting. Whereas the primary curriculum allowed more flexibility, this was not the case within the secondary school settings. In addition, the more specialised nature of the BEE virtual 3D model (created originally as research dataset) posed to some extent barriers for curricular alignment in the three schools. For instance, some of the teacher participants could not see how to create relevant activities within their curriculum objectives and as a result were unenthusiastic about engaging with the model. As Lackovick et al (2015) point out even when teachers can imagine opportunities to utilise heritage site artefacts within the curriculum, they need more guidance and support in order to implement these successful.

Additionally, rigid assessment regimes also hindered a longer and more in-depth engagement with the 3D model. In the case of the two secondary schools, concerns over forthcoming exams and the pressure applied to teachers to produce tangible outcomes were reflected in their involvement. Furthermore, similar to other school-based research conducted in this area to date, it was found that time constraints can curtail the customizability of technology-based curricula (Lin et al., 2011). As Banaji et al. reason (2010, p. 6) technology-based creativity and innovation are often supressed ‘by an overloaded curriculum, by lack of time for flow in the teaching and learning schedule, by other systemic barriers such as summative assessment and league tables’.

Research has shown that attempts to implement new digital technologies in formal educational settings will involve some level of disturbance to current practices and the degree to which these disruptions will be tolerated will affect technology acceptance (Underwood & Dillon, 2011). As such, all these ‘structures and rules that organise the work of instruction’ or else ‘the grammar of schooling’ (Tyack & Tobin, 1994, p. 454) are seen to be particularly stable and still prevail formal educational settings, making the appropriation of digital artefacts such as the BEE 3D model particularly challenging.

Technical challenges and implications

Based on their prior experience with commercial-off-the-shelf (COTS) games, students noted limitations regarding social presence and interactivity. The multi-user games and virtual environments some students were familiar with allowed ‘acting’ on the world and could be used as communication, spatial and experiential spaces (Hew & Cheung, 2010). In contrast, the single-user 3D model of the BEE did not allow users to affect the scene or feel as though they were inhabiting a shared environment. Indeed, any feature to enable collaboration within the virtual environment without requiring physical co-presence that commercial software such as Second Life allows (Girvan & Savage, 2010; Konstantinidis, Thrasyvoulos, Terzidou, & Pomportsis, 2010) would have been wel-comed by the students (e.g. a ‘chat’ tool). Although perceived as simple requests by the students, this would have required additional modelling of interactive features in the model itself, delivery through an interactive gaming platform (e.g. Unity), which pos-sesses interaction functionality but not the pedagogy-oriented multimedia annotation functionality offered by VSim, and also for each instantiation of the program to be net-worked, as opposed to standalone.

The perceived importance of social presence should not be under-estimated, and is well-supported by the literature. As Mikropoulos and Natsis (2011, p. 770) argue presence or the user’s sense of being there can ‘transform the users of a VE into partici-pants in an alternative world’. Similarly, virtual worlds are seen to allow users to inter-act in a way that conveys a sense of presence lacking in other media (González et al., 2013, p. 332). However, to move collaboration from the informal, cross-computer model delivered by this study to enabling it within an inter-connected, fully-fledged vir-tual world has significant resource implications.

Students’ prior experience with COTS games also created high expectations of realism, however, this would also require high hardware specifications which would not have been possible to deliver within a school setting. As such, the tension between offering real-time navigation and interaction with large 3D datasets and providing graphical quality that can compete with COTS games is an ongoing challenge for the use of 3D within classrooms. The original (extremely detailed) BEE 3D model had been optimised for delivery via VSim on school computers, resulting in a reduction in graphical quality in terms of both textures and polygon count. Teachers and students typically either did not understand or were not interested in the technical limitations of hardware, software, and raw data, instead expressing a desire (or expectation) for commercial-level graphics, comprehensive modelling data, and reliable, high-frame-rate, non-laggy interaction, all delivered on the hardware typically found in school labs. Ironically, these limitations appeared to become more relevant and important to users as they became more engaged with the experience (i.e. it was the students who were most excited about exploring the Exhibition who were most disappointed that they could not go inside the buildings). These desires are firmly supported by the literature on learning within 3D environments, for example, Whitelock, Brna, and Holland (1996) reason that representational fidelity, immediacy of control and presence are the basic characteristics for conceptual learning within virtual environments. Similarly, Pellas and Vosinakis (2017) reason that the representational fidelity of 3D virtual worlds offers an interactive environment that can facilitate authentic problem-based learning conditions in view of fostering students' cognitive thinking skills. However, the logistics of achieving them cannot be separated from the limitations of the overall learning situation.

Last, it is clear that the strong advantages for spatialized understanding and engagement provided by free exploration within a 3D scene also have the accompanying risk of loss of orientation. Virtual navigation was often challenging especially for non-expert users who would often 'get lost'. Similar research has suggested to have software elements to overcome such orientation problems (Ibanez et al., 2011) while a different study adopted the use of a joystick to control the orientation and position of the user (Barbalios et al., 2013).

Conclusion

As this paper has highlighted, a range of perceived pedagogical and other opportunities were reported across the three case studies. These were at large associated with the potential of virtual 3D models to facilitate rich learner engagement and motivation, promote formal and informal as well as peer learning and enhance teamwork and collaboration. Furthermore, the opportunity to co-create and share highly personalised digital artefacts such as their own virtual tours was also welcomed by the participants across all case studies. In particular, a lot of students acknowledged that their sense of presence within the 3D model played an important role and enhanced their learning experiences which would have been less rich had they only drawn on text, images or video to support their learning.

Within a wider institutional context, it appeared that the flexibility and freedom the schools were allowed as to how they could utilise the virtual 3D model to best fit their classroom practices was doubled-edged in its outcomes. While for the primary school this led to a more creative use of the tool to inform the curriculum in meaningful ways and create relevant activities, for the other two schools this resulted in more limited and often compromised engagement. As such, the study's findings indicate a sharp contrast between primary and secondary school settings with regard to the customisability of both the National Curriculum in England and the Scottish Curriculum for Excellence. Notably the primary school classroom allowed for greater flexibility and could accommodate more creative practices compared to the more rigid and outcome-driven secondary curriculum.

While some teachers felt there was real value in engaging with the model and providing them with a break from their usual teaching routines, other teachers had concerns about the lack of fit with their curriculum subject area, the time made available to them to prepare, and hinted that their only reason for engaging with the project was due to senior management pressure. It must also be noted that other perceived barriers identified across the three case studies were the pedagogical skills needed for creating relevant and meaningful tasks in 3D models and the time to plan and design these tasks supporting the findings of González et al. (2013).

Also, students' previous experiences with COTS games created high expectations of realism and of additional features that would enable an embodied, social presence and would allow online collaboration within the virtual environment. However, addressing these requests would entail further modelling of interactive features in the legacy model itself and delivery through an interactive gaming platform. This would require high hardware specifications, which might have not been possible to deliver within a school setting, and would create significant resource implications.

All in all, it is reasonable to conclude that the use of the BEE virtual 3D model within formal educational settings was perceived to create pedagogical and other opportunities for teachers and teachers but was also underpinned by a range of institutional and technical barriers. This study has suggested that a one-size-fits-all unproblematic adoption of 3D legacy data in classrooms is not possible. If researchers and educators alike wish to see such legacy artefacts become more widely adopted by schools, more attention needs to be paid towards overcoming these barriers and supporting teachers in creating meaningful teaching and learning activities for their students.

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