Virtual Skiddaw: A case study investigating the effectiveness of 3D virtual field trips in supporting outdoor fieldwork

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Table of Contents

1 Overview

In this project[1], we had the following research objectives towards investigating the pedagogical advantages of virtual field trips and the challenges for their adoption:

1. Understanding the (potential) role of VFTs in the curriculum in schools and higher education institutions (HEIs)

   We have primarily focussed on Geography, Geology, Environmental Sciences and Biology - disciplines that have a long tradition of physical fieldwork and first-hand experience of phenomena out-of-doors.

2. Gathering the requirements for a 3D VFT application - based on evaluation of The Open University's 3D virtual geology fieldtrip – the *Virtual Skiddaw* application[2]

3. Challenges for adoption of 3D VFTs

Towards the research objectives, we investigated the following:

- pedagogical underpinnings of 3D virtual environments and 3D VFTs in disciplines such as geology, biology, environmental science/studies and geography which are founded on field observations, exploration and enquiry.
- potential of integrating VFTs within the curricula in schools and in HEIs.
- perceptions of educators, students and assessment bodies towards 3D VFTs, and virtual fieldwork, in general; we used the *Virtual Skiddaw* App in workshops and presentations to illustrate the concept of a 3D VFT.

The empirical investigations have been **user-centred**[3] – focussing on the stakeholders and particularly, the end-users such as educators, students and fieldwork specialists, and we have interacted with them via interviews, workshops, demonstrations and a survey to elicit their perceptions and requirements.

[1] Project outline and video on Daden's website: https://www.daden.co.uk/case-studies [accessed 14 October 2019]
[2] Shailey Minocha and Tom Argles - Evaluation of The OpenScience Lab's 3D Virtual Skiddaw application, **video resource**, https://www.youtube.com/watch?v=oIosxNYrLis [accessed 14 October 2019]
[3] Stone, D., Jarrett, C., Woodroffe, M. and Minocha, S. (2005) *User Interface Design and Evaluation*, Morgan Kaufmann.

2 Outline of the report

This report comprises of the following sections:

- Section 3 is an introductory section on VFTs.
- In section 4, we discuss the pedagogical underpinnings of VFTs and specifically 3D VFTs.
- In Section 5, the OU's 3D virtual geology field trip application (App), *Virtual Skiddaw* is described. The *Virtual Skiddaw* App was used in our empirical work to illustrate the concept of a 3D VFT.
- In Section 6, the research design of this project is discussed.
- The results of our empirical investigations are presented in Section 7.
- In Section 8, we discuss our reflections and interpretations.
- The list of publications related to *Virtual Skiddaw* and the bibliography are in Sections 9 and 10, respectively.

3 Virtual field trips

Since their first tentative incarnations, VFTs have attracted robust criticism – and worse – from field scientists determined to see them as the thin end of an inexorable wedge pushing physical field courses out of the curriculum. Of course, VFTs can be used as replacements; but disciplines such as geology, biology, environmental science/studies and geography are founded on field observations, exploration, and enquiry. The skills for such disciplines are best learned and practised in the field - where the concerns are to discover and to be curious[4]. In fact, fieldwork by its very definition[5] involves leaving the classroom and engaging in activities through first-hand experience of the phenomena out-of-doors.

We would prefer to see VFTs being used to support, enhance and extend physical fieldwork so that students can make the most of their time out in the field. We perceive VFTs an invaluable aid in the goal to maintain physical fieldwork in the curriculum - at all levels.

The discussion and examples on VFTs in this and other sections of the report are from Geography, Geology, Environmental Sciences and Biology - disciplines that have a long tradition of physical fieldwork and first-hand experience of phenomena out-of-doors - and these disciplines have been our focus in this project.

3.1 Role of virtual field trips

In certain situations, VFT learning and teaching might be the only option. For example:

- accessibility for those who cannot attend physical field courses due to mobility, or other health and personal constraints
- introducing the nature of fieldwork to school students in a uniquely engaging format
- building familiarity with fieldwork for educators - so that they are more comfortable with, and, subsequently, are more likely to run physical field trips for their students
- for facilitating interactions with experts, students and educators in other institutions (nationally and internationally)
- for learning about global issues where travel may not be feasible – e.g. for global learning in geography[6] – in VFTs, students can learn about local, national and global issues and conduct complex geographical enquiries of contemporary issues in society and the environment.

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[4] The Association for Science Education Outdoor Science Working Group's (OSWG) report, *Outdoor Science*, sponsored by the Nuffield Foundation, 2011, https://www.nuffieldfoundation.org/outdoor-science [accessed 14 October 2019]

[5] Fieldwork in a physical field trip refers to all educational activities from early years through to post-16 and in FE and HEIs that takes place outside the classroom and makes use of outdoor natural and built environments.

[6] Global Learning Programme, Geographical Association, http://www.geography.org.uk/projects/globallearningprogramme [accessed 14 October 2019]

OU has been developing virtual fieldwork components for its distance students for decades (interactive activities and videos on DVDs, Web-based interactive activities[7] aided by videos, sample data, etc.). With so few opportunities to gain fieldwork experience, distance-learning students would be disadvantaged without an alternative; hence the impetus for this latest innovation – developing virtual geology field trip – *Virtual Skiddaw* - in a 3D gaming engine.

3.2 Current state of virtual fieldwork

Currently, VFTs fall into four classes: multimedia, Geographic Information Systems (GIS)-based, virtual world and mobile apps. Multimedia virtual field trips typically comprise a collection of photos, text, and static maps delivered via a website or DVD. More innovative examples may use video, audio, map service mashups, or panoramic images (e.g. Google Expeditions[8]).

The simplest VFTs are no more than guided virtual tours, with no interactivity. An alternative, synchronous, approach is that taken by 'FieldTripZoom'[9], a commercial video-conferencing company, which allows museums to stream lectures and tours to schools – although it is focused mainly on indoor/on-site field trips. No multimedia VFTs that we are aware of use 3D immersive spaces (beyond limited 3D panoramas), or have multi-user functionality.

The second class of VFT is represented by web-based and traditional GIS packages. Examples include: Google Earth-hosted content (mainly simple tours), mobile apps (such as iGeology[10] from the British Geological Survey, which shows geology overlain on the 3D landscape), projects within desktop GIS that are expensive and cumbersome for teaching, and web-based map services. These are all single-user products with limited interactivity, are seldom immersive, and lack explicit teaching.

The third class of VFT derive from developments in 3D virtual environments (VEs) using gaming engine technology (e.g. models of the Snowdon area[11] and using Minecraft[12] for mapping[13], much early work in 3D virtual world, Second Life[14], Yellowstone in OpenSim[15]). These provide accessible 3D simulations of fairly extensive areas. However, the level of detail is low, and pedagogy and privacy are hard, if not impossible, to control.

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[7] For example, an activity as a part of a virtual environmental field trip is available in OU's Open Science Lab: https://learn5.open.ac.uk/course/format/sciencelab/section.php?name=soils [accessed 14 October 2019]

[8] Google Expeditions, https://edu.google.com/products/vr-ar/expeditions/ [accessed 14 October 2019]

[9] FieldTrip Zoom, http://www.fieldtripzoom.com [accessed 14 October 2019]

[10] iGeology, British Geological Survey, http://www.bgs.ac.uk/igeology/ [accessed 14 October 2019]

[11] Donert, K. (2003) The Virtual Montana Project: Using open and distance learning to support fieldwork-based activities, *International Journal of Fieldwork Studies*, http://www.researchgate.net/publication/255653260_The_Virtual_Montana_Project_Using_Open_and_Distance_Learning_to_support_fieldwork-based_activities [accessed 14 October 2019]

[12] Minecraft, Minecraft is a game about breaking and placing blocks. https://minecraft.net [accessed 14 October 2019]

[13] Minecraft, Ordnance Survey, https://www.ordnancesurvey.co.uk/blog/tag/minecraft/ [accessed 14 October 2019]

[14] Second Life, http://secondlife.com [accessed 14 October 2019]

[15] OpenSim, http://opensimulator.org/wiki/Main_Page [accessed 14 October 2019]

The fourth kind of VFTs are in the form of mobile apps of 360-degree photospheres or 360-degree videos. Google Expeditions (GEs) are guided field trips to places that students experience on a smartphone through a VR viewer called Google Cardboard[16]. The GE app (available for Android and iOS platforms) has more than 750 expeditions. An expedition comprises of 360-degree photospheres of a location (e.g. Rio de Janeiro). GEs enable visualisation of locations which may not be feasible or easy to visit in real life (e.g. Great Barrier Reef or Tolbachik volcano). Further, GEs have simulations to envision concepts and systems such as the human heart, the respiratory system, or the process of pollination.

The 3D virtual geology field trip – the *Virtual Skiddaw* App has formed the basis for investigations in this project (third class of VFTs discussed above). *Virtual Skiddaw* App[17] was jointly developed by Daden and OU using the Unity 3D gaming engine[18]. The application is based around a 10km x 10km low to medium detail model of the terrain around Skiddaw with overlaid photogrammetry-derived mesh and textual imagery, and augmented with in-built Unity terrain and flora. The virtual embodiment in the form of avatars and the multi-user environment give a sense of co-presence and provides opportunities for collaborative learning. *Virtual Skiddaw* includes licensed map data from Ordnance Survey (OS), and digital topographic data from Infoterra via Getmapping plc. In Section 5, we discuss the features of *Virtual Skiddaw*.

In the next section, we discuss the pedagogical theories that underpin student learning and engagement in 3D VEs and 3D VFTs.

[16] Google Cardboard, https://vr.google.com/cardboard/ [accessed 14 October 2019]
[17] Video: *Virtual Skiddaw* – Virtual Geology Field Trip, **video resource**, https://vimeo.com/78057630 [accessed 14 October 2019]
[18] Unity 3D, https://unity3d.com [accessed 14 October 2019]

4 Learning in 3D environments and 3D virtual field trips

There are several pedagogical theories that underpin student learning and engagement in 3D VEs and especially for the self-directed learning in the proposed 3D VFTs: experiential learning through simulations, observational, reflective and collaborative-learning, knowledge construction through socialisation in a 3D avatar-based VEs[19], and learning by doing. The over-arching theory is socio-constructivist educational theory[20], which states that people construct their understanding through experience, in social situations by collaboration, and by reflection individually, and in social contexts within a group. This 'group' may comprise of students or educators. The socio-constructivism includes authentic learning contexts ('contextual' or 'situated' learning) by making the learning purposeful and meaningful.

In the next section, we discuss the affordances of 3D VEs that support socio-constructivism.

4.1 Affordances of 3D virtual environments

The differences in traditional 2D Web-based learning and 3D virtual environments are summarised in Table 1[21].

Table 1: Differences between 2D learning and learning in 3D VEs

Affordance	2D Synchronous Learning (e.g. webinar)	3D Synchronous Learning (e.g. in a 3D VE)
sense of self or representation	photo; name and profile	avatar and profile (an avatar is a visual representation of the user of their real or surrogate identity and appearance)
bridging distance	same time and on the same website	same time in the same virtual space as avatars (similar to face-to-face interactions)
sense of presence	disembodied	embodied
sense of space	website (within the webinar environment, for example)	within a 3D space with others - it is similar to occupying the same space in the real-world in face-to-face situations
experience	interaction	immersion[22] - perception of being *physically* present in

[19] Minocha, Shailey and Roberts, Dave (2008) Laying the groundwork for socialisation and knowledge construction within 3D virtual worlds. *ALT-J: Research in Learning Technology*, 16(3) pp. 181-196. Available from: http://oro.open.ac.uk/16142/ [accessed 14 October 2019]
[20] Holmes, B. and Gardner, J. (2012) *e-Learning: Concepts and Practice*, SAGE Publications Ltd.
[21] Adapted from Table 3.2 on page 62 in Kapp, K. M. and O'Driscoll, T. (2010) *Learning in 3D: Adding a new dimension to enterprise learning and collaboration*, John Wiley & Sons.

Affordance	2D Synchronous Learning (e.g. webinar)	3D Synchronous Learning (e.g. in a 3D VE)
		the VE and in the presence of others - sense of actually “being there together” or co-presence – a feeling of reality rather than virtuality with other geographically dispersed users
authenticity of the learning spaces	through images, videos	realistic display of the environment (as in the real-world) 3D spaces; or can be designed non-realistically too (such as platforms in the sky or underwater learning spaces)
collaboration and peer-to-peer learning	to be explicitly planned	emerges naturally through spontaneous and serendipitous interactions

The affordances of 3D VEs support learning and teaching in various ways:

- sense of presence of others in a multi-user avatar-based environment, thereby, enabling richer collaborative learning than in 2D equivalents (e.g. 2D or web-based learning management systems or web-based synchronous conferencing tools such as webinars). Physical presence (as avatars) in 3D VEs gives students and teachers a feeling of physically being there – co-presence – even though it is a VE.
- sense of location, fostering spatial literacy, understanding of spatial relationships.
- a persistent learning and social space to facilitate and to encourage both serendipitous and planned interactions between students, educators, and others as they engage in collaborative and purposeful activities.
- experiential learning or “hands-on experience” by being in direct contact with a 3D realistic environment (or the reality being studied), as opposed to learning in which the student is reading or hearing about or discussing the reality[23].
- contextual learning and teaching (CLT)[24] – whereby educators are able to relate the subject matter content to real-world situations within (3D) simulated

[22] Bredl, K, Groß, A, Hünniger, J, and Fleischer, J. (2012) The Avatar as a Knowledge Worker? How Immersive 3D Virtual Environments may Foster Knowledge Acquisition, *The Electronic Journal of Knowledge Management* Volume 10 Issue 1, pp15-25, available online at http://www.ejkm.com
[23] Keeton, M. T. (2004) *Experiential Learning*, in the *Encyclopedia of Distributed Learning*, Anna Distefano, Kjell Erik Rudestam and Robert J. Silverman, SAGE Publications.

contexts – enabling students to practise skills and concepts that can be transferred to physical fieldwork situations. 3D VEs (and their affordances, Table 1) facilitate learning activities that lead to improved transfer of knowledge and skills to real-life situations through contextualisation of learning[25].

CLT emphasises planning and critical thinking, collecting and analysing information and data from a variety of sources, and transfer of knowledge from classroom to out-of-classroom contexts. CLT is based on the hypotheses that students tend to retain higher-level knowledge and skills longer when their experiences occur in multiple contexts that are as close to real-life situations as possible.

- exploratory learning[26] - being able to define one's own workflow and learning by exploring the 3D VE - allowing for independent observations, discovery and personalised learning experiences in a less structured way than more textual-based instructional approaches.
- exploration and learning in immersive 3D environments support more engaging and motivating learning experience than 2D environments.
- being able to experience situations and learning which may not be possible/easy in the physical fieldwork - non-realistic characteristics such as being able to fly, having an aerial view of the landscape, or fading away avatars who come in the way while sketching the rocks or making observations, or being able to 'teleport' without having to walk or fly.

As well as the primary visual stimuli, 3D VEs and the 3D VFTs may also incorporate ambient audio to heighten the sense of immersion in the field experience; such sensory input focuses the concentration and aids recall.

The 3D virtual geology field trip - *Virtual Skiddaw* has several realistic features to create an 'authentic learning space': the landscape has been developed from data acquired directly from the area; an authentic soundtrack has been weaved into the experience to increase that feeling of immersion; and the audio guidance from the 'virtual tutor' audio mimics a typical field trip. Further, the emphasis throughout the VFT is on the user - observing recording and assembling data and questioning it, navigating from site to site and ultimately piecing together the clues to the geological story. The 'authentic' learning experience is certainly richer and more interactive than reading a textbook or clicking through a static (2D) website, and hence more effective for learning.

These are some other VFTs or educational e-games that frame the learning activity in the form of a problem-solving scenario, explicitly fostering CLT:

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[24] Lynch, R. L. (2006) Contextual Teaching and Learning, in the *Encyclopedia of Educational Leadership and Management*, Fenwick W. English, SAGE Publications.
[25] Rapanotti, Lucia; Minocha, Shailey; Barroca, Leonor; Boulos, Maged N. Kamel and Morse, David R. (2011) *3D virtual worlds in higher education*. In: Olofsson, Anders D. and Lindberg, J. Ola eds. *Informed Design of Educational Technologies in Higher Education: Enhanced Learning and Teaching*.
[26] De Freitas, S. and Neumann, T. (2009) The use of 'exploratory learning' for supporting immersive learning in virtual environments, *Computers & Education*, 52, pp. 343-352.

- Placer gold mining game (http://www.see.leeds.ac.uk/misc/miner/)
- Geotechnical e-game (http://www.keele.ac.uk/gge/resourcesforeducation/geoteche-game/)
- Education City (http://www.educationcity.com/)
- SimIsle (http://www.mobygames.com/game/simisle-missions-in-the-rainforest)

In the next section, we consider the Kolb's experiential learning model to illustrate how it is integral to 3D (virtual) fieldwork and physical fieldwork.

4.2 Learning by doing in 3D VFTs

The value of experiential learning (or 'learning by doing') was recognised by early philosophers including Aristotle and Confucius, and formalised by David Kolb[27] (Fig. 1). Kolb's model is cyclical involving four steps: concrete experience, observation and reflection, forming abstract concepts and testing in new contexts. Learning through firsthand observation, experimentation, exploration, discovery and reflection results in deeper understanding and greater recall. As Confucius remarked, around 450BC: "*Tell me, and I will forget. Show me, and I may remember. Involve me, and I will understand*."

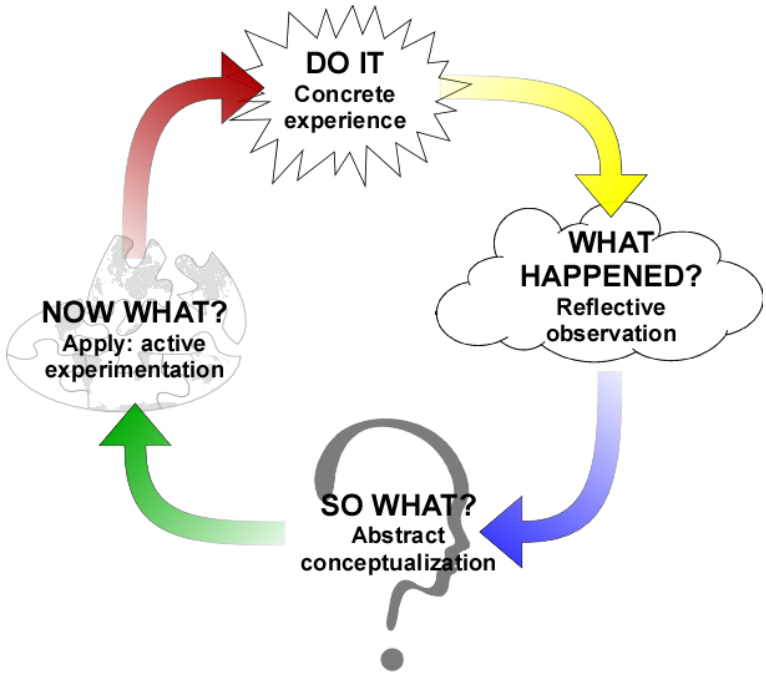

Fig. 1: Kolb's model of experiential learning

While physical field courses are a classic example of experiential learning, VFTs also engage students actively, prompting observation and exploration of the online contexts from a range of perspectives. VFTs not only exploit a much richer, more engaging learning mode than traditional 'book learning', they can also forge a highly beneficial, synergistic relationship with physical field trips in the curriculum (we discuss this in detail in Section 7).

[27] Kolb, D.A. (1984) *Experiential learning: experience as the source of learning and development*. Englewood Cliffs, New Jersey: Prentice-Hall.

In Kolb's context, experience relates to applying knowledge and skills to lived experiences (e.g. as in the workplace). However, in a 3D VE, although the experiences are 'virtual', they may be as definitive as those in the live context due to the 3D affordances (as outlined in Table 1[28]). In fact, combining real and virtual interactions through physical fieldwork and VFT, respectively, may reinforce the learning objectives (and intended outcomes). For example, in pre- (physical) fieldwork situations, VFTs facilitate practising and allowing for mistakes to be made in a secure environment. Some critical fieldwork skills such as sketching, orientation and using the compass, grain-size measurements, getting acquainted with the maps and note-taking can be practised by students using digital tools within the 3D environment (as in the *Virtual Skiddaw* App), and in conjunction with the physical items they will use in the field (e.g. pens, pencil and field notebooks). In post- (physical) fieldwork situations, VFTs can help reinforce the learning, facilitate, enable completion of any incomplete tasks of the physical fieldwork, and allow for additional observations.

We have adapted Kolb's model of experiential learning to propose a model of experiential learning in fieldwork that combines the experiences of conducting field work in VFT with physical fieldwork (Fig. 2). It has the following five steps:

- experience a VFT individually and collaboratively through social interactions
- practice, explorations and observations in physical field trips
- reflection, practice, further analysis of data and interpretation in VFTs after physical field trips
- reinforcement of learning and knowledge construction from both virtual and physical experiences through educator-driven de-briefing, feedback and group discussions
- applying the learning to new situations and contexts in the real world and testing it via assessment.

[28] Also, see: Minocha, S., Tudor, A. and Tilling, S. (2017). Affordances of Mobile Virtual Reality and their Role in Learning and Teaching. In: The 31st British Human Computer Interaction Conference, 3-6 Jul 2017, University of Sunderland's St. Peter's Campus, UK. Available from: http://oro.open.ac.uk/49441/ [accessed 14 October 2019]

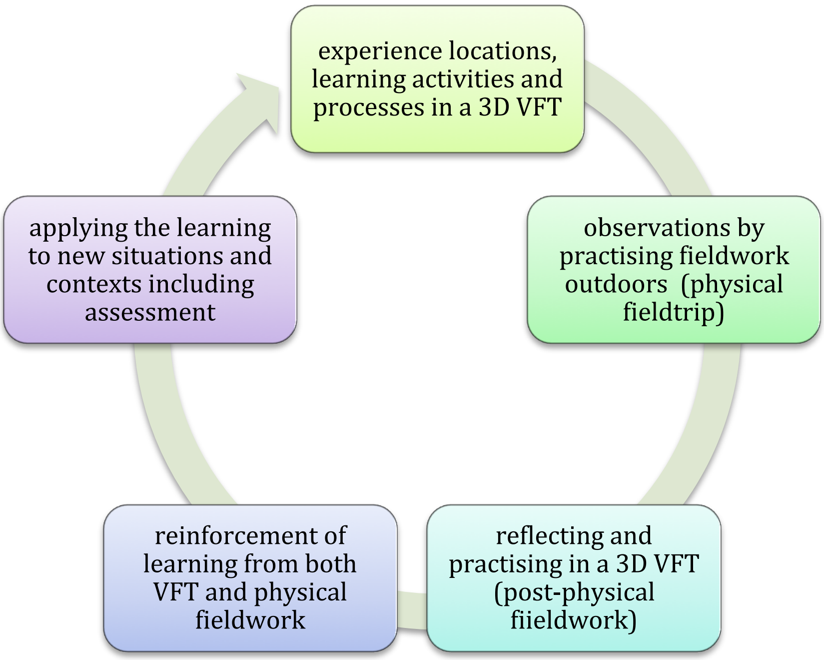

Fig. 2: Experiential learning in VFTs and in physical fieldwork (adapted from Kolb's model, Fig. 1)

This model in Fig. 2 emphasises individual and group learning and the synergistic learning through 'doing' and reflection in both virtual and real-world contexts.

The role of a student in a 3D VE is more empowering than in 2D spaces because of the opportunity to construct their own pathways and to be able to transfer learning between virtual and real-world contexts. 3D VFTs have the potential to support behavioural change and student engagement in fieldwork in virtual as well as physical spaces.

It is likely that school students, in particular, will be increasingly familiar (and comfortable) with a broad spectrum of virtual representations of the world, from simple animations, through both recreational and educational games, online simulations and blockbuster computer-generated movies. They will be unfazed by 3D VEs and VFTs, and will be adaptable to what is presented to them – which has indeed been confirmed in our demonstrations to school students in this project.

5 The *Virtual Skiddaw* App

Virtual Skiddaw[29] is a browser-based 3D Geology VFT App within The Open Science Laboratory (OSL)[30]. It was developed with a 3D game engine (Unity 3D[31]). It is an avatar-based multi-user environment. The multi-user capability offers the potential for collaborative group work, even among groups that are geographically dispersed.

A key tenet of the OSL is to use real data, wherever feasible, as a foundation for its experiments and investigations. So, aerial imagery and digital topography data for a 10 km x 10 km chunk of northern England were combined to create the broad landscape of *Virtual Skiddaw*. The landscape can be 'clothed' in different guises with one click: a geological map, for instance, or a 1:25,000 Ordnance Survey topographic map (Fig. 3).

Fig. 3: Composite oblique aerial view of *Virtual Skiddaw* landscape, showing the aerial imagery (right), topographic map (lower left) and simple geological map (top left).

Embedded within this low-resolution background are six smaller sites scanned in much more detail (Fig. 4), allowing users to make observations in-world on the exposures of rock. Some of these sites also contain 3D models of rock hand-specimens, scanned at an even higher resolution so that grain-scale observations and measurements can be made (Fig. 5). When observing these hand specimens,

[29] *Virtual Skiddaw*: 3D geology field trip, https://learn5.open.ac.uk/course/format/sciencelab/section.php?name=skiddaw_1 [accessed 14 October 2019]
[30] The Open Science Laboratory, The Open University, UK, https://learn5.open.ac.uk/course/view.php?id=2 [accessed 14 October 2019]
[31] Unity 3D: http://unity3d.com [accessed 14 October 2019]

the user can also view a thin section of the same rock interactively via a direct link to OU's Virtual Microscope[32] from within the App.

Fig. 4: A '3rd person' view of detailed Site 6. The partially-completed task list has been accessed via the second button on the panel (HUD, heads-up display) in the top left corner. The user could switch to first person view for sketching, so that their avatar was no longer in the way of the exposure.

Users are guided in-world between the six sites, and there is an initial tutorial walkthrough of the application's features as well as contextual help available at any stage. Before rushing into the fieldwork, users must first select some items to take on the field trip, depending on the terrain and prevailing weather conditions. On arriving at each site, the user is welcomed by a spoken introduction (with on-screen text), mimicking a tutor on a physical field trip. A 'tick list' of tasks (Fig. 4) to complete is then presented, focusing on observations they can make at the site or using the map overlays. One task might be to make a sketch of one particular view of the exposure (using the compass for orientation), or to measure the grain size of andalusite crystals in a hornfels (Fig. 5). On leaving a site – provided all the tasks have been ticked off – a summary is provided in the same way as the 'tutor introduction'.

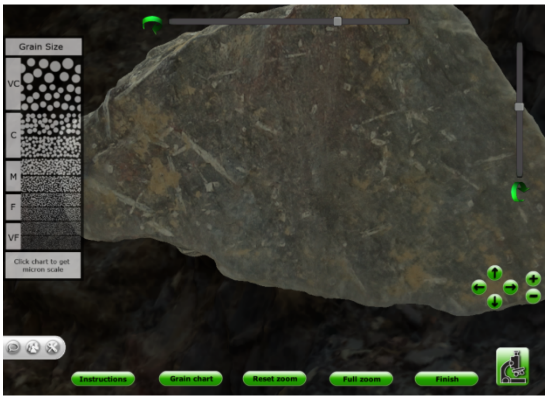

Fig. 5: Rock sample at Site 2 at full zoom, with grain chart to assess crystal sizes. On-screen buttons allow the 3D model to be rotated and shifted horizontally and vertically. The microscope button links to the thin section of this rock in the Virtual Microscope.

[32] A Level: Virtual Microscope, The Open Science Lab., The Open University: https://learn5.open.ac.uk/course/format/sciencelab/section.php?name=a_level_microscope [accessed 14 October 2019]

Once clear of a site, the user is prompted to run or fly to the next site, following a logical, linear learning journey that visits the sites in order. Alternatively, they can choose to go 'off piste' and roam around the landscape, exploring the sites in any order – perhaps teleporting between them via the overhead map view. Most functions are keyboard-accessible and adjustable (for instance, running speed, audio volume). Transcripts of all the spoken and on-screen text, and answers to questions, are available on the *Virtual Skiddaw* web page[33] in the OSL.

A sense of presence is crucial to the success of any virtual world, though people interact with them in different ways. Users of *Virtual Skiddaw* may switch between first person (as if they were the avatar), or third person (with their chosen avatar visible in front of them). Other avatars can be faded out (if they are in the way of a sketch, for instance), and there is a text chat facility for users to share their experiences or discuss the geology. Chat range is adjustable, so tutors can recall students from wherever they have strayed on the fellside, or restrict discussions to those at a single site. Finally, background audio (recorded on location) contributes a powerful sense of immersion in a real landscape.

[33] *Virtual Skiddaw*: 3D geology field trip, https://learn5.open.ac.uk/course/format/sciencelab/section.php?name=skiddaw_1 [accessed 14 October 2019]

6 Research design

In this section, we outline the research objectives and discuss the **user-centred** research methodology.

6.1 Research objectives

The following objectives guided the investigations in this project.

1: Understanding the (potential) role of VFTs in the curriculum in schools and higher education institutions (HEIs)

We have been primarily focussed on Geography, Geology, Environmental Sciences and Biology – disciplines that have a long tradition of physical fieldwork and first-hand experience of phenomena out-of-doors.

2: Gathering the requirements for a 3D VFT application - based on evaluation of the *Virtual Skiddaw* application

We used the *Virtual Skiddaw* App in workshops and presentations to illustrate the concept of a 3D VFT. In these interactions, we gathered additional requirements for the *Virtual Skiddaw* App and for the design of 3D VFTs, in general.

3: Challenges for adoption of 3D VFTs.

6.2 Methodology

During this project, the data was collected from a variety of sources (Table 2) through discussions and feedback in a range of service design[34] workshops, interviews, demonstrations and structured discussions, face-to-face or on phone, and online survey and email interviews.

Data sources and data collection

The description of the event, stakeholder types and the number of participants are listed in Table 2:

Table 2: Data sources, dates of the events and the number of participants

Description	Participants
Online VFT survey (SurveyMonkey)	25 (students, educators and field trip professionals)
Higher Education Network 'eGaming in GEES[35] disciplines' workshop as a part of the Geological Society of London Conference, Plymouth University	17 educators from further education (FE) and higher education (HE)
OSL Stand at the JISC Digifest, Birmingham	Several people visited our stand and two significant requirements were recorded
eSTEeM[36] conference, The Open University	12 (5 in the poster session with whom we also had email correspondence after the event; 7 participated in the structured discussion)
Science Circle meeting in the 3D virtual world, Second Life[37]	18 (international participation by colleagues involved in STEM education within 3D VEs and in the real-world)
Virtual Worlds Education Roundtable Forum in Second Life	23 (international participation from educators and students who are involved in learning and teaching, and conducting research in 3D VEs)
OU Educators meeting on 3D VFTs	5
Innovate UK monitoring meeting at Daden Ltd. in Birmingham	1 + project team
Milton Keynes (MK) Geography Teachers Network Meeting (local school in MK)	12 Geography teachers from schools across MK
Meeting with Ordnance Survey	4 + 3 project team members

[34] Service Design, https://www.interaction-design.org/literature/book/the-encyclopedia-of-human-computer-interaction-2nd-ed/service-design [accessed 14 October 2019]
[35] Geography, Earth and Environmental Studies (GEES)
[36] eSTEeM, The Open University, UK, http://www.open.ac.uk/about/teaching-and-learning/esteem/
4th Annual eSTEeM conference, http://www.open.ac.uk/about/teaching-and-learning/esteem/events/the-4th-esteem-annual-conference [accessed 14 October 2019]
[37] 3D virtual field trips in Science: opportunities and challenges, http://sciencecircle.org/?page_id=937 [accessed 14 October 2019]

Description	Participants
Conversation with an assessment body	2 + 2 project team members
Birmingham school	2 workshops with GCSE level and A-level students: 20 students and 7 teachers

Data analysis

We applied the sense-making approach of thematic analysis for the analysis of the qualitative data from various sources.

Thematic analysis is an analytic approach "*for reducing and managing large volumes of data without losing the context, for getting close to or immersing oneself in the data, for organizing and summarising, and for focusing the interpretation.*"[38] Thematic analysis is a systematic approach to the analysis of qualitative data that involves identifying themes or patterns in the data (guided by the research objectives); coding and classifying data according to themes; and interpreting the resulting thematic structures by seeking commonalities, relationships, overarching patterns, or principles.

In the next section, we present the results of our data analysis: themes and sub-themes for each of the research objectives along with quotes from our empirical investigations.

[38] Lapadat, J.C. (2010) *Thematic Analysis*, in the *Encyclopedia of Case Study Research*, Albert J. Mills and Gabrielle Durepos and Elden Wlebe, SAGE Publications. Also, see: How to do thematic analysis of user interviews, https://www.interaction-design.org/literature/article/how-to-do-a-thematic-analysis-of-user-interviews [accessed 14 October 2019]

7 Results of our empirical investigations

In this section, we present the results (themes from the data) from our empirical investigations along with quotes from the participants. The three sub-sections correspond to each of the research objectives listed in Section 6.

7.1 Role of a virtual field trip in the curriculum

The various themes for the first research objective are now discussed.

VFTs and the curricula in schools

The significance of physical fieldwork in the curricula was reinforced in our empirical investigations[39]:

> *specific skills (mapping, logging, sample collection); regional geology, paleontology, engineering geology) and field experience (survey; educator)*[40]
>
> *development of study skills, subject skills and social skills to give them the chance to look at familiar and unfamiliar environments in a critical way it is expected (survey; educator)*

However, the advantages of VFTs feed directly into the National Curriculum for Geography and/or Science, at GCSE and/or A Level. The synergies of VFTs with physical fieldwork would contribute to several aspects, including 'Geographical skills and fieldwork' (KS1-KS3 Geography; DfE 2013[41]), 'Experimental skills and strategies' (KS4 Science, DfE 2014[42]) and the 'Applied Fieldwork Enquiry' component of the new GCSE assessment (WJEC 2015[43]). Indeed, digital technologies are explicitly linked to fieldwork in the KS2 geography programme of study.

A guidance document (OFSTED 2013[44]) identified several important elements of the geography curriculum that could be improved and enriched by use of a VFT (e.g. fieldwork skills, use of the outdoor environment, geographical enquiry, map skills, concepts of scale, ICT/GIS/multimedia).

Although we only refer to the curriculum in England, we understand that the content in Wales and Northern Ireland is very similar. In Scotland, the opportunities for

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[39] The box has the data (quotes) from our empirical investigations in this project.
[40] The italicised text in the parentheses is the source of data/quote.
[41] National curriculum in England: geography programmes of study, https://www.gov.uk/government/publications/national-curriculum-in-england-geography-programmes-of-study [accessed 14 October 2019]
[42] Proposed national curriculum framework (for England) with draft KS4 science, https://www.gov.uk/government/consultations/draft-order-and-regulations-key-stage-4-science [accessed 14 October 2019]
[43] Geography: Ofqual reformed qualifications: http://www.wjec.co.uk/qualifications/geography/index.html [accessed 14 October 2019]
[44] Ofsted's view of Global Learning and Geography, http://www.geography.org.uk/download/GA_GlobalLearningandOfsted.pdf; also see: https://www.gov.uk/government/collections/ofsted-examples-of-good-practice-in-geography-teaching [accessed 14 October 2019]

fieldwork in Science and Social Science (which incorporates Geography) are similarly emphasised[45].

Table 3 presents a breakdown of specific features of VFTs and how they link to elements of the national curriculum in Science and Geography at different levels.

Table 3: Mapping VFTs onto the national curriculum[46]

VFT feature	Curriculum	Subject	Level
Draped maps/imagery	Interpret OS and other maps, aerial & satellite photographs	Geography	KS3
	Use maps, atlases, globes and digital/computer mapping to… describe features studied	Geography	KS2
	Use aerial photographs and plan perspectives to recognise landmarks and basic human and physical features	Geography	KS1
Multi-discipline virtual sites	Use fieldwork in contrasting locations to collect, analyse and draw conclusions from geographical data…	Geography	KS3
	select, plan and carry out the most appropriate types of scientific enquiries to test predictions	Science	KS3
	observing closely, performing simple tests, identifying and classifying, using their observations and ideas to suggest answers to questions	Science	KS1
Range of subject-specific data embedded in environment (e.g. rock samples, river flow data, animal or plant information, ecosystem data)	…using multiple sources of increasingly complex information	Geography	KS3
	Use fieldwork to observe, measure, record and present human and physical features… using a range of methods, including… digital technologies.	Geography	KS2
	Making and recording observations and measurements using a range of apparatus and methods	Science	KS4
	Interpreting observations and other data, including identifying patterns and trends, making inferences and drawing conclusions	Science	KS4
	Relationships in an ecosystem	Biology	KS3
Landscape components of	Understand… the key processes in… physical *(and potentially also human)*	Geography	KS3

[45] Scotland's curriculum for excellence, https://scotlandscurriculum.scot [accessed 14 October 2019]
[46] Contributed by Tom Argles, Faculty of Science, The Open University, UK, tom.argles@open.ac.uk

VFT feature	Curriculum	Subject	Level
virtual world: models or scans of rock, soil, natural, artificial or archaeological landscape features, plants, water bodies	geography		
	Describe and understand key aspects of: biomes and vegetation belts, rivers, mountains, volcanoes and earthquakes, and the water cycle… types of settlement and land use	Geography	KS2
	Make and record observations and measurements using a range of methods for different investigations; and evaluate the reliability of methods and suggest possible improvements	Science	KS3
Tools embedded in (or linked to) the virtual world, e.g. compass; grain scale; virtual microscope; other potential tools/sensors	Use the eight points of a compass, four and six-figure grid references, symbols and key (including the use of Ordnance Survey maps)	Geography	KS2
	Use simple compass directions… and locational and directional language… to describe the location of features and routes on a map	Geography	KS1
	applying a knowledge of a range of techniques, apparatus, and materials to select those appropriate both for fieldwork and for experiments	Science	KS4
	use appropriate techniques, apparatus, and materials during fieldwork and laboratory work, paying attention to health and safety	Science	KS3
Equipment selection activity	Evaluating risks both in practical science and the wider societal context, including perception of risk	Science	KS4

While Table 3 considers features in existing or planned VFTs, future virtual world applications could incorporate a much wider range of natural environments, such as underwater marine ecosystems; glacial or polar landscapes, the atmosphere, other planetary bodies, or outer space – adding multiple links to parts of the schools' curricula not mentioned here (e.g. Physics, Chemistry) as well as opportunities for HE.

My interests are in heritage sites ... with similar challenges and also role-play scenarios for interpreter services industry (Science Circle workshop)

The historical recreations sound like a good angle for history degrees. (Science Circle workshop)

I have also recently helped colleagues in the foreign languages bring their students to the Smithsonian Day [for] activities and displays in SL [Second Life. a 3D virtual world]. (educator in Science Circle workshop)

VEs and 3D VFTs facilitate experiences and visits related to the curricula where it may not be possible to conduct physical fieldwork – such as a problem-based learning scenario of visiting a coral reef ecosystem, discussing the threats to the biodiversity in that coral reef and explaining what is being done and could be done to reduce the effects of the threats[47]. Another example could be visiting a rainforest in Ghana and identifying the risks to it, evaluating the impact of human activity, how the logging could be carried out in a sustainable manner and the ways in which the rainforest could be a source of income for local people[48].

> *I think this [3D VFT] is a great idea and I give it my full support. It [Virtual Skiddaw] is certainly an impressive looking simulator compared to any attempts at creating "virtual" field trips I have ever seen. I can see the uses it could have alongside the real field trips we offer and obviously as a distance learning tool." (survey; fieldwork specialist)*

We haven't presented a similar Table (as Table 3) for FE or HE as our evaluation of the relevant documents (e.g. QAA's Subject benchmark: Geography[49]) has shown that activities for several of the 'skills, abilities and attributes' (some of those similar to the ones listed in Table 3) can be developed and practised in 3D VFTs. Further, our experiences with *Virtual Skiddaw*, which was developed to support second-level undergraduate geology, have affirmed the role of 3D VFTs to support the development of fieldwork skills in FE and HE contexts.

Advantages for students

Development of fieldwork skills: Examples of fieldwork skills that can be developed and practised in VFTs are: understanding ordnance survey maps and developing cartographic skills, interpreting cross-sections and 3D relationships, using equipment/kit such as the compass, microscope and grain chart, and practising rock-sketching skills *(workshop as a part of the Geological Society of London conference, Plymouth and eSTEeM Conference)*[50]

> *…we feel that this could be a useful tool for rehearsing geographical skills - very important revision tool; it gives life to the curriculum" (meeting with an assessment body)*
>
> *…active learning, learning through doing etc. (survey; educator)*
>
> *…to help students link theory with the real world (survey; educator)*

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[47] Example from the sample assessment materials of Geography A (Geographical Themes) (9-1) – J383 (from 2016). The world around us, http://www.ocr.org.uk/qualifications/gcse-geography-a-geographical-themes-j383-from-2016/ [accessed 14 October 2019]
[48] Example from the sample assessment materials of Geography B (Geography for Enquiring Minds) (9-1) - J384 (from 2016). Geographical Exploration, http://www.ocr.org.uk/qualifications/gcse-geography-b-geography-for-enquiring-minds-j384-from-2016/ [accessed 14 October 2019]
[49] QAA Subject benchmark statement: Geography, https://www.qaa.ac.uk/docs/qaa/subject-benchmark-statements/sbs-geography-14.pdf. Also, see QAA Subject benchmark statement: Earth sciences, environmental sciences and environmental studies, https://www.qaa.ac.uk/docs/qaa/subject-benchmark-statements/sbs-earth-sciences-14.pdf [accessed 14 October 2019]
[50] The italicised text in the parentheses is the source of data/quote.

In *Virtual Skiddaw*, students can make observations on scales ranging from the kilometre down to the micrometre, using the thin sections in the linked Virtual Microscope. Students are advised to record their observations, including sketches, in a physical field notebook (rather than on-screen) - giving them the skills of how to maintain a physical field notebook. Each site in the VFT has a few specific sketch-points marked, so students can practise sketching and compare their results, or a tutor can set a sketch from one particular viewpoint as an exercise. Another field skill involves orientation using a compass. The compass feature built into *Virtual Skiddaw* is not an exact facsimile of the real instrument, but it allows students to gain familiarity with the concepts of azimuths and bearings for wayfinding and description of geological features. For instance, to specify a sketch from a particular sketchpoint the direction in which to view the exposure is essential (and not always obvious); the compass is a handy tool for this.

Pre-field trip orientation and preparation: For many students, fieldwork brings a 'fear of the unknown', especially if the outdoor environment is relatively unfamiliar to them. Introducing aspects of fieldwork through a VFT helps bridge this gap between their digital experience and expertise, and the natural environment/ Some examples are: introduction to the concept of fieldwork for novices, familiarisation with the area and the context in which the learning activities will be carried out, orientation, to understand health and safety requirements and selecting the 'right' equipment for the location, weather and planned activities.

> *…if they [3D VFTs] are able to make them prepared for a physical field trip - it is a really good idea - students like to get into rivers and on the beaches - river studies - flow meters - students collect the data - so, how they could be prepared for real-life work by having access to the kinds of data that they will be collecting (meeting with an assessment body)*
>
> *The virtual field trip will help students (and teachers) to prepare for the trip e.g. by giving them an idea of the terrain and particular features that they should look out for. Obviously, the virtual world doesn't replicate the experience of bad weather conditions, low visibility or other distractions etc. that they might encounter on a real world field trip. Therefore, I suggest that this type of activity may help to focus a student's mind on the real, physical world that they will encounter. (eSTEeM poster session; and HE educator with EU-wide experience of developing learning materials for FE and HE)*

Post-field trip de-briefing, reflection and revision: An educator can use a VFT to de-brief the students after a physical field trip, or students could use it for reflection after the physical field trip, or as a revision tool ahead of examinations. The de-briefing and reflection will help reinforce the concepts, observations made and interpretations of the data collected. A de-brief of this kind that promotes reflection will help consolidate learning. A VFT will also help fill any gaps encountered in the data collection phase during a physical field trip.

In our service design workshops, school students mentioned that there were no opportunities to reflect on the experiences after the physical field trip, either in the form of presentations or situating the field trip in their learning and assessment. *(Service Design workshop)*

I think this [VFT] can be useful too, as a reminder of the locations and techniques used, as a framework in which the actual data can be logged and aid to writing up. (eSTEeM poster session; an educator with over 10 years experience of taking 16-18 years old to ecology field trips)

After the real world field trip, a virtual world may be used to aid students' reflection on the experience, perhaps by revisiting features of particular interest to find out more or revising concepts that they didn't grasp the first time round. (eSTEeM poster session and a follow-up email; an HE educator with EU-wide experience of developing learning materials for FE and HE)

Extension of field trip experience to homes (access from home for socialisation and collaboration): If students were able to access VFTs in their homes, their parents would also be able to view the locations that are being considered for physical field trips. The opportunities for students' exploratory learning will be greater - which will enhance student engagement and motivation for outdoor fieldwork. In addition, the multi-user environment allows for other students and the educators to come together to have an induction ahead of a physical field trip and to work on activities within the VFT.

Greater effectiveness of physical field trips (in terms of learning and engagement): The preparation in a VFT will make the time spent during a physical field trip more effective. Students can focus on collecting data and making sense of it in the field, rather than having to learn basic fieldwork skills *in situ*. Examples of such skills are: 'how to collect data', how to maintain a fieldwork notebook and do field sketches, or how to use tools such as a grain chart or compass. *(eSTEeM conference)*

Virtual exercises where students can encounter species as they will look in their natural habitat - size is always an issue here are recognising species from photographs – [it] does not prepare you for how they will look in reality – (usually overgrown with other species!), and learning how to use keys would be great preparation. I would think the same applies for geological specimens. (eSTEeM poster session and a follow-up email; an educator with over 10 years experience of taking 16-18 years old to ecology field trips)

The pedagogical advantages of VFTs have also been identified in the GEES subject centre, Learning and Teaching guide[51]: instant access to learning environments, multiple revisiting of field sites, to view seasonal variations, to slow down or speed up natural processes, to compare and contrast different environments and processes, and ability to display non-outcrop data (e.g. seismic lines, geochemistry). However, similar to our views, this guide emphasises that VFTs should not be a replacement for the real fieldwork experience.

Greater efficiency of physical field trips (in terms of time and number of physical field trips): Initial preparation, practice of fieldwork skills and induction in the VFT, would release additional time for extended activities and for deeper immersion in

[51] Maskall, J. and Stokes, A. (2008) *Designing effective fieldwork for the environmental and natural sciences*, GEES Subject Centre Learning and Teaching Guide, The Higher Education Academy Subject Centre for GEES, Plymouth University, Plymouth.

inquiry learning during the physical field trips. Alternatively, the time could be used to run more physical trips (to alternative locations for example). *(eSTEeM conference; meeting with the Ordnance Survey)*

> *Much time in the field is wasted because students aren't adequately prepared and able to start work immediately. In biology (my field) species recognition is a particular problem and it takes a lot of time getting students to recognise and name species in order to carry out quantitative fieldwork.*
>
> *... practising techniques in a virtual field trip (sampling and counting) can only help students hit the ground running when out and about. Briefing students in the field is challenging (making yourself heard) so on screen briefing and a dummy run through would be invaluable. (eSTEeM poster session and a follow-up email; an educator with over 10 years experience of taking 16-18 years old to ecology field trips)*

Risk-assessment for physical field trips prior to going on a physical field trip: Health and safety considerations and risk assessment are critical aspects that educators and managers of field trips have to plan for and inform students and parents ahead of a physical field trip. Interaction within a VFT and evaluating the risks and dangers ahead of the physical field trip can help in the planning for possible risks in physical fieldwork.

> *Virtual field trips can also help risk assessment planning. (eSTEeM poster session; an educator with over 10 years experience of taking 16-18 years old to ecology field trips)*

As an aid when on physical field trips: If the VFT can be seen on mobile devices while on the physical field trip, it can support physical fieldwork.

> *If you could take the onscreen version out with you on a mobile device and if it matched or complemented the real field site then so much the better. (eSTEeM poster session and a follow-up email; an educator with over 10 years experience of taking 16-18 years old to ecology field trips)*
>
> *It would be helpful for orientation by looking at the maps being draped on the mountains in the App and match it with the landscapes when out in the field (e-learning consultant in JISC Digifest)*

Being able to complete physical field trips that may have got disrupted by weather or other interruptions: If the VFT has the same location as the physical field trip, activities that would otherwise be 'lost' can be conducted in a VFT. (*meeting with an assessment body)*

As a supplement to physical field trips: In all the evaluation workshops that we have run at HE level or with school-teachers (with UK and non-UK educators), there is a common accepted view that STEM funding is in decline. So, VFTs may have a greater role to play when students have limited opportunities to attend physical field trips – and, therefore, a combination of physical field trips and VFTs can provide a richer learning experience than being constrained to fewer physical field trips. *(across all the data collection modes)*

> *With real life trips becoming more difficult, there will be a growing demand for virtual trips. (Science Circle workshop)*

Combining realism and non-realism for enhanced engagement and learning experience: 3D VFTs facilitate experiences of processes and locations that may not be possible or extremely difficult to arrange in real life: draping maps over mountains and other landscapes, studying the foreshore through changing tides, investigating the marine life on the ocean floor, investigating desert dunes that may be difficult to visit for UK students; or being able to visit spaces that are 'protected' in the real world, where physical visits and footfall is highly restricted. *(Geography Teachers Network Meeting, Milton Keynes; meeting with an assessment body)*

> *We can visit protected spaces virtually as well so there will be less of a 'footprint' in the area... (Science circle workshop)*
>
> *Potential donors can see WHY we need to save a location or what is special about it... (Science circle workshop)*
>
> *Dry land content at A Levels - sand dunes required for fieldwork to take place - that will be very helpful in VFTs (meeting with an assessment body)*
>
> *Yes, we could build sand dunes in Kuwait, for example. Somebody goes and does [the digital photogrammetry of] the dry land in Kuwait. (response by the researcher to the dry land comment)*

There are also non-realistic interactions within a 3D VFT that can aid learning and student engagement (as in *Virtual Skiddaw*): for example, being able to fly to different sites within a location; or flying to get an aerial view of the location; teleporting to different sites; using a virtual microscope within the VFT; being able to fade other avatars in case they come in the way while making observations; or viewing cross-sections of the landscape to view the geological characteristics.

Potential of investigating urban environments in 3D learning spaces: Even though urban environments can be modelled and developed in 3D environments for study of urbanisation, the clutter in urban environments can make them difficult to model as compared to open landscapes and seascapes.

> *yes possible - will involve all the activities that we do anyway - such as digitising, modelling but it is harder for urban environments, there will be so much clutter (researcher's response to a query from the assessment body)*

Replacement or near-equivalent experience for students with mobility and other constraints: VFTs could be useful for children and young people who are unable to go to physical field trips due to health or mobility constraints.

> *…my school is very rural... Field trips simply can't happen. This gives us an avenue and they enjoy it. Adds incredibly to the curriculum. (Science Circle workshop)*

> *Yes, that is one of the biggest advantages... give experience to those who would find it difficult to experience in person.... (Science Circle workshop)*

In addition, VFTs will provide a rich experience of practical fieldwork to pupils in pupil referral units[52] who have been excluded or cannot attend mainstream school for various reasons: for example, children with behaviour issues, those who have short- or long-term illness, school phobics, teenage mothers, pregnant teenagers, or pupils without a school place.

> *Have you heard of the pupil referral unit where students are taken out of mainstream education due to mental problems or behavioural problems or any other problems with the family - but they have 'right to access' - small number of students so getting them to do field trips might be difficult - with 6th Formers, access to finances is difficult - and, therefore, giving them access to case studies is challenging - so, I do think that VFTs will be helpful for accessibility. It will open the doors for them particular when you saying that VFTs can be used for different subjects like Geography, Geology and will bring the curriculum "alive". (meeting with an assessment body)*

Facilitates collaboration among students and interactions with the educator(s): A 3D multi-user VFT facilitates collaboration amongst students for group working and to foster team-working skills in geographically dispersed situations (e.g. while doing homework, or studying at a distance, or collaborating with other institutions). If the 3D location caters for activities on more than one discipline, students from different disciplines can interact.

For example, A-level Computing students designing and developing artefacts in the 3D environment – e.g. model of a brain which Biology students interact with for conducting some learning activities, and also give feedback to their Computing counterparts about the design of the brain's model.

In-world collaboration with local schools, other schools in the country and also with international schools is a possibility in 3D virtual environments.

> *"One Unity3D application (founded by MIT Media Lab) featured ocean environments and invited users to create fish, etc., co-operative building..." (Science circle workshop)*

Development of spatial literacy skills: Spatial literacy is a fundamental skill in geography, earth and environmental sciences, and is considered a key aspect of the learning process for students. Realistically rendered 3D landscape visualisations or being able to drape 2D maps onto 3D landscapes can support the development of students' spatial literacy skills: for example, a sense of location to find a place on a map when out in the field, developing map-reading skills, recognising landmarks, and comprehending orientation and direction.

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[52] Children outside mainstream education: https://www.gov.uk/government/publications/2010-to-2015-government-policy-children-outside-mainstream-education/2010-to-2015-government-policy-children-outside-mainstream-education#appendix-1-alternative-provision [accessed 14 October 2019]

I enjoyed the flying experience and being able to see from a bird's eye view (Year 9 school student, Manchester)

For example, in *Virtual Skiddaw*, the user can explore the virtual landscape by walking and experience a view similar to that of physical fieldwork; or by running they can accelerate that visualisation beyond the speeds achievable in the field; and by flying over the landscape they enjoy perspectives impossible during a physical field trip. The ability to raise a slice of the subsurface up for viewing 'above ground' encourages the user to start constructing mental models of the geology underground.

Simply sampling this rich menu of different views provides valuable practice in switching back and forth between different dimensional perspectives, building confidence in 3D visualisation. Becoming accustomed to seeing geological details in relation to their wider context also sets a useful benchmark for how to frame their future observations of exposures in the field. So a VFT session might be ideal for students preparing to embark on fieldwork - especially independent fieldwork - for the first time.

Learning science through inquiry and problem-based learning: Some of the key features that support inquiry-based learning and problem-solving in 3D VFTs are: simulations in 3D VEs - both realistic and non-realistic, to be able to bring in real-time and real data for a specific location and within that location in a 3D VE, to be able to collaborate in a multi-user environment, and the synchronous interactions with experts, educators and fellow-students.

Inquiry-based learning[53] is an approach of CLT that engages students in "what-if" scenarios and investigations to seek solution or explanation or decision to some kind of query. It involves observing, critical analysis and reflection. Data collected during physical field trips can be brought into the 3D VFT for that location/site or process to analyse and synthesise the data, and to communicate their findings. The realistic setting (the 3D context) and the ability to collect more data and to analyse it individually or in a group within the 3D VFT supports inquiry-based learning. For example, students may walk into a 3D landscape that is a popular walking site in Cumbria. Students could enquire about the impact of walking on the environment such as soil erosion, congestion, pollution, and disruption to farming and disturbance to wildlife. Aided with data, students can assess the impact of tourism and come up with solutions on how the impact could be reduced and the tourism could be developed in a sustainable manner.

Problem-based learning[54] is also another approach of CLT that uses real-world problems as a context for students to apply critical and problem-solving skills to generate solutions. Using their prior knowledge, students analyse the problem and elaborate on solutions through discussing, critiquing and peer-review. For example,

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[53] Jennings, L. B. and Mills, H. (2010) *Inquiry-based Learning* in the *Encyclopedia of Educational Reform and Dissent*, Thomas C. Hunt, James C. Carper, Thomas J. Lasley II and C. Daniel Raisch, SAGE Publications, Inc.

[54] Savery, J. (2010) *Problem-based Learning* in the *Encyclopedia of Educational Reform and Dissent,* Thomas C. Hunt, James C. Carper, Thomas J. Lasley II and C. Daniel Raisch, SAGE Publications, Inc.

students could 'drape' OS map (an extract) on the landscape under consideration for a wind farm and discuss the possible impact of the wind farm on the local area[55].

Advantages for educators

Getting students prepared for a physical field trip: A VFT can provide a safe induction environment: for example, to guide about the equipment and kit requirements for a physical field trip; attend tutor-briefings ahead of a physical field trip; and socialise with fellows-students ahead of a field trip in a distance-learning or part-time education contexts. If the VFT has the same location as the physical field trip, getting familiarised with the location and carrying out learning activities as a preparation for the physical field trip would be helpful. In fact, a VFT would act as a catalyst for inspiration and engagement with physical field trips for both students and educators.

Enable educators to rehearse and plan before a physical field trip: The educators could use a VFT as a tool to plan activities for physical field trips and lesson plans for classroom sessions. Some educators find planning and running a physical field trip daunting; a VFT could help break down those inhibitions and encourage field trip provision.

The Ofsted' report[56] recognises the excessive educator workload when planning for physical fieldtrips *"… to visit locations beforehand and to plan them in their own time"* [p.23]. Looking at a VFT will help them to understand the requirements of the physical field trip, get acquainted with the area if they haven't been there beforehand to plan the health and safety requirements. The Ofsted report also mentions about the time and effort required in drawing up health and safety procedures for physical fieldtrips. Planning in VFTs ahead of physical field trips will provide reassurance and inform risk assessment during the preparation phase of field trips.

> *yes, absolutely VFT will be perceived as a useful tool for educators to prepare their lesson plans for physical field trips; but the skills are varied. (meeting with an assessment body)*
>
> *familiarise themselves with locations that they haven't been before (meeting with an assessment body)*

Continuing Professional Development (CPD) for educators: A VFT will help towards CPD of educators, enhance their confidence and even encourage them to carry out more physical field trips, as the VFT will make the planning easier for them.

The *Outdoor Science* report[57] recognised that one the key challenges facing schools in carrying out fieldwork is teachers' confidence and expertise in teaching

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[55] Example from the sample assessment materials of Geography A (Geographical Themes) (9-1) – J383 (from 2016), *Living in the UK today*, http://www.ocr.org.uk/qualifications/gcse-geography-a-geographical-themes-j383-from-2016/ [accessed 14 October 2019]

[56] Ofsted report: *Learning outside the classroom: how far should we go*? https://dera.ioe.ac.uk/9253/, [accessed 14 October 2019]

[57] The Association for Science Education Outdoor Science Working Group's (OSWG) report, *Outdoor Science*, sponsored by the Nuffield Foundation, 2011, https://www.nuffieldfoundation.org/outdoor-science [accessed 14 October 2019

and learning outdoors. The report also discusses the challenges for building CPD dedicated to fieldwork for newly-qualified teachers and technicians: *"..CPD for early-career teachers is important and needs to include support to biology specialists for 'thinking outside the box', developing an open mind to the potential of fieldwork across the sciences amongst all science teachers and offering ideas and resources to stimulate new practices*" (p.9).

As per the NFER report[58], the main barrier for undertaking science-specific CPD is the financial burden of accessing CPD [p.5]. If the (same) VFT that is aimed for teaching and learning is also used for CPD, it would make it cost-effective for educators to undertake CPD. In fact, the report emphasises the role of internal CPD: "*CPD leaders recognise internal CPD as the most effective form as it is tailored to the needs of the school and the effects can be on-going*" [p.4].

> *CPD for science teachers in the UK is poorly supported and undervalued in schools. Also scientists don't talk to geographers etc. There is an opportunity here [with the VFT]. (email correspondence with a field studies expert)*

Learning analytics: In the *Virtual Skiddaw App*, the user's (student) interactions within the 3D environment can be recorded and presented for analysis by educators. So, if the (recorded) data indicates that a student or a group of students are unable to complete a particular activity, then the educator can plan some interventions such as: checking if there is a problem in the navigational design – perhaps the students never find their way to that activity; or the activity requires some additional explanation by the educator or in-world guidance to support the student(s); or perhaps the activity itself needs to be re-designed for greater clarity and comprehension.

By being able to record and monitor students' interactions (learning analytics) in a 3D VFT and to plan and implement personalised interactions to support a specific student or a group of students provide additional tools to the educator to monitor student learning and achievement – and, thereby, influence student attainment: *"The resulting data-driven decisions can support optimal use of both economic and pedagogical resources while offering a structure for improved educational outcomes*"[59].

7.2 Requirements for the 3D virtual field trip App

The demonstrations of *Virtual Skiddaw* and user-centred evaluations yielded the following requirements for the *Virtual Skiddaw* App and for the design of 3D VFTs, in general.

A 3D terrain that caters for multiple disciplines: If the same location or 3D terrain hosted several different strands of learning (in different disciplines such as geology, geography, ecology, environmental science, hydrology, engineering, archaeology), the 3D VFT would be more widely adopted and users would gain much richer

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[58] National Foundation for Educational Research (NFER): An investigation of Headteachers' and teachers' views towards science-specific CPD, https://www.nfer.ac.uk/an-investigation-of-headteachers-and-teachers-views-towards-science-specific-cpd/ [accessed 14 October 2019]
[59] 7 things you should know about analytics, https://library.educause.edu/resources/2010/4/7-things-you-should-know-about-analytics [accessed 14 October 2019]

experiences. There are potential synergies between different disciplines: geology and geography; ecology and environmental science; computing and any other discipline; and archaeology and geography.

> *If the same location or 3D terrain hosted several different strands of learning (in different disciplines such as geology, geography, ecology, environmental science, hydrology, engineering, archaeology), the 3D virtual field trip (VFT) service would be more widely adopted and users would gain much richer experiences (meeting with a field studies expert)*
>
> *generating a [3D] landscape (e.g. Skiddaw, Snowdon) and different disciplines could generate lesson plans in that landscape - so, we could have Geology activities, or Forensic activity for Geo-scientists, or ecology learning activities or something related to Environmental Sciences within the landscape - so, how a landscape serves more than one discipline (workshop as a part of the Geological Society of London conference, Plymouth)*
>
> *Cross-disciplinary uses might make it more widely acceptable... I could see having applications in history or change of the environment, sampling (statistics), ecology, etc." (Science Circle workshop)*

A 3D terrain that caters to more than one discipline will maximise the benefit from a single location, and increase the potential for adoption across schools and higher education institutions. Such an environment would be more financially viable for an institution, particularly schools - which implies that they pay for one VFT that meets the requirements of more than one subject/teacher.

> *biggest selling point is being able to use it across multiple lessons, not just geography (member of School's Senior Leadership Team)*
>
> *however, for access to field trips I can see them making a flat subscription fee, especially if it's multidisciplinary." (Science Circle workshop)*

Integration of avatar clothing/kit selection with different conditions (weather, terrain, activities): This requirement is to more closely mimic the planning and safety requirements of a physical field trip. *(workshop as a part of the Geological Society of London conference, Plymouth; comment from current OU student)*

Having a greater selection of avatars: The *Virtual Skiddaw* App has six avatars. Having a wider choice of avatars for different ages and ethnicities will serve school students and students of FE and HEIs. *(Science Circle workshop)*

Flexibility to be able to adapt individual avatars: It is common in 3D virtual worlds to be able to modify the avatars to create a sense of individual identity. Further, avatars can be customised to represent the institution; this could be useful when more than one institution come in-world to interact collaboratively. *(researchers' experiences and research on identity in the 3D virtual world, Second Life)*

Having the ability to be able to download the VFT: Institutions would like the option to download the VFT on their local servers for more control to access, security and adaptation for their context and students. However, multi-user interactions won't be possible in this configuration.

> *I'd prefer to have a downloadable application rather than a browser plug-in based app – more reliable and gives me more control (school ICT manager)*

Bringing in real data within the 3D environment: Being able to integrate real data for interrogation and practise without having to visit the physical locations. *(meeting with an assessment body)*

Bringing in real-time data within the 3D environment: Being able to integrate real-time data via sensors within 3D environments for interrogation by students at far-way distances from the physical locations. *(meeting with an assessment body)*

> *Linking to sensors deployed in the physical world – some of these could be FSC [Field Study Council) sites – so that learning activities could be embedded in the proposed 3D landscape that would utilise real data (and visualisations) from the sensors and streamed within the 3D VFT and/or from real-time data (and visualisations) and streamed within the 3D VFT. In the virtual world, users (individually or collaboratively) will be able to organise this data, analyse the data and draw interpretations within the context of the (actual) landscape but in a virtual world. (OU Educators meeting on 3D VFTs)*

Scope for having multi-institutional virtual field trips for socialisation and collaboration: 3D VFTs are multi-user environments. It is not uncommon in Second Life, a 3D virtual world, for educators and students from all over the world to meet up in the 3D learning spaces for meetings, discussions and field trips. In fact, it is the 'international' educational community in Second Life that has made Second Life as the venue for annual international conferences (e.g. Virtual Worlds Best Practices in Education) and weekly educational forums (e.g. Science Circle and Virtual World Educators Roundtable forum). Interacting with students and educators from other institutions (nationally and internationally) will provide insights about global issues and learning opportunities beyond one's classroom and school.

> *…especially if they could socialize with other students from around the world when they do it!" (Science Circle workshop)*
>
> *[it will provide] ability to collaborate; global collaboration (survey; educator)*

Scope for (virtual) international field trips: It may not be possible to visit rain forests in Ghana, or the coral reef in Australia, or to experience the marine life on ocean floors. However, the simulations in 3D VFTs provide opportunities for experiencing places and phenomena in a virtual environment.

> *"Distance to certain areas... Vic [educator] probably doesn't take his students from the USA to Stonehenge UK on a weekly basis... here he can" (Science Circle workshop)*

7.3 Challenges for adoption of VFTs

This section outlines the challenges for adoption of VFTs from our empirical data.

Being convinced about the role of VFTs: Our experiences of demonstrating *Virtual Skiddaw* in this project and in other contexts have been positive and there has been an easy acceptance of the concept of a VFT. However, there could be resistance to the ideas of VFTs – and especially if it is perceived as replacing physical fieldwork. Educators in our survey and workshops expressed the following concerns:

> *I am gravely concerned about how virtual scenarios are looked increasingly upon by university management as viable alternatives to genuine fieldwork, idealised learning scenarios do not offer any alternative to the development of real field observational skills, and they offer the students an unrealistic alternative to real geology, which is never available for genuine geological work." (survey; educator)*
>
> *don't recommend this type of poor immersive environment as replacement for real life immersive learning. (survey; educator)*
>
> *I would need to know that it doesn't replace real field trips." (survey; educator)*
>
> *as long as virtual interaction are seen as a supplement to real world scientific instruction and not a replacement for the subtle nuances and processes required to do good science in the real world… (Science Circle workshop)*

Some educators may not be convinced about the role of VFTs in supporting physical fieldwork in the pre- and post- contexts of physical field trips.

> *why such a briefing is necessary, under what condition are these VW [virtual world] explorations are needed before going onto a real site." (survey; educator)*

Some educators/institutions may not be convinced until they have the opportunity to try out the 3D VFTs:

> *but even before that you have to convince people of the utility of this... they have to experience it themselves to become 'believers'…. It also goes back to the 'virtual frog' phenomenon - some people are convinced that face-to-face is the only way to experience something… (Science Circle workshop)*

As with any technology, some time is required for induction and training, and also the concerns of educators about the etiquette and other guidelines for interaction that they should set up for their students.

> *I would have trouble finding the time (survey; educator)*
>
> *orientation, training, practice, safety, logistics...[are some of the challenges for adoption] (Science Circle workshop)*

Digital literacy skills of educators: The digital literacy skills of educators in schools, FE, and HE vary considerably.

> *With GIS also, we have found that educators have different level of expertise; not all teachers are IT literate. (meeting with an assessment body)*

The adoption of VFTs will depend upon the institution's leadership but, most importantly, on the individual educator's motivation and their digital literacy skills.

We suggest a digital skills audit to assess the educator's digital skills so that the induction and CPD programme could be personalised for the educator concerned. In fact, a similar audit for students could be also useful to determine the IT support and training that the students will require. Such an audit will also help to ascertain the educator workload and the time that they would need to enhance students' digital literacy skills.

Costs to schools: The affordability of adopting VFTs will depend upon the development costs but also the costs involved in induction and training of educators to include VFTs in their provision. Decisions will be based around an assessment of the educator workload in introducing VFTs in the curricula weighed against the benefits to educators' skills and confidence, their CPD, impact on teaching practice, and possible impact on student attainment and achievement.

> *A financial model based on virtual fieldwork exclusively might not create sufficient revenue; but if fieldwork became a subset of much broader teacher CPD, initial teacher training, that might create sufficient critical mass? (meeting with a field studies expert)*
>
> *costs, technology requirements, technological training and support needed, student interest in using virtual field trips, confirmation that these would be in addition not instead of existing field provision (survey; educator)*
>
> *cost, quality and locations [are the challenges] (survey; educator)*

Capability and capacity of schools to design and develop (involving digital photogrammetry, 3D modelling): Our investigations have shown that schools may not be in a position to develop 3D VFTs and to contribute VFTs. Designing and developing 3D environment and a VFT requires multiple specialist skills and time. However, we hope that an introduction to the scope of 3D environments in education through the use of 3D VFTs will encourage and enthuse the teachers and students to undertake 'digital making' projects which we discuss in the next section.

Availability of funding in HEIs or access to grants to design and develop 3D VEs: Through our investigations, we envisage a model that HEs will develop the 3D VFTs and which will be introduced for adoption by schools, FE colleges and other HEIs. However, realising such an 'ideal' scenario will depend upon how 'generic' the VFTs are that are developed by the HEIs to enable their adoption over the entire spectrum of educational institutions (schools, FE and HE institutions).

Further, the copyrights of the artefacts and other licensing aspects will need to be negotiated.

> *Cost, what developments are in place for different trips and could we work to help propose new trips? How will the licence work? i.e. could students do it on their computers at home or would there be a restricted campus only licence for example (survey; educator)*

Realising the VFTs will most importantly depend upon access to grants/funds to HEIs to develop 3D VFTs, and/or the possibility of setting up cross-disciplinary (e.g. design and computing; arts and earth sciences; biology and computing) final year graduate or post-graduate student projects or PhD projects to develop 3D VFTs and associated materials.

IT infrastructure and support in institutions: The levels of IT infrastructure and support vary across schools and other institutions.

> *Some schools have just one PC for the entire classroom while other schools are buying iPads for each student. (meeting with an assessment body)*
>
> *funding for new IT infrastructure/support always an issue" (survey; educator)*
>
> *faculty can use whatever they choose, but IT will only support what they deploy. Cost and possible extent of use across the university would be considered by IT before a new deployment. (survey; educator)*

While our investigations haven't revealed any serious constraints or reservations by the IT managers, the infrastructure (availability of equipment, the operating systems that they support, network bandwidth) and IT support to educators and students will be critical factors for the adoption of VFTs. The diversity in the firewalls in the networks of individual institutions and, consequently, the access to the Cloud server for multi-user collaboration, the Web-browsers that they support and the plug-ins that these browsers allow are some of other IT considerations that will influence the adoption of the 3D VFTs in individual institutions.

> *Our external access is controlled by the Local Authority – so you need to get them on side (ICT manager at an Academy schools)*

8 Reflections

This section outlines a number of considerations for realisation of VFTs based on reflections from this project. We have distilled these aspects from our investigations and which may require further discussion and reflection.

Digital making by students: involvement of students in developing 3D VEs

Digital making is distinct from using digital devices – it is a way of understanding how technology works. It is '*learning about technology through making with it*'[60]. Schools are digital making hubs. Digital making embodies interdisciplinary work and cross-curricular learning. Designing and developing a 3D virtual landscape or 3D artefacts for STEM education using 3D modelling skills will join up 'digital making' with ICT curriculum as it will provide opportunities to students at KS3 and KS4 to develop computer science skills[61]. For example, students could develop a 3D model of a brain that will be used by Biology students; the inputs and critique of Biology students and teachers will involve interdisciplinary dialogues and interactions giving students the opportunity for cross-curricular learning, developing team-working skills and about developing software systems that meet the user's requirements[62].

This opportunity of digital making is in accordance with the recommendation in NESTA's report on Young Digital Makers: '*There needs to be greater access to a variety of making opportunities catering for a wider variety of young people and their different interests, ages and genders*'.

Digital technology-enabled assessment: can VFT be a part of assessment?

The ETAG report[63] (p. 32) states: '*Schools that were making extensive use of digital technology reported that there was a mismatch between what they were doing and what their students would be assessed on. This meant that they reduced their use of digital technology and moved back to traditional forms of teaching about three months before high stakes national assessments*'.

We are not suggesting a VFT as a means for assessment. Currently, the diversity in the provision of computing equipment and digital literacy of students and educators does not allow for a VFT to be a part of the assessment.

[60] NESTA's report on Young Digital Makers: Surveying attitudes and opportunities for digital creativity across the UK, March 2015, http://www.nesta.org.uk/publications/young-digital-makers [accessed 14 October 2019]
[61] National curriculum in England: computing programmes of study, September 2013, https://www.gov.uk/government/publications/national-curriculum-in-england-computing-programmes-of-study/national-curriculum-in-england-computing-programmes-of-study [accessed 14 October 2019]
[62] There is already evidence of different disciplines interacting to create 3D VEs for learning and teaching in HEIs: *Virtual Skiddaw* is a collaboration between OU's School of Computing and Communications and School of Environment, Earth and Ecosystem Sciences; 'Geological mapping in a virtual world' is a joint initiative between Leeds College of Arts and School of Earth and Environment, University of Leeds, http://www.slideshare.net/angrybeth [accessed 14 October 2019]
[63] Education Technology Action Group: Our Reflections, 2015, http://etag.report [accessed 14 October 2019]

schools are not ready for computer-based systems for assessment. IT in schools is not up to speed on this. Computer-based assessment is really not on the cards as not all students will be able to access. The take up will be minimal. The main thing holding back is access within schools. We understand that there are major and amazing opportunities but they are not on the horizon. (meeting with an assessment body)

However, a VFT is a learning space for preparation, revision and reflection – an environment to develop and practise fieldwork skills and to prepare for assessment. Further, the features and learning activities within a VFT match with what the students are assessed on – hence, we expect a VFT to become an integral part of the curriculum.

Difficulty with identifying the impact of 3D VFTs on attainment

Nesta's report on Decoding Learning[64] concluded that the *"new technologies cannot, in themselves, improve learning. The context within which they are used is crucial to their success or otherwise"* (p. 53). Several factors constitute this *context of learning* and consequently the impact on learning and student attainment: for example, the knowledge and skills including digital literacies of the people involved (e.g. educators, students, IT support), the IT infrastructure at the institution (network speeds, availability of equipment) and in homes (access to broadband and computing resources), willingness of the stakeholders (including parents; assessment bodies) to adopt technological innovations, costs, and the privacy, security and safety of the learning environment. We suggest that institutions apply 'The Learning Context' framework in Fig. 4.1 of this Nesta report for self-evaluation and as a guiding tool for the adoption of 3D VFTs.

It is anyway difficult to derive causal relationships between the ICT innovation and its effectiveness and effectiveness in learning and teaching.

As Twining et al. (2006, p. 18)[65] state:

'*It is necessary to recognise that education is a complex, dynamic system of interrelationships and of checks and balances (Lesgold 2000). ICT innovations are difficult to assess because they are rarely directly causal (McFarlane et al 2000) and because the context is not a neutral backcloth on which the teaching and learning are played out. While many students, staff and researchers will testify to effective learning in technology-supported classrooms, these are existence proofs of effectiveness rather than the 'hard' evidence required to convince the sceptics of the value of educational technology (Underwood and Dillon 2004).*'

While a 3D VFT will support the effective and efficient conduct of a physical field trip and enable the development of fieldwork skills, it may be difficult to obtain hard evidence to directly link the contribution of the VFT towards summative assessment and attainment. There are other benefits of virtual fieldwork in 3D VEs – developing

[64] Decoding learning: The proof, promise and potential of digital education, (2012). NESTA, http://www.nesta.org.uk/publications/decoding-learning [accessed 14 October 2019]
[65] Twining, Peter; Broadie, Roger; Cook, Deirdre; Ford, Karen; Morris, David; Twiner, Alison and Underwood, Jean (2006) Educational change and ICT: an exploration of priorities 2 & 3 of the DfES eStrategy in schools and colleges. Becta, Coventry, UK.

team-working skills, becoming enthusiastic and feeling motivated for the subject. These effects have the potential to influence positively the choice of science and geography as a future subject to study.

However, students' experiences, comparisons of student-performance data in VFT and non-VFT scenarios, students' level of engagement and enthusiasm with physical fieldwork, student-retention, numbers and level of student-participation are some of the metrics that can provide insights in assessing the impact of 3D VFTs on attainment.

Digital literacy of students: opportunities and challenges

For preparing students for the digital workforce, the House of Lords Digital Skills Committee report[66] has identified that: *'…digital and technology skills should be considered complementary to numeracy and literacy. Digital literacy is an essential tool that underpins other subjects and almost all jobs.*[67]' The inclusion of a VFT in the curriculum supports the goal of digital education and to prepare the students for the future digital workforce. The VFT provides an opportunity to students to purposefully experiment with technology. However, lack of (adequate) digital literacy skills of students could be a barrier for adoption of VFTs in the first place.

Digital literacy of educators: opportunities and challenges

The Digital Skills report (referred above) has identified that teachers may not have the ability to impart digital literacy skills to the students. They have proposed: '*New and existing teaching staff need significant contact with industry to see the latest technologies in action and subsequently pass such knowledge on to young people*'. The report recognises that there is an urgent requirement for industry to provide comprehensive input into the education system and that the government should encourage strong partnerships between the industry and education (paragraph 125). However, lack of (adequate) digital literacy skills of educators could be a barrier for adoption of VFTs in the first place.

Role of VFTs in continuing professional development for educators

The 3D VFT App provides a learning spaces for 'effective' Continuing professional development (CPD)[68] for educators. These spaces facilitate context-relevant reflective-learning on one's own but also enable collaboration within the same institution but also with teachers and experts in other institutions. Teachers can share lesson-plans and experiences synchronously within the 3D learning spaces or asynchronously via forums and mailing lists.

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[66] Make or Break: The UK's Digital Future, February 2015, http://www.parliament.uk/business/committees/committees-a-z/lords-select/digital-skills-committee/news/report-published/ [accessed 14 October 2019]

[67] Digital literacy as important as English and Maths, Parliament warns, https://www.tes.co.uk/news/school-news/breaking-news/digital-literacy-important-english-and-maths-parliament-warns [accessed 14 October 2019]

[68] Twining, Peter; Davis, Niki; Charania, Amina; Chowfin, Aleta; Henry, Fiona; Nordin, Hasniza and Woodward, Clare (2015) Developing New Indicators To Describe Digital Technology Infrastructure In Primary And Secondary Education. UNESCO Institute for Statistics, Montreal. Available from: http://oro.open.ac.uk/42423/ [accessed 14 October 2019]

Use a summer school/summer project approach to get teachers involved early on in site and lesson creation (member of Senior Leadership Team of a school)

Realising interdisciplinary fieldwork

One 3D virtual landscape/location can support interdisciplinary interactions and activities – for example, an activity could involve assessing the impact of a proposed wind farm: the discussions will involve impact on the birds, habitat loss, impact on local residents and the tourism. This interdisciplinary research concentrates on an overlap between ecology, social and physical geography, conservation biology, ecosystem science, and so on. A 3D environment enables students and experts from different disciplines to interact and discuss the impact of the wind farm – without having to travel in the physical world. Role-playing activities could be set up – for example, a local resident, a farmer, a historian, and so on, to enact the various roles/perspectives for analysing this situation.

'*This stress on interdisciplinarity [fieldwork] reflects a belief that the complexity of pressing contemporary social or environmental problems means HE must equip students with the adaptability and holistic thinking to tackle issues which defy disciplinary boundaries*'[69].

A Science HE educator and with extensive past experience of having taught in schools at KS2 and KS3 stages and who attended our poster session in the eSTEeM conference emphasised the significance of interdisciplinary interactions amongst educators and students. She contributed two scenarios (by email and after the conference) from her experiences in school teaching where the inter-disciplinary interactions had had a positive impact on student learning and engagement, and realisation how different disciplines could co-exist within learning activities. Her contributions are included below:

Launceston castle is a Motte and Bailey castle in Cornwall. The secondary school in Launceston where I taught Maths was a large state (comprehensive) school. The History department had a section in its curriculum on Local history and the Mathematics materials we used had a section on co-ordinates that included examples of use including that of archaeologists digging trenches. We therefore put together a combined activity lasting a total of 6 hours, which included 3 trips to the castle. The project was effectively owned by Maths and History with principal aims being to teach a) Maths and History through a local example and b) pilot joint working across curriculum areas. The major positive outcome was amazement from the students (11-12 year olds) that two different "school" subjects could be linked in a reality on their doorstep. The major disadvantage was that we had to juggle lessons a little to get a two hour slot to take them down to the castle- maybe 10 mins walk there and back from the school.

[69] Harmer, N. and Stokes, A. (2014) *The benefits and challenges of project-based learning A review of the literature*, *PedRIO Paper 6*, Plymouth University. https://www.plymouth.ac.uk/uploads/production/document/path/5/5857/PedRIO_Paper_6.pdf [accessed 14 October 2019]

The second example is about an individual student aged 15yrs. He had to do a project for his GCSE Maths and I whilst I did not teach him Maths, I had a parallel group. I was however part of the staff group working with around 30 youngsters on the "Ten Tors" event walks/ camps on Dartmoor organised by the Army. This student was doing really good navigation work with a compass; really good map interpretation to physical domain work; and lots of interpretation of map symbols. An acceptable GCSE project - he was in a bottom set mathematics group- was around map reading. He totally failed to consider it as a project until I TOLD him it would be excellent and he sheepishly asked his Maths teacher. A classic case of the youngster not equating "school work" with his "interest" work on the Ten Tors.

(A Science HE educator with extensive past experience of having taught in schools at KS2 and KS3 stages; poster session at the eSTEeM conference)

Potential opportunities that can stem from bringing in real data sets and locations that can be used by several disciplines

An individual 3D VFT App will provide a 3D landscape of a location and teachers of different disciplines can build activities of this location. Further, different disciplines can draw on the 'real' datasets that will be brought into this location: for example, A level environmental geographers (studying geography) and ecologists (studying biology) could (and do) use environmental quality data (for freshwater etc.).

Scope for collaboration among disciplines and educators

The availability of data rich virtual sites and sites that cater for more than one discipline and/or interdisciplinary fieldwork, as discussed above, will encourage more exchange of expertise, resources and good practice among educators of different disciplines in schools, FE and HE.

Initially this [sharing of resources, good practice, etc.] might happen in a virtual world, but by raising awareness of the potential there might be a response in the real world with teachers seeking out colleagues in other subjects that they have never dealt with before. (email correspondence with a field studies expert)

The collaborative facility of a 3D virtual field trip would provide a valuable resource to facilitate interactions between Science teachers from different disciplines in drawing out and exploring particular themes e.g. the geology and human geography of a particular site (possibly, the archaeology?). (eSTEeM poster session; an HE educator with EU-wide experience of developing learning materials for FE and HE)

Learning analytics

We discussed about the potential of learning analytics for educators in being able to monitor student progress and achievement and, thereby, influencing student attainment[70]. For the individual student, analytics can be a valuable tool for self-assessment and a powerful component of a personal learning environment.

[70] Learning analytics, https://net.educause.edu/ir/library/pdf/ELI7079.pdf [accessed 14 October 2019]

However, there are several aspects that need to be considered for the potential of learning analytics to be realised: for example, optimal analysis of the data, making sense of the data, presenting the data in a format that enable educators to take decisions, data literacy skills of the educators and other involves stakeholders to be able to make sense of the data, visualisation formats and ethical issues of storing and using student data. The research and practice in the area of learning science or learning analytics or educational data mining and the concept of big data has been constantly growing over the last few years. The OU is one of the leaders in this research domain. We understand that OU is the first educational institution in the world to develop the 'Ethical use of Student Data for Learning Analytics Policy'[71] for the ethical use of student data.

In the next two sections, we have listed some resources related to this report.

[71] Ethical use of student data for learning analytics policy. http://www.open.ac.uk/students/charter/essential-documents/ethical-use-student-data-learning-analytics-policy [accessed 14 October 2019]

9 Publications and presentations related to *Virtual Skiddaw*

[72]Minocha, Shailey; Tilling, Steve and Tudor, Ana-Despina (2018). Role of Virtual Reality in Geography and Science Fieldwork Education. In: Knowledge Exchange Seminar Series, Learning from New Technology, 25 Apr 2018, Belfast.

Tudor, Ana-Despina; Minocha, Shailey; Collins, Melanie and Tilling, Steve (2018). Mobile virtual reality for environmental education. Journal of Virtual Studies, 9(2) pp. 25-36.

Minocha, Shailey; Tudor, Ana-Despina and Tilling, Steve (2017). Affordances of Mobile Virtual Reality and their Role in Learning and Teaching. In: The 31st British Human Computer Interaction Conference, 3-6 Jul 2017, University of Sunderland's St. Peter's Campus, UK.

Argles, Tom; Burden, David; Tilling, Steve and Minocha, Shailey (2017). FieldscapesVR: Virtual world field trips to extend and enrich field teaching. In: International Geological Congress, Abstracts, 35, article no. 2109.

Burden, David; Argles, Tom; Minocha, Shailey; Rock, James; Tilling, Steve and Wheeler, Phil (2017). Fieldscapes – Creating and Evaluating a 3D Virtual Field Trip System. In: iLRN 2017 Coimbra: Workshop, Long and Short Paper, and Poster Proceedings from the Third Immersive Learning Research Network Conference (Beck, Dennis; Allison, Colin; Morgado, Leonel; Pirker, Johanna; Khosmood, Foaad; Richter, Jonathon and Gütl, Christian eds.), Immersive Learning Research Network, pp. 18-29.

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Argles, Thomas; Minocha, Shailey and Burden, David (2015) Exploring the affordances of virtual fieldwork in a multi-user, 3-D digital environment. In: *Higher Education Network (HEN) Annual Meeting of the Geological Society of London*, 21-22 January 2015, Plymouth University, Plymouth.

Minocha, Shailey; Davies, Sarah-Jane; Richardson, Brian and Argles, Thomas (2014) 3D virtual geology field trips: opportunities and limitations. In: *Computers and Learning Research Group Annual Conference 2014*, 10-11 June 2014, The Open University, Walton Hall, Milton Keynes, UK.

[72] This and the other publications are available in OU's research repository (ORO): http://oro.open.ac.uk/view/person/sm577.html [accessed 14 October 2019]

Argles, Tom (2014) Virtually fieldwork? Lessons from a digital Lakeland landscape. *Teaching Earth Sciences* 39, 23-27.

Minocha, Shailey (2014) Developing a 3D virtual geology field trip in Unity 3D: reflection of our experiences. In: *Virtual Worlds - Best Practices in Education (VWBPE), Connections*, 9-12 April, 2014, Second Life and OS (OpenSimulator Grid).

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10 Resources

Please refer to various reports/resources mentioned in the footnotes of the report. This section has some additional resources that have influenced the content of this report.

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