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How to cite:

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.

For guidance on citations see [FAQs](#).

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Version: Version of Record

Link(s) to article on publisher's website:

<https://kess.org.uk/2018/05/02/prof-shailey-minocha-dr-ana-despina-tudor-ou-role-virtual-reality-geography-science-fieldwork-ed>

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Role of Virtual Reality in Geography and Science Fieldwork Education

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Introduction

Fieldwork involves leaving the classroom and engaging in learning through first-hand experience of phenomena in outdoor settings. Exploration in natural habitats introduces students to the variety and unpredictability of the real world and increases their interest in scientific inquiry. However, over the last decade, there has been a decline in field-study opportunities in schools.

In this policy paper¹, we describe the first extensive user-centered research programme into the role of technology-enabled virtual field trips as a means for improving the effectiveness of the outdoor fieldwork experience. In our year-long research project² funded by Google and The Open University (OU), we have investigated how Google Expeditions, a smartphone-driven mobile virtual reality application, bridges virtual fieldwork with physical field trips and facilitates inquiry-based fieldwork and experiential learning. Despite the simplicity of the technology, a lack of educator training and resources may prohibit uptake of mobile virtual reality in school education.

Fieldwork education

Fieldwork has a long tradition in geography and in certain sciences, notably geology, biology and environmental sciences. Fieldwork involves leaving the classroom and engaging in learning and teaching through first-hand experience of phenomena in outdoor settings. Exploration in natural habitats introduces students to the complexity and messiness of the real world, stimulates their curiosity, and increases their interest in scientific inquiry³.

Fieldwork provides students with an opportunity to engage with and adapt to uncertainty enabling the kind of deep learning that comes from direct experience. A positive impact on long-term memory has been reported due to personalised learning outcomes from fieldwork, sensory experience and the memorable nature of fieldwork's context and setting. Students have been able to recall the details of a species that they had had first-hand experience in the field rather than one where an educator had described to them in a classroom setting.

Learning and teaching in a field setting enhances environmental literacy, instills social responsibility towards preservation of biodiversity and raises awareness of ethical questions about other living beings. Fieldwork is valuable for educators too - in enhancing their confidence and expertise through shared experiences in the field; and interaction with students is vital in forming the relationships that are important in the classroom.

However, over the last decade, there has been a decline in field-study opportunities in secondary schools in the UK, US, Australia and several other countries. The barriers to outdoor fieldwork include:

¹ All the web-links in this document were last accessed on 18 April 2018.

² Google Expeditions research programme at The Open University, UK, <http://www.shaileyminocha.info/google-expeditions/>

³ The place of fieldwork in geography and science qualifications, 2014. <http://www.field-studies-council.org/media/1252064/lambert-reiss-2014-fieldwork-report.pdf>

diminishing profile in school curricula and timetables; fear and concern about students' well-being, health and safety; large class sizes; increasing number of non-specialists teaching secondary school subjects; and shortage of financial resources and administrative support for organisation of physical field trips.

The use of technology-enabled virtual field trips through photographs, videos, live expert seminars, web-based interactive experiments, and three-dimensional (3D) simulations have been promoted as a potential replacement for physical field trips, but more commonly as a means for improving the effectiveness of the physical fieldwork experience. Even though virtual field trips (VFTs) are perceived as being complementary to physical field trips, the literature on the role of VFTs in fieldwork education is surprisingly sparse.

In this policy paper, we describe the results of the first extensive research programme into the role of VFTs in fieldwork education. In our year-long research project, we investigated how Google Expeditions, a mobile virtual reality (VR) application, bridges virtual fieldwork with physical field trips. Our research has involved examining the role of Google Expeditions (GEs) in primary and secondary school science and geography. While we do not believe VFTs can entirely replace physical trips, our research includes the roles that VFTs nevertheless play in learning and teaching when students realistically cannot go on physical field trips.

A particular strength of our user-centered approach is that we have consulted fieldwork-based education experts and curriculum experts to identify the opportunities of mobile VR-based VFTs, alongside conducting research in classrooms and in a physical field trip with students and educators.

Google Expeditions

Google Expeditions are guided field trips to places that students experience on a smartphone through a VR viewer called Google Cardboard⁴. The GEs app⁵ (available on Android and iOS platforms) has over 700 expeditions⁶. An expedition comprises of 360-degree photospheres of locations such as Grand Canyon, Antarctica and Iceland. Further, GEs have 360-degree simulations to envision concepts and systems such as the human heart, the respiratory system, or the process of pollination.

Using a tablet and via the GEs app, the educator guides the students to look at the scenes of an expedition. The students use the app in the 'follower' mode and experience the GE/VR through the smart-phone embedded within a VR viewer. **Figure 1** (a) shows a tablet and a Google Cardboard VR viewer with the phone slotted in; in (b) the tablet is in 'guide' (or educator) mode and the phone is in 'follower' (or student) mode. On the tablet, the educator selects a point of interest (the circle). **Figure 2** shows an educator 'guiding' students to look at expeditions via their VR viewers in a Science lesson.

Virtual field trips in the Google Expeditions App

Google Expeditions are aimed at bringing field trip experiences into classrooms to encourage outdoor fieldwork.

For geography and science education, there are two kinds of virtual field trips in GEs:

- places that you may be able to visit but it may not always be feasible due to resource, distance, safety and mobility constraints; e.g., London Olympic Park to study urban re-generation, or to Egypt to learn about rocks and their use, or Kilauea, an active volcano; and
- places that may not be possible to visit, such as the surface of Mars, or the International Space Station.

⁴ Google Cardboard, <https://vr.google.com/cardboard/>

⁵ Google Expeditions, <https://edu.google.com/expeditions/#about>

⁶ There are over 700 Google Expeditions listed in this spreadsheet: <http://bit.ly/1GxJ9xf>

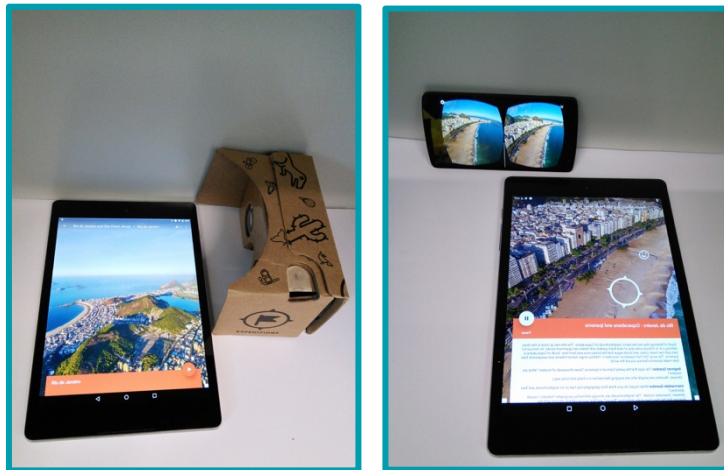


Figure 1: (a) Tablet and Google Cardboard viewer with the phone slotted in; (b) The tablet is in 'guide' (educator) mode and the phone is in 'follower' (or student) mode



Figure 2: A Science educator in a primary school 'taking' students to a 'virtual field trip' of Egypt to look at pyramids via the Google Expeditions App

Research programme

The focus of our year-long research programme in primary and secondary schools in the UK has been to investigate how mobile VR can be integrated into mainstream classrooms in science and geography fieldwork, subjects that have a long tradition of physical fieldwork. Our project collaborators were UK's Field Studies Council (FSC)⁷, an environmental education charity and two leading subject associations

⁷ Field Studies Council, <https://www.field-studies-council.org>

of Geography and Science in the UK: The Geographical Association (GA)⁸ and The Association for Science Education (ASE)⁹.

The research questions (RQs) were:

RQ1: 'How can GEs support inquiry for fieldwork?' and

RQ2: 'How can mobile VR-based VFTs such as in GEs support physical fieldwork?'

Empirical research

For RQ1, the data collection involved:

- semi-structured interviews with 6 national curriculum experts of geography, science and fieldwork-based education to understand their perceptions about role of mobile VR-based VFTs in inquiry;
- 24 in-class lessons using GEs between Years 4-11 taught by 20 educators to 549 students (255 in geography and 294 in science); maximum class size was 32 and a typical lesson lasted for 60 minutes; 1 to 4 GEs were used in each lesson (in all, 21 distinct GEs were used);
- post-lesson semi-structured interviews with all 20 educators (9 in geography, 11 in science).

On the day of the lessons, we took the equipment (see **Figure 1**) with us and set it up for the students and educator(s). The educator(s) ran the lesson with GEs in the same way as they would normally run a lesson. Towards the end of a GE-lesson, students carried out two written activities:

- formulate questions they had on the topic of the lesson; here our aim was to investigate the extent to which GEs provided them with the stimulus for inquiry; and
- students described if and how VR had facilitated their understanding and learning during the lesson.

At the end of each lesson, educators looked at randomly-chosen subset of student-scripts (Figure 2) and analysed the quality of the questions based on a codebook for inquiry-based learning that we had developed. Questions were classified as 'high-order', 'medium-order' or 'low-order questions'.

A high-order question is analytical, or addresses predictions, or is evaluative: example: *What causes the coral to bleach?* A low-order question is descriptive (factual) and the answer can be a definition, or the answer can have a quantitative component (e.g., "how many"), or the answer can have a location component (e.g., "where" questions): example: *How many types of corals are found in the Great Barrier reef?*

Figure 3 shows examples of two of the expeditions that were used in geography lessons.

The data collection to understand how GEs can support physical fieldwork (RQ2) involved:

- expert informant interviews during a workshop with 19 fieldworkers from FSC (see **Figure 4**); a typical fieldworker has 9.5 years of experience and, between them, they teach over 2,000 school groups visiting FSC centers over a year;
- four workshops involving a total of 55 geography and science school educators; and
- one physical field trip to a local nature reserve of a school, which lasted for two hours¹⁰. The trip involved 3 geography educators and 68 students in Year 7; during the field trip, students used GEs

⁸ The Geographical Association, <https://www.geography.org.uk/home>

⁹ The Association for Science Education, <https://www.ase.org.uk/home/>

¹⁰ The results from this field trip are discussed in this presentation, 'Mobile virtual reality for environmental education' at the Virtual Worlds Best Practices in Education (VWBPE), 2018 conference: <https://www.youtube.com/watch?v=G7YGSfpS9wQ>

outdoors and completed a reflective post-field trip activity. We conducted interviews with 2 of the three geography educators after the physical field trip.

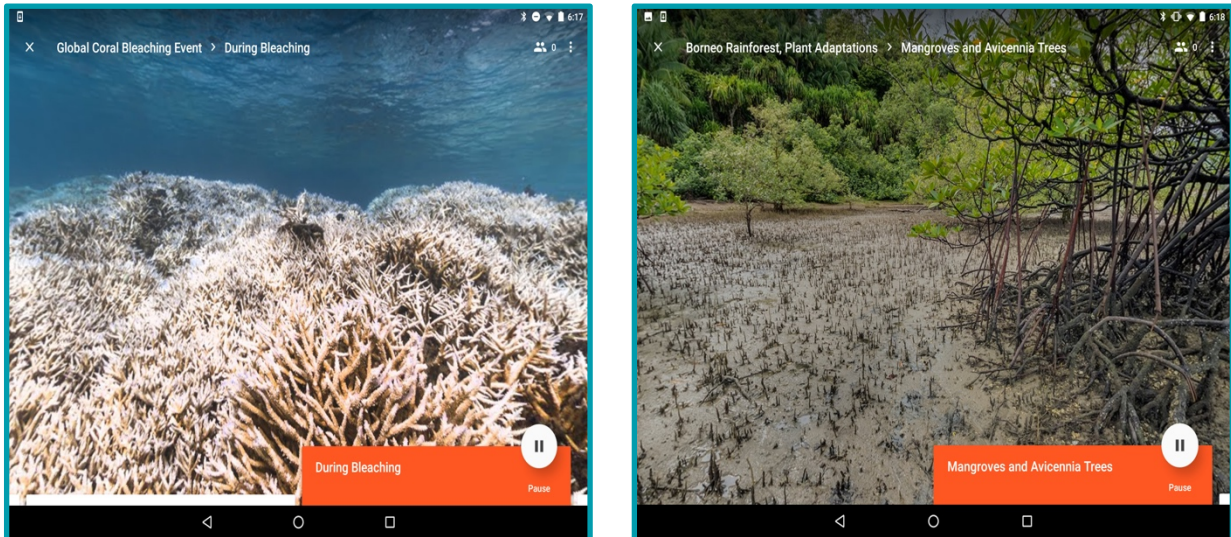


Figure 3: a) Coral bleaching event in the Great Barrier Reef; and b) Borneo rain forests – mangroves and avicennia trees



Figure 4: Workshop with fieldworkers at an FSC venue

Data consolidation and analysis

In addition to analysing the data for the two research questions, we had an overarching objective to empirically-derive the technological affordances of GEs that support learning and teaching. These

technological affordances refer to the user interface design characteristics of smartphone-driven VR with 360-degree photospheres (GEs, in our case) that influence learning and teaching¹¹.

In the following two sections, we provide an overview of the results of our research programme corresponding to the two research questions: RQ1 and RQ2, respectively and how the affordances of GEs influence fieldwork education.

Role of Google Expeditions in fostering curiosity and formulating inquiry

Research which was originally conducted in the History but has since been applied in other disciplines that have inquiry integral to their curriculum such as in geography and science, has shown that there is a need for an initial stimulus material (ISM) or a 'hook' to raise curiosity and generate a 'need to know'.

An ISM could be a photo, a painting, newspaper article, video, a presentation, a map, or a role-play activity, and an educator encourages students to work in pairs or groups – so that they could learn to interrogate the ISM and then generate their own questions for inquiry. An ISM helps to cultivate conceptual understanding through concrete examples that connect with the students' known and familiar experience.

Google Expeditions as initial stimulation material

Our empirical research for RQ1 has shown that the affordances of GEs 360-degree visual authenticity, 360-degree navigation and 3D view, give a first-hand experience of the physical location and its context. Through GEs, educators are able to relate subject matter content to real-world locations and situations – giving students an ISM and a 'need to know'.

Further, the affordance of single-user handling where each user/student experiences the field trip through their own virtual reality headset gives students a personalised learning experience which raises their curiosity and shapes their understanding for independent inquiry: *"if you were doing it [the lesson] in virtual reality, students could come up with the investigative questions, think what approach they would use, and even start trying out various ways of approaching the question, without any outside influence from the teacher, really."* [Science curriculum expert, ASE].

The affordances of GEs enable students to: 'visit' the location, analyse the context, and to generate questions: *"presenting the students with these [VFT] scenarios saying 'based on the immersive habitat you are looking around you, what are the likely impacts on food webs? The sort of ecological relationships you would find in this habitat'. And the importance of the habitat is...it would begin to open up genuine inquiry."* [Science curriculum expert, FSC].

Google Expeditions in formulating inquiry and generating questions

Over all the 24 lessons, in the post-lesson interviews with us, the educators reported on a greater prevalence of high-order questions than they had experienced with the same set of students in their 'normal' lessons involving textbooks, videos, photos, etc.

Preparing inquiry ahead of a physical field trip

A field sciences expert in our participant-set said that a lesson in VR is like a pilot study for a physical field trip and supports the development of 'specific' questions for inquiry for the fieldwork location: *"it [lesson with VR] would be like a pilot study.... The big abilities [via GEs] would be to get familiar with the*

¹¹ Please see paper on affordances of GEs: 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, 3rd - 6th July 2017, University of Sunderland's St. Peter's Campus, UK. Available at: <http://oro.open.ac.uk/49441/>

location [in VR], ask questions about that location and plan methods that work in the context on that place instead of [deriving] quite generic questions.” [FSC fieldworker and field sciences expert].

Formulating inquiry ahead of the field trip will help to plan the strategies for data collection, thereby, enabling an effective use of the (limited) time in the field: *“coming up with inquiries of what they need to find out about the place which would then develop the questions and then how do we collect that data? And is it easy? And that sort of things.” [Geography educator, workshop participant]*

Supporting physical fieldwork

For RQ2, ‘How can VR-based virtual field trips such as in GEs support physical fieldwork?’, our data shows that VR-based ‘authentic’ VFTs forge a synergistic relationship with physical field trips through technology-facilitated experiential learning.

The affordances of 360-degree visual authenticity, 360-degree navigation and 3D view create an authentic learning space in VFTs which facilitate the delivery of conceptual knowledge and experiential knowledge of fieldwork. VFTs support the physical field trips by providing a complementary experience that extends from pre-physical field trip phase, during the physical field trip, and after the physical field trip. Through the affordance of 360-degree navigation and single-user handling, students have control over where they spend time to look at a location in a VFT in GE and gain spatial awareness and spatial relationships – places and events and how they are connected.

For each of the phases of physical fieldwork, we discuss the perceptions of educators, curriculum experts and fieldworkers on how VFTs via GEs can contribute towards learning and teaching fieldwork-based education.

Pre-physical field trip phase

Preparing before a field trip and developing the necessary fieldwork skills in a VR environment is beneficial for students, educators and support staff for an efficient and effective use of the time in the field during outdoor fieldwork. VFTs in VR-based GEs contribute towards pre-physical field trip experience in the following ways:

Understanding outdoor fieldwork

Given the limited opportunities for fieldwork, it is vital that students and their parents, educators and support staff understand about what is involved in a physical field trip. They can look at the GE/VFT of the planned location or any other location even if it’s different from the planned location of the physical field trip to comprehend fieldwork-based learning and teaching: *“you could be saying “right, this is what we’ll be seeing, let’s try and work out a little bit about this environment before we go on to do our own environment.” [Geography educator, field trip]*

Familiarisation with the location of the field trip

A VFT helps to familiarize students, educators and support staff with the location of the intended physical field trip: *“for timing [...] this will allow them [students] to plan ahead for how long it will take them to access the site and to carry out the physical measurements.” [FSC fieldworker, workshop]*

Risk assessment

Educators, parents and students can conduct risk assessment in a VFT: *“you can go out in the field and talk about risk assessment, but you need to have done that beforehand. The students need to be good at looking at what the risks might be. Showing it to them beforehand and going, “Okay, what do you think the risks are going to be?” would be really useful.” [Geography curriculum expert, GA]*

Training of the support staff

Physical field trips are frequently supported by non-specialist support staff who may have no experience or inadequate training of supporting physical field trips. VFTs support their training and help towards their planning; *“[...] to see how accessible it [location] is, is there a road network close by? how long it*

takes them to get there? how long is it going to take to actually access the site they like.” [FSC fieldworker, workshop]

Formulating questions for inquiry

During the analysis for RQ1 and reported earlier in the paper, we have seen the role of VFTs in formulating and planning the inquiry process ahead of the physical field trip which may save time when in the field; *“If you could actually show them the place that they're going, they could almost come up with questions before they went out so that they didn't waste time in the field and so they could have all those hypotheses and those ideas already developed”* [Geography curriculum expert, GA].

Comparing and contrasting locations and habitats

Comparing and contrasting locations and habitats are typical activities in geography and science field education; *“you would use GE to compare your habitat you're interested in working on, or maybe are working on over a period of time, you want to compare it with similar habitats in other parts in the countries or beyond.”* [Science curriculum expert, ASE]

Observation skills

Once students learn how to observe, they can start thinking about the questions they will ask when in the field and plan the data collection methods that they will apply in the field. *“simple observation and link to spatial awareness. So just awareness. An awful lot of people go on trips, not only they haven't been to that site, they haven't been to anything that looks remotely like that site, sometimes never before in their lives”* [Environmental science expert, FSC].

During a physical field trip

VFTs in VR-based GEs contribute towards physical field trip experience while in the field in the following ways:

To view beyond what is visible to the naked eye

During a physical field trip, VFTs facilitate exploring areas of the location that may not be accessible by foot or otherwise: *“GE gives you a different perspective, the 1st person view, a kind of outsider view that you wouldn't get without a helicopter or an aerial view”* [FSC Fieldworker and field sciences expert]; *‘[GE] shows ‘big’ bird's eye [view] perspectives, angles images that might not be viewed otherwise.’* [FSC Fieldworker, workshop]

From international context to a local context

In our project, a geography educator used the GE of Environmental Change in Borneo during a physical field trip to a nature reserve in the Chilterns area in Southern England. The simplicity of the equipment associated with mobile or smart-phone-driven VR of GEs (as compared with VR headsets tethered to high-spec machines) enabled the use of VR in the field (see **Figure 5**).

The learning outcomes of the activity was to sensitize Year 7 students about the impact of environmental change in their local nature reserve because of the proposed development of a High-Speed train route (HS2) nearby. The students looked at GE of Borneo rain forests to understand the environmental change due to real estate development, tourism and palm oil plantations.

Students were able to relate the changes in Borneo rain forests to their local nature reserve and to map the broader context of urban development and its impact on nature: *“It is very helpful to see what we are trying to understand, because it's quite hard to comprehend what would happen to the Chilterns if HS2 were to happen and seeing the jungle [in Borneo] and what happened to it was unbelievable and should never have happened.”* [Year 7 student].

Post-physical field trip

VFTs in VR-based GEs contribute towards post-physical field trip experience in the following ways:

De-briefing

Students and educators can re-visit the locations in VFTs for de-briefing, to reflect and to evaluate the outcomes of the field trip, and to reflect on the reliability, accuracy and quality of the research methods and collected data for the inquiry: *“when they come back from a field trip, they’ve got to be able to understand how reliable [is] the [work] they did it. So that will certainly be a good way, if they had an expedition, they could really look at the flaws in what they did and did they choose the right number of sample sizes?”* [Geography educator]

Students who were able to only partially participate in the field trip or none at all due to mobility or other constraints, can participate in de-briefing involving VR-based VFT with students who had conducted the physical field trip.

Applying and transferring knowledge to other locations

VR-based VFTs provide venues for practicing *“once they’ve analyzed their (field) data they’ve realized they could have done it somewhere else. Then they could go and do it virtually somewhere else.”* [Geology educator, member of the field trip team]; and applying fieldwork knowledge to other contexts: *“[...] try to transfer the skills that they’ve developed in a physical field trip into... the skills they know by using them in a different setting and that different setting is a virtual one.”* [Fieldworker and field sciences expert, FSC]



Figure 5: Students looking at the Borneo Rain Forests Expedition during a field trip to a local nature reserve

Discussion

We have shown that through their technological affordances, VFTs in VR-based GEs provide authentic learning spaces and the experience of ‘being there’ - which supports the pedagogical approaches of inquiry-based fieldwork and experiential learning in fieldwork-based education. The in-context learning and teaching afforded by GEs stimulate the student-questioning in the inquiry cycle and in inquiry-based

learning. We have discussed how mobile VR-based VFTs via GEs facilitate ‘visits’ to locations that may not always be feasible (**Figure 6**). Further, instead of perceiving VFTs as replacements for physical field trips, we have shown that by combining virtual and physical interactions through VFTs and physical fieldwork, respectively, the fieldwork education is, in fact, strengthened. The student’s learning experience is enriched beyond what they would get if they were only using VFTs or going to a physical field trip without support from VFTs.

We have investigated the role of GEs as VFTs, but the results are applicable for other mobile VR-based VFTs that provide a 3D view of authentic locations, for example, in mobile VR via 360-degree videos¹². Other mobile VR-based VFTs may have additional affordances such as being able to fly or may have avatars to move within the environment¹³. Our focus has been on science and geography in school education. Disciplines such as history and archaeology have a long tradition of outdoor fieldwork and VFTs may be able to support other disciplines, and in Further and Higher Education.

The most effective use of any form of VR (GEs or 360-degree videos or 3D avatar-based virtual environments) will be when it is combined with other technologies such as videos, podcasts, wikis, blogs, forums and mobile apps and is situated within the learning outcomes of the lesson/curriculum. The adoption of virtual reality and technologies, in general, in schools and in further and higher education is still in its infancy and its development will progress and mature as the evidence-base on the pedagogical effectiveness of these technologies grows.



Figure 6: a) Chernobyl – nuclear disaster aftermath; and b) International Space Station

Challenges for adoption of Google Expeditions and other technological innovations

Despite the simplicity of the technology and the widespread usage of smart phones, there are several barriers for adoption of GEs and other forms of mobile VR, and other technologies, in general, in school education.

¹² For example: After Shock, (360-degree video) A virtual reality documentary, <http://aftershock.wateraid.org>

¹³ For example: Virtual Skiddaw: A 3D Geology Field Trip, https://learn5.open.ac.uk/course/format/sciencelab/section.php?name=skiddaw_1 is a multi-user avatar-based 3D geology field trip. Also, see: Argles, Tom; Minocha, Shailey and Burden, David (2015). Virtual field teaching has evolved: benefits of a 3D gaming environment. In: *Geology Today*, 31(6) pp. 222–226. Available at: <http://oro.open.ac.uk/44881/>

The costs of the equipment (a phone per student in a class, a tablet for the educator, VR viewers and the router) and the maintenance (safe storage, software updates) are a major challenge for most schools.

Educators in the UK and worldwide are handling unmanageable workloads due to poor retention of educators, increase in class sizes, and constant changes to policy, curriculum and assessment at local and national levels. Continuing professional development (CPD) is being squeezed out of timetables and is not prioritised and funded. A report¹⁴ on recruitment and retention of teachers discusses that lack of time, resources for travel and substitutes for lesson-taking are some of the barriers educators face in engaging with intensive off-school CPD programmes. We made similar observations on the lack of CPD and training opportunities for educators when we visited schools as a part of the GEs research programme.

Further, educators may not have the skills and support to evaluate the pedagogical effectiveness of their technological innovations. Even the most innovative educators may not have the time, confidence, and skills to integrate novel technologies such as GEs in their curriculum, and to make a case for equipment, training, and IT support and infrastructure.

A report¹⁵ published in April 2018 has reported parents' concern over the impact of virtual reality on children's wellbeing – whether and how virtual reality might cause social isolation because virtual experiences can be so enticing that users (children) may retreat to the virtual world in lieu of the real world. However, as the report points out that similar fears were associated with television, movies, and even comic books.

Usage of VR headsets can sometimes lead to discomfort by having to hold the cardboard viewer for too long, or cause eye strain, headaches, or in some cases nausea¹⁶. Long-term effects of children's use of immersive VR on their still-developing brains and health are unknown, but most parents are concerned, and experts advocate moderation and supervision. In our empirical investigations, the educators followed an implicit rule that students used GEs for no more than 10 minutes at a time without break. The educators interleaved VR-viewing times with activities and discussion.

Policy recommendations from our research programme on the role of virtual reality in fieldwork education

Supporting outdoor fieldwork: Despite the positive impact of outdoor fieldwork, it has declined in schools to a point that in science education, the quality of subject teaching is threatened. Fieldwork courses in disciplines which have had a long tradition in outdoor field trips are becoming less frequent, more local than previously, of a shorter duration, day trips in contrast to residential courses, and fewer opportunities for re-visits for reflection, further inquiry or assimilation of knowledge. Over the last decade, VFTs have been proposed to complement physical field trips and to provide experience of locations that students may not be able to visit.

Our research has shown that VFTs can complement physical field trips and provide students a “global” experience of locations around the world. For example, a science educator we collaborated with took her students to the local cemetery to learn about the use of rocks and then showed them the expeditions Egypt, India, Peru and Jordan to teach about use of rocks throughout history in various cultures and places (**Figure 2**). We recommend the use of VFTs in disciplines such as science, geography, history and arts to complement outdoor fieldwork, to provide additional insights but also to

¹⁴ Recruitment and Retention of teachers, House of Commons, Education Committee, 2017. <https://publications.parliament.uk/pa/cm201617/cmselect/cmeduc/199/199.pdf>

¹⁵ VIRTUAL REALITY 101: What You Need to Know About Kids and VR, April 2018. <https://news.stanford.edu/2018/04/04/emerging-research-shows-potential-power-vr-kids/>; Report available from: <https://www.commonssensemedia.org/research/virtual-reality-101>

¹⁶ The very real health dangers of virtual reality, December 2017. <https://edition.cnn.com/2017/12/13/health/virtual-reality-vr-dangers-safety/index.html>

support learning in situations where physical field trips may not be feasible and for inclusion of students with special educational needs¹⁷.

Cross-disciplinary interactions within lessons and in outdoor fieldwork: Throughout our research, educators showed interest in integrating VR as a tool across the curriculum and the use the same expedition by educators of different subjects: for instance, an expedition about the Pyramids can be used in a science class to set the context for an outdoor field trip related to rock types. This expedition could also be used in a mathematics lesson, or in a history lesson, or indeed in geography, in order to create a unified understanding of a particular location or concepts across different disciplines. We recommend the use of VR-based VFTs such in GEs to integrating student's understanding of concepts and processes across disciplines and for educators to have cross-disciplinary interactions.

Inquiry-based learning: Inquiry-based learning (IBL) enables the development of skills for scientific investigations such as problem-solving and critical thinking. A range of empirical work has shown that IBL has very positive learning outcomes for students in terms of achievement, enthusiasm, ownership and research skills development. In STEM¹⁸ education, inquiry-based instruction resembles scientific inquiry by engaging students in instruction that parallels the work of scientists.

Generating questions is at the core of any inquiry cycle – questions that are situated within the learning outcomes in a lesson or for fieldwork in disciplines such as ecology, environmental sciences, biology and geography where fieldwork is an integral part of the curriculum. However, the didactic and traditional educator-led transmission of facts and knowledge are still popular, and they inhibit creative thinking and development of questions by students for an effective inquiry-based learning in classrooms and for physical field trips. Researchers and educators consistently report that students ask few questions in schools, and most questions are for clarifications, rather than efforts to gain new knowledge.

In Northern Ireland, students in primary education receive less inquiry-based science education than the international average (40%), England (41%), and the Republic of Ireland (43%)¹⁹. In our research, we have shown that students generated more high-order questions in the sessions when VR-based VFTs were used as ISM. Educators stated that students showed more interest and engagement in the lessons when they used the technology and the questions they asked were more analytical and predictive in nature. Hence, we recommend the use of VR-based VFTs to foster creativity and inquiry.

Continuing professional development of educators: While much of the extant literature on IBL reports on the benefits and effectiveness of using inquiry, it also highlights that educators face difficulties while attempting to implement inquiry approaches in their classrooms. This is mainly due to the fact that many current educators have learned science and other disciplines that would benefit from enquiry (e.g. history, geography) through traditional approaches or because educators may not be aware of IBL and its pedagogical benefits. Other obstacles include time constraints caused by content-laden curricula, assessment procedures that are inappropriate for inquiry approaches and lack of confidence or training to embed it within everyday learning and teaching.

The STEM research Paper of Northern Ireland Assembly²⁰ Review which aimed to address a number of issues, including a decline in interest in STEM and a lack of confidence among many primary educators in relation to teaching science, has highlighted as areas for further consideration to Department of Education (DE): to ensure a strong focus on professional development and raising the

¹⁷ SEN legislation and policy in Northern Ireland, NIAR 178-15, May 2015.

<http://www.niassembly.gov.uk/globalassets/documents/raise/publications/2015/education/5715.pdf>

¹⁸ STEM: Science, Technology, Engineering and Mathematics

¹⁹ Primary Science: Teaching Time and Enquiry-Based Learning, NIAR 266-14, April 2014.

<http://www.niassembly.gov.uk/globalassets/documents/raise/publications/2014/education/8814.pdf>

²⁰ Science, Technology, Engineering and Mathematics (STEM) in 2015, NIAR 620-15, November 2015.

<http://www.niassembly.gov.uk/globalassets/documents/raise/publications/2016/education/1916.pdf>

number of applications for places on STEM Initial Teacher Education (ITE) courses to make STEM more inquiry based and developing new STEM resources. In line with this 2015 review and on the basis of our research investigations, we recommend the professional development of educators focus on pedagogical approaches such as IBL and on the use of technological interventions such as VR-based VFTs to support the process of inquiry within the classroom and in outdoor fieldwork within STEM and other disciplines.

Continuing professional development for subject expertise: The curriculum experts we collaborated with stated that the diversity of the virtual field trips in the GEs app can support educators' subject knowledge of locations, processes and events that they may use as examples in their lessons. For instance, educators can explore the expedition "Queen Elizabeth Olympic Park" in preparation for a lesson on urban regeneration, that is, the impact on local communities and the environment since London hosted the Olympics in 2012. Another example is learning to about processes that can't be experienced/visualised easily, such as coral bleaching events in the expedition on "Coral bleaching and global warming".

Acknowledgements

This research was funded via Google's Virtual Reality Research Programme²¹. The views expressed in this policy brief are those of the authors and not necessarily those of the funding bodies or individual organisations. We are thankful to the educators, curriculum experts, fieldworkers and students who gave their time and inputs.

²¹ Open University and Google bring virtual reality into schools, 28 September, 2016. <https://ounews.co/science-mct/science-environment/open-university-google-virtual-reality-classroom/>