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ORIGINAL RESEARCH ARTICLE

Cheap, accessible, and virtual experiences as tools for immersive study: a proof of concept study

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Virtual and augmented reality technology is becoming more commonly available within a plethora of environments in which we exist, including educational environments. With advances in technology, and more exposure to its capabilities, there is a greater expectations and reliance on it. However, much of the hardware (and some of the software) which makes this technology usable is expensive and inaccessible to many. This article introduces a method for capturing and providing cost-effective virtual reality experiences, used here as a tool to give students improved accessory data and context regarding geological lab samples. The method introduced utilises the Google Cardboard camera app and Google Cardboard viewers. The virtual reality environment created is a mini-immersive experience that could be provided to students, or collected by students for their own use. The article reports results from a study of 20 participants who answered a questionnaire outlining their experiences of implementing the method. They responded positively, highlighting the applicability of the method to the task, the ease of use of tool and the accessibility of technology. Image quality of the method was raised as an area for improvement.

Keywords: virtual reality; Google Cardboard; virtual fieldwork; photosphere; immersive learning environment

Introduction

Over the past few decades, educators with the responsibility of designing teaching and learning materials and environments have taken an active role in implementing technological innovations within these areas. The majority of these technologies are digital in nature, and include: electronic voting systems (e.g. Kennedy and Cutts 2005; Simpson and Oliver 2007), microcontent (i.e. blogs and wikis) (e.g. Alexander 2006; Hsu 2007; McLoughlin and Lee 2007), social software (e.g. McLoughlin and Lee 2007, 2010; Schroeder, Minocha, and Schneider 2010), videos and audio content (e.g. Gamoran Sherin 2003; Maag 2006) and lecture capture (e.g. Edwards and Clinton 2018; O'Callaghan *et al*. 2017). This educational reform (i.e. the embedding of technologies in the curriculum) has been well supported by educators themselves, a factor, which according to Means (1993, 1994) is critical to ensuring the success of

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an educational reform. Many of these technological innovations have been widely hailed as successful and beneficial to teaching and learning activities and environments. A quick literature search for the various technologies will throw out multiple publications, often focusing on the benefits of a particular innovation to a particular group of teachers or (more often) learners. However, there is evidence that the implementation of a technological innovation within the teaching and learning environment can often be negative, particularly if the innovation isn't implemented correctly. It has been highlighted by Kirkwood and Price (2014) that technology's influence throughout higher education has increased, yet its effective educational contribution is not yet fully appreciated/understood. Kirkwood and Price (2014) go on to say that many (educators) implementing these innovations often focus on how changes occur in teaching styles and methods, whilst neglecting the changes in how teachers and learners learn. Selwyn (2007, p. 90) highlights several undesirable outcomes (including dehumanisation, disenchantment and alienation) from technological innovation. He further argues that the haste to implement technological augmentations into higher education teaching and learning has caused '…many educationalists and technologists to lose sight of the guiding principles and underlying purpose of university education'.

This article introduces and outlines the usefulness of cheap, accessible and simple virtual reality (VR) environments in the study of geological samples; however, the method is easily transferable to any subject (or topic) where spaces external to the immediate learning environment are relevant. The technology used in this project is Google Cardboard, a simple and affordable VR package, with the ultimate aim of better linking geological fieldwork and laboratory practical sessions. As stated above, many innovations lack an appreciation of *how* students learn, and it is with this in mind that this technology has been chosen, and not because it is novel or 'exciting'. Within the geosciences, fieldwork is considered an important component of the teaching and learning landscape (e.g. Boyle *et al*. 2007; Elkins and Elkins 2007), a concept recognised for over a century (Geikie 1912). Butler (2008, p. 10) lists the following factors as examples of why fieldwork is important:

- It is the real world – the only place to learn and practise core subject skills
- It is the only place students can make their own field observations and learn from the experience
- It is the best place to acquire 3D visualisation of concepts and relationships, e.g. the relationship between rock units, and with topography
- It is a great place to promote robust attitudes to data acquisition, especially for equipment-based activities
- Uniquely, it can provide motivational/inspirational activities
- It is a great way to enhance social and teamwork skills
- It promotes deeper learning through first-hand experience and immersion.

Butler (2008, p. 11) continues to list several reasons for why the field environment is useful as a teaching and learning environment:

- Setting student-led tasks
- Reinforcing scientific method through hypothesis-testing
- Developing integrative skills ('joined up science')

- Problem solving, particularly through the interpretation of incomplete data-sets and managing uncertainty
- Dealing with real-life, real-time interdisciplinary problems
- Showing the limitations of observations/measurements in problem solving
- Developing self-reliance amongst students, taking personal responsibility for safety practices.

From the above lists, it is obvious to see that working in the field is an important aspect of geoscience education. It is an environment that is both easy to teach in (it, of course, has its difficulties, limitations and inclusivity issues; see Giles, Jackson, and Stephen 2020) and beneficial to learn in (both staff and students are often teaching and learning together). In lab sessions (at Keele University, we typically run 3 h sessions with students completing practical-based work), students find themselves with similar intended learning outcomes to those in action on field courses and many of the points given in above-mentioned Butler's lists apply. However, some of the context brought to life by the immersion within the field environment is lost (3D visualisation, relationships between rock units, context in which samples are obtained/observed etc.). There is often a vast gulf between the material looked at in practical or lab classes (often small (relative to *in situ* examples) and show the best possible example of a particular feature) and that material's origin – observed on field courses (where examples are *in situ* and in 'context'). This leads to certain practical-based activities to be associated with threshold concepts and troublesome knowledge (Meyer and Land 2003, 2005) that are comparatively 'harder' to help students cross the related conceptual threshold than they might be on a comparable learning activity on a field course. The technology introduced here was selected to bridge the disparity between the field and lab (and potentially home/remote) learning environments and enrich the learning experience, rather than an innovation designed to form an entirely new approach to a teaching and learning problem. By immersing students into mini field experiences, it was hoped to remind them, and keep them aware, of the origins (processes of formation, environments of deposition) of the samples they were describing and interpreting. This action was designed to change the way the students would interpret, view and ultimately understand the samples they were given and the associated tasks. The secondary reason for choosing this technology was in response to the recent emphasis on VR environments as teaching and learning spaces (see section 'The Technology' below). Much of this technology is expensive and therefore not accessible to all educators and learners – the technology presented here was chosen because of its low cost, ease of use and wide availability.

As part of a module taught to second-year geology students, which is focused on the reconstruction of past environments from evidence in the rock record, geological hand samples are examined as standards. The VR imagery was introduced along with these rock samples to use as a supplementary data source for students to use should they wish. Geological hand samples are generally fist sized lumps of rock collected from locations around the globe. The mini VR immersions introduced here bring those samples into the context of its location of origin (or a similar outcrop or modern environment of deposition) providing students with an immersive experience related directly to the sample. This provides students with a larger and immersive scale of reference; posing questions such as the following: Did the sample come from thinly or thickly bedded strata? Is the sample typical of the location it was collected? What strata sit above and below the sampled specimen?

The information provided is hoped to better enable the description and, particularly, interpretation of the studied samples. The innovation is designed to help learners develop from basic description and identification of samples to the interpretation of what those descriptions tell us about the origins and history of the sample. It is also hoped that the introduction of this technology may provide students with a new skill and manner of collecting data that they can use when they collect their own samples. Small-scale, cheap and accessible innovations, such as this one, are also a potential avenue to explore to increase accessibility and inclusion within the geosciences. Whilst not specifically tailored to, or in any way a response to the COVID-19 situation of 2020 (this study was conducted years before this event), this sort of technology would be well suited as a viable tool to encourage and enable immersive VR use in a blended and/or remote learning environment.

Data for this pilot study were received from 20 students (out of total 44 in the session). Ethical approval was sought, and obtained for this project from the relevant institutional ethics panel.

The technology

Virtual reality, digital outcrops and digital 3D visualisation are rapidly becoming commonly used tools in the geological sciences (Lin and Loftin 1998; McCaffrey *et al.* 2008; Trinks *et al.* 2005 and many more). These methods are often used where large-scale data sets are being handled, and particularly when creating analogues and geological models from outcrops. In the geosciences, the methods are not only commonly used in the petroleum sector (for a detailed review, see Hodgetts 2013) but also used in palaeontology (e.g. Bates *et al.* 2008), volcanology (e.g. Boudreaux *et al.* 2009), for virtual field courses (e.g. Lang, Lang, and Camodeca 2012), structural geology (Wu and Xu 2003) and geological heritage (Martínez-Graña, Goy, and Cimarra 2013) etc. All these examples given here (i.e. cited sources) have one thing in common; they are dealing with specialist equipment and/or software (often with a big price tag!) and large-scale data, and most of these examples need (reasonably) powerful computers to create and run the visualisations.

The use of VR within an educational setting is certainly becoming more commonplace. The number of evidence-based studies about this innovation are, however, low in number. Examples where VR has led to an increase in either attainment or preparedness in students include Bellamy and Warren (2011), Webster (2015) and Allcoat and von Mühlenen (2018). Of these studies, the number of students experiencing VR are small (Webster = 25 and Allcat and von Mühlenen = 33), the same is true for this study. Numbers of VR users in this study are small due to the costs and logistics of setting up such activities. Allcoat and von Mühlenen (2018) presumably had a similar situation – it seems the VR element of their study was conducted with a limited number of VR headsets. It is reasonable to assume that until studies such as this, and those cited immediately above, become more commonplace, it is unlikely that large arrays of VR equipment with bespoke imagery will become commonplace in the educational environment. This study had some small funding associated, which made it viable, and it was acknowledged that the sample number was small. The nature of this study, aiming to create a cheaper and accessible VR innovation, is hoped to enable an increase in the use, and further study, of the use of VR in educational settings.

Google Cardboard combines a viewer and a smart phone app. The viewer comes in different varieties, with price ranging from a few to tens of pounds (more expensive versions are also available). The Google Cardboard app is free and allows individuals to experience immersive environments using a smart device and cardboard viewer. Google Cardboard has been implemented in a variety of geology courses but only as a tool to provide virtual field courses (Delabrida *et al*. 2016; Mather *et al*. 2015; Moysey *et al*. 2015). Few examples exist where the use of a second Google app, Google Cardboard Camera (GCC), is used (Burden *et al*. 2017 is the only example found). With GCC, a user is able to capture their own 3D, 360° images using a smart device; these images, referred to as fieldscapes and photospheres by Burden *et al*. (2017), are then experienced as a fully immersive environment using a viewer. Here the Google Cardboard is used as a tool that links hand samples with the environment in which they were collected, so rather than providing a virtual field course, a virtual snapshot or mini immersive environment is given. Lui and Slotta (2014) refer to this type of environment as an 'immersive simulation'; they used large projections around a classroom (rather than the VR viewers used here) and concluded that such an environment bettered student engagement. The implementation of VR technology here is purposefully a supplementary source of data, that is, the students would be able to complete the task (of describing and identifying samples) without the Google Cardboard. Litherland and Stott (2012) when investigating virtual fieldwork concluded that these types of resources are best used as integrated tools rather than as replacement. The students were introduced to the technology, how it works, how much it costs and how it operates. If the students found it useful, they were then able to take the method away, and create their own immersive experiences, this co-creation and ownership of the technology is something that is commonly unattainable through other established VR methods (individuals can also use this method recreationally).

Method/implementation

Rock samples were obtained from a variety of locations. At these locations, a photosphere was also collected using a smart phone and GCC. Thin sections were made of the rock samples (to allow students to observe the rocks in microscopic detail). The photosphere images were shared with students via email (if a device is able to show photospheres, it will open up the image in GCC) and within a Google Classroom, which has students as its members. The photospheres were introduced to students in a practical lab, and used as a supplementary material for part of that lab sessions work. The tools used (smart phones, Google Cardboard viewers and the GCC app) were all introduced to students with a live demonstration of capturing and viewing a photosphere. Some of the pedagogical theory of immersive, interactive and blended learning styles was also introduced briefly. This brief introduction was hoped to ensure better engagement with the method – if students could understand *why* they were using the VR, it was thought they would use it more effectively. Students in the lab were asked to consider completing a questionnaire relating to their experience, focussing on the value that students perceived the VR experience to bring to the assignment. The questions were designed to encourage short answers and not take up a significant amount of student's time. The questionnaire consisted of 14 questions covering a broad variety of angles relating to innovation, including the general topic of VR usage and ease of use of Google Cardboard, whether the photospheres influenced student's answers in the lab and several questions related to the use of (student's personal device) smart devices, and VR viewers and the innovation's wider use for a geology/geoscience degree programme. Twenty students completed and returned questionnaires; it is recognised that this is not a large cohort, but innovating for smaller cohort numbers is important, as their perceptions and values of innovations should be disseminated as much as innovations for larger cohorts. The sample size is also massively influenced by the cost of mass VR equipment (and associated costs of gathering bespoke data) – a barrier, for which this study hopes to begin providing alternatives.

Results

The results are presented here as three themed groupings of questions: (1) The first theme (consisting of questions 1 through 7) related to the use of photospheres via VR; whether it influenced student's resulting descriptions and interpretations and how useful and easy the method was to use. (2) The second theme (questions 8, 9 and 13) looked at the inclusivity of the innovation. (3) The final theme (questions 11, 12 and 14) looked at continued use and potential routes for improvements.

Theme 1: usage and influence

The first theme deals with the ease of usage and the perceived usefulness of photospheres within the practical assignment that students were undertaking as well as in a wider context (see Figures 1, 2 and 3 for participants' responses). The majority of participants had used VR before, this was generally through gaming or other VR headset applications. None of the participants found the technology hard to use, with the majority finding it 'easy'. The majority of participants

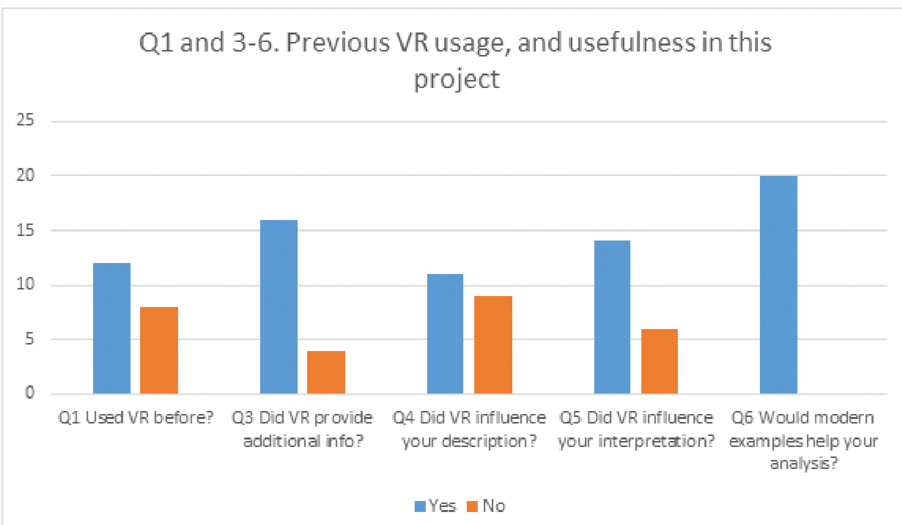

Figure 1. A column chart showing results for questions 1, 3, 4, 5 and 6. Response for each questions was a strong 'yes', with question 6 being unanimous (left-hand columns = yes; right-hand columns = no).

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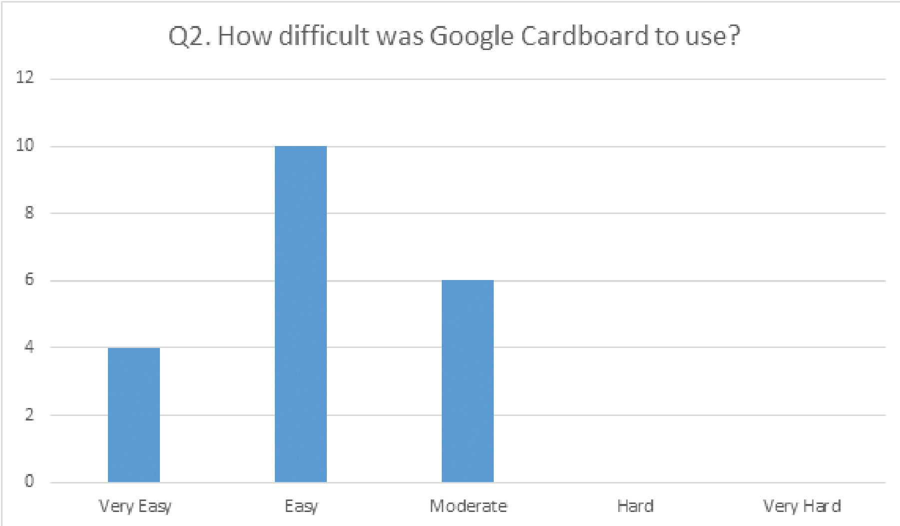

Figure 2. A cluster column chart showing opinions on the difficulty level of using the Google Cardboard app and viewer. Participants clearly indicated that they found this easy.

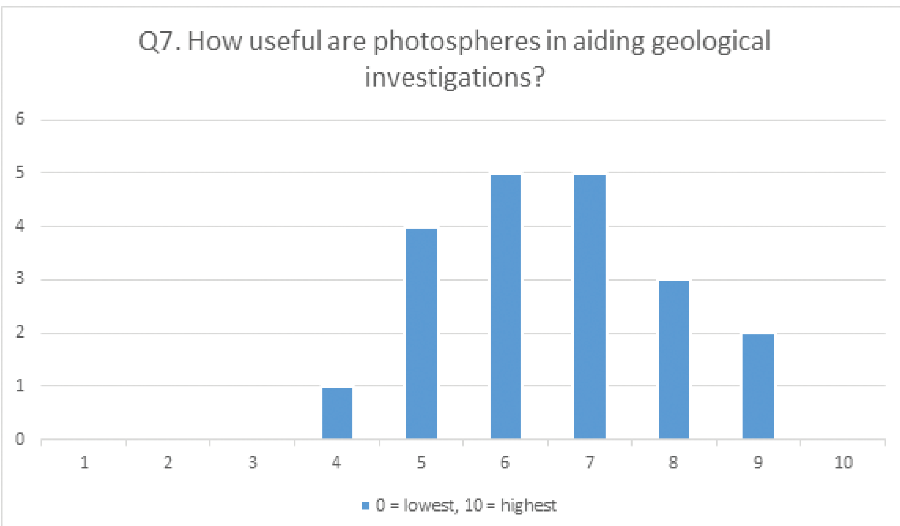

Figure 3. A cluster column chart indicating how useful photospheres could be in geological investigations as perceived by participants.

suggested that photospheres provided additional information and influenced their interpretation of rock samples: 'Better understanding of morphology of outcrop'; 'helped understand the environment [of deposition]'. Just over half of the participants said that it influenced their description: 'Allowed to visualise the outcrop and see samples in the context of wider structures'. All participants suggested that photospheres of modern depositional environments would help with these kinds of practical assessments: 'View of environ[ment] helped'. Question 7 was posed to gauge the opinions on the wider application of photospheres in geology, and the respondents were positive, suggesting that they thought the method could be quite useful in other geological topics.

Theme 2: inclusivity of the innovation

The second theme looked at the perceived inclusivity of the method (see Figure 4 for participants' responses). Asking how students felt about using their devices (a smart phone), the viewers (these were provided) and whether they would use the method for the future assignments (in this case the students final year mapping project was highlighted as they conducted field studies for this over the summer). Participants were overwhelmingly happy to use their own devices for this task, with only 10% of the participants not happy using theirs; one of the reasons was that they could not get the Google Cardboard app to work on their phone. The majority of participants said that they would be happy purchasing their own viewer; the same number of participants opined that including a viewer in the 'Geology Pack' (this includes a compass-clinometer, hard hat, high vis, etc.) that the students received at the beginning of their course would be good. Participants were asked to briefly explain their answer for question 8 ('Would you use this method to collect your own data?'), most of the responses to this question were 'No', the explanations mostly provided were that the collection method was too much effort: '[Too] much effort and time to image rock surfaces', or the quality was too poor: 'Depends on picture quality'.

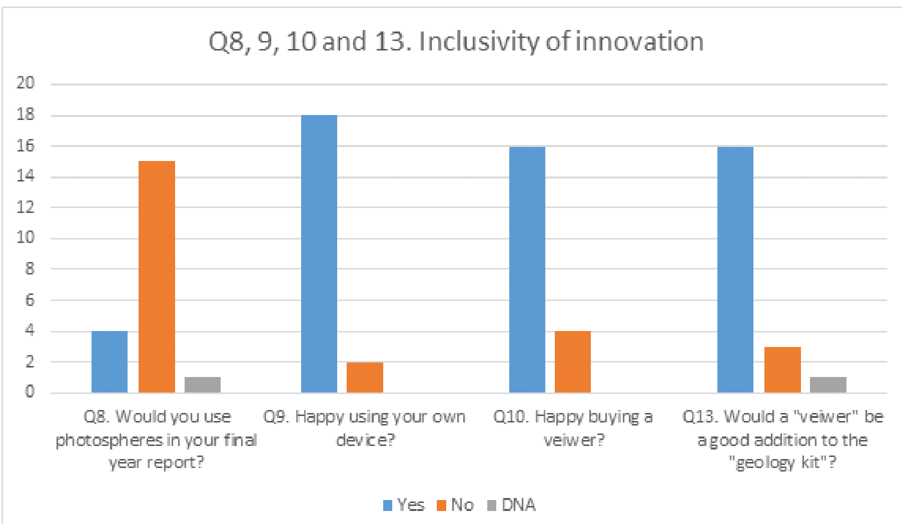

Figure 4. A column chart showing the results for questions 8, 9, 10 and 13. Respondents answered strongly 'no' for Q8, and strongly 'yes' for Qs 9, 10 and 13. The 'geology pack' referred to in Q13 is a set of equipment that the students were supplied with when they arrived at the university (Qs 8 and 13; left-hand columns = yes; middle columns = no; right-hand column = did not answer. Qs 9 and 10; left-hand columns = yes; right-hand columns = no).

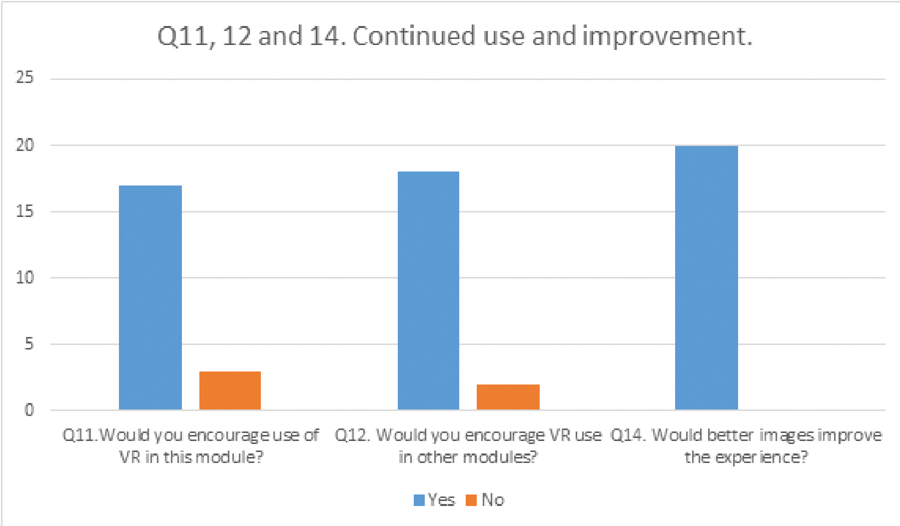

Figure 5. A column chart showing the responses for questions 11, 12 and 14. Responses for all three questions are very positive, with response to Q14 as unanimously 'yes' (blue, left-hand columns = yes; orange, right-hand columns = no).

Theme 3: continued usage and potential improvement

The third theme centred on the future use and potential improvements to the photosphere method (see Figure 5 for participants' responses). The majority of participants indicated that they would advocate the continued use of VR in both the module, in which this concept study was undertaken, and the other parts of their degree programme. Examples of other geological themes that participants thought VR could be used include sedimentology, igneous and metamorphic geology, geophysics, structural geology and any modules that have large-scale models of Earth phenomenon, or where context of outcrop could improve the understanding of hand and thin section samples. Participants unanimously agreed that better quality images would improve the VR experience undertaken.

Discussion

The results are discussed in this section, with critical reflection of participants' responses. The discussion is broken down into three themes as identified in the 'Results' section.

Theme 1: usage and influence

It is perhaps not surprising that over half of the participants had used VR before (Q1, Figure 1); it is becoming increasingly affordable and resources are more common than ever before. However, there were still a good proportion who had not used any VR before, so it was reassuring to see that none of the participants found using the method 'hard' or 'very hard' (Q2, Figure 2). As indicated in the

'Introduction', this innovation was chosen because of its easiness to use and accessibility. These responses confirmed this assumption, and hopefully meant that the devices were used as intended, and therefore a 'true' experience of the innovation was gained by participants. For Q3, most participants indicated that the innovation provided them with additional information for the analysis they were conducting; just four of the 20 participants perceived no additional information. Nearly equal participants suggested that this additional information influenced their description of rock sample, whilst the majority (14 out of 20 participants) indicated that their interpretation was influenced. The latter two results indicate that the use of photospheres influences the interpretation of samples (i.e. how they may have been deposited in the case of geological samples), rather than the description. This feedback suggests that the experience enabled participants to move beyond the basic description and recognition of rock samples and began to organise observed features into a more developed interpretation that was supported by the supplementary data provided by photospheres. This deeper appreciation of the origins of the sample is something which is expected of our learners as they progress through their degrees, and is something which is commonly recognised through work on field courses – this suggests that the innovation has gone someway of bridging the space between field and lab learning (at least in terms of providing context to the samples provided). It is interesting that all participants thought that the photospheres of modern environment, equivalent to the samples' depositional settings, would be beneficial; it might be that a student has never seen these modern environments before (other than in lecture slides, books etc.) and that they need more context of them, and a photosphere might bring that context. One of the principle concepts of geology is that of uniformitarianism (the present is the key to the past); modern environments help put ancient rocks into the context of their environment of deposition. The understanding of environments through field experience has been highlighted in the list provided by Butler (2007, p. 10) in the 'Introduction'. Immersive VR experiences of these environments are potentially applicable to most of the points given in that list, and could be the reason that students (with good experience of learning in field courses) might be asking for VR experience of modern environments. Individual comments given were mostly positive and reflected the core reason as to why this method was chosen: to provide additional context to the samples used. Figure 3 shows that the majority of participants believed that the use of photospheres was/would be beneficial for geological investigations. No further details were provided on how these photospheres would be beneficial, but one assumes that the learners perceived that better interpretations could be derived with such data (as a supplement to field data/samples etc.).

From a teaching perspective, this method was easy to implement. The hardware and software were easy to obtain, use and explain to learners. The simplicity of this method potentially leads to the material being used in the intended way, which could be the reason that the innovation was apparently successful in enabling learners to produce enhanced interpretations of their samples. Looking at the use of this technology from a perspective of learning theory, one could evoke experiential learning and constructivism. Experiential learning theory advocates that learning could be achieved through the integration of concepts, observations and experience through action (Kolb 2014). The photospheres introduced here are linked with the experience and observation factors of this theory. The photosphere provides a direct link

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(the 'bridge' between field and lab alluded to in the 'Introduction') to field experiences and allow students to conceptualise the sample in an authentic setting, adding to the observations that could be made from the sample. Importantly, the innovation gives students the agency to construct their own learning (and as previously stated, this method was partially chosen as students could take ownership of the method and use it themselves). This aspect of the technology and its implementation goes well with the idea of constructivism (Tobin 2012), where the manner in which learners learn is acknowledged as vital for the understanding and building of knowledge. The method allowed students to utilise photospheres, and the data they provided if they wished, constructing their own learning.

Theme 2: inclusivity of the innovation

For an innovation of this kind to work, it was necessary that the technology was inclusive (Selwyn 2007); the method was purposefully implemented to include additional information, so that students could complete the task without using the innovation if they didn't feel comfortable or couldn't use the technology (e.g. visual impairment, prone to migraines from VR usage). Nearly all participants were happy using their own smart phones (Q9, Figure 4); one participant couldn't get the app to work on their phone, this individual borrowed a friend's device. There is some anecdotal evidence that students were sometimes wary, or unwilling to use their own devices in a learning environment; the willingness in this case could arise from the way the device was being used – in a way that is abstract from the student's normal social use of the phone. The students indicate that they would be happy paying for a (cheap) viewer themselves, or have it provided as part of the equipment supplied to them at the beginning of their studies. This detail could be interpreted as a sign that students enjoyed the method and believed it to be beneficial in the lab learning environment, as they were willing to spend their own money to use it.

As part of this theme, the students were asked whether they would use the method in their independent mapping projects (students spend 3–5 weeks in the field collecting data, then write a report after returning from their area of study). This question (Q8, Figure 4) was included to see whether the students would be willing to use this method outside of the staff-led teaching, and to gauge how applicable the method would be to their own studies (i.e. did they gauge the potential the method has for bridging field-based learning with lab-based work? Do they understand that they learn differently in different settings?). The majority of students said that they would *not* use this method in their independent mapping, in the written expansion of their answers, several cited the poor quality of images (and all respondents suggested that better quality of images would improve the experience, Q14, Figure 5) and that a photo would be better for their reports, and several others commented that it was too much effort. This response is quite possibly a failing during the introduction of the method; do students see themselves as agents responsible for the creation and collection of educational material? Picture quality is also an opportunity for possible solution, different devices could be used to collect photospheres (360° cameras, for example); however, this vastly reduces the availability and accessibility of the method. The photospheres collected here aren't the type of images that one would be able to include in a (typical) report; students may feel that collecting suites of traditional photos is a better use of their time.

Theme 3: continued usage and potential improvement

It is encouraging that the majority of students said that they would recommend the usage of mini VR for both this module (Q11, Figure 5) and others (Q12, Figure 5). This indicates that the students perceived some benefits from the method and would be happy to use it again. The spatial element of the method has been understood by students, and the context it provided for 3D elements seems to be clear. As a potential development, the respondents unanimously agreed that better quality images would enhance the experience. Within a setting similar to where this study was undertaken (i.e. a standard lab class), better quality images would be possible to provide (using a different tool/device to generate them – e.g. 360° cameras are becoming widely available). However, the quality of images for student's own work should be good enough if the photosphere is taken carefully, as the photospheres allow the user to immerse themselves into an environment to provide context to samples they have collected or locations they have visited – and not to use as images in a report. Images provided by Google as examples are of much higher quality and are presumably collected with 3D/360 cameras or camera sphere setups.

Conclusions and next steps

The participants' responses were generally very positive, indicating that the method was user-friendly and easy. The participants seemed to gain information by using the technique and it particularly helped them interpret the samples they were using – which is what this technological intervention was designed to do. The data suggested that the learning philosophy behind the innovation wasn't purveyed clearly to the students at the time they were introduced to the technology; perhaps this could be attributed to the short time for which the students had used the technology, or the students' perception on the creation and responsibility for generating educational materials. Whilst the students clearly found it helpful for interpreting, they appeared to be not thinking about why it might be helpful. This could be the reason that they are unwilling to use the method for collecting photospheres themselves (for their independent mapping project). Another factor that could have influenced their choice to not use the method was that it didn't fit into any obvious assessment criteria.

The factor responsible for generating the main negative result was image quality. The quality, when looking through the viewer was not perfect; the author is not sure whether this was due to the Google Cardboard app, the scale of the photospheres taken, the time at which they were taken (i.e. would slower capturing result in better photospheres?), or the device used to capture photospheres – could a 360° or 3D camera capture better images? Whilst better images would be helpful, particularly for lab-based sessions where data could be provided, the image quality used here was more than good enough for the given task; so this issue may also fall within management expectations and the proper introduction of technology.

- The innovation was inclusive, the students found it easy to use and would be happy to use it again.
- Photospheres successfully bridge some elements of field teaching with lab work.
- Further use of photospheres was encouraged by students.
- Students found photospheres a benefit to completing the description and, in particular, the interpretation of geological samples.

- Students didn’t, perhaps, understand pedagogical benefits of the method (i.e. immersing themselves into an environment that enables different learning activities), this was most likely a management expectation issue.
- The quality of image was not perfect; this could again fit into management expectation – the images don’t need to be perfect…. The use of clearer images is something to look into, particularly the collection of photospheres with a 360° camera.
- Google Cardboard viewers and the GCC app are a reliable and cheap VR provisions.

This study is seen very much as a foundation to larger studies on VR usage in education. Until cheaper and accessible VR methods, such as the one proposed here, become more commonplace, VR usage in the educational setting is going to be restrictive and inaccessible to the majority of potential users.

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References

Alexander, B. (2006) ‘Web 2.0: a new wave of innovation for teaching and learning?’, *Educause Review*, vol. 41, no. 2, p. 32.

Allcoat, D. & von Mühlenen, A. (2018) ‘Learning in virtual reality: Effects on performance, emotion and engagement’, *Research in Learning Technology*, vol. 26. doi: 10.25304/rlt.v26.2140

Bates, K. T. *et al*. (2008) ‘Three-dimensional modelling and analysis of dinosaur trackways’, *Palaeontology*, vol. 51, no. 4, pp. 999–1010. doi: 10.1111/j.1475-4983.2008.00789.x

Bellamy, M. & Warren, A. (2011) ‘Using online practicals to support lab sessions’, Unpublished paper [online]. Available at: http://edshare.soton.ac.uk/id/document/243301

Boudreaux, H. *et al*. (2009, November) ‘V-volcano: addressing students’ misconceptions in earth sciences learning through virtual reality simulations’, *International Symposium on Visual Computing*, Springer, Berlin, pp. 1009–1018.

Boyle, A. *et al*. (2007) ‘Fieldwork is good: the student perception and the affective domain’, *Journal of Geography in Higher Education*, vol. 31, no. 2, pp. 299–317. doi: 10.1080/03098260601063628

Burden, D. J. H. *et al*. (2017) ‘Fieldscapes – creating and evaluating a 3D virtual field trip system’, *Coimbra: Workshop, Long and Short Paper, and Poster Proceedings from the Third Immersive Learning Research Network Conference* (*iLRN 2017*), eds D. Beck *et al.*, Immersive Learning Research Network, pp. 18–29. doi: 10.3217/978-3-85125-530-0-09

Butler, R.(2008) *Teaching Geoscience through Fieldwork*, Higher Education Academy Subject Centre for Geography, Open University, Earth and Environmental Sciences, [online] Available at: https://www.researchgate.net/profile/Rwh_Butler/publication/237656424_Teaching_Geoscience_ through_Fieldwork/links/02e7e53870eff62fc5000000/Teaching-Geoscience-through-Fieldwork.pdf

Delabrida, S. *et al*. (2016) 'Building wearables for geology: an operating system approach', *ACM SIGOPS Operating Systems Review*, vol. 50, no. 1, pp. 31–45.

Edwards, M. R. & Clinton, M. E. (2018) 'A study exploring the impact of lecture capture availability and lecture capture usage on student attendance and attainment', *Higher Education*, vol. 77, no. 3, pp. 1–19. doi: 10.1007/s10734-018-0275-9

Elkins, J. T. & Elkins, M. L. (2007) 'Teaching geology in the field: significant geoscience concept gains in entirely field-based introductory geology courses', *Journal of Geoscience Education*, vol. 55, pp. 126–132. doi: 10.5408/1089-9995-55.2.126

Gamoran Sherin, M. (2003) 'New perspectives on the role of video in teacher education', in *Using Video in Teacher Education*, ed J. Brophy. Emerald Group Publishing Limited, Bingley, pp. 1–27. doi: 10.1016/S1479-3687(03)10001-6

Geikie, J. (1912) *Structural and Field Geology for Students of Pure and Applied Science*, 3rd edn, Oliver and Boyd, London, 452 pp.

Giles, S., Jackson, C. & Stephen, N. (2020) 'Barriers to fieldwork in undergraduate geoscience degrees', *Nature Reviews Earth and Environment*, vol. 1, no. 2, pp. 77–78. doi: 10.1038/s43017-020-0022-5

Hodgetts, D. (2013) 'Laser scanning and digital outcrop geology in the petroleum industry: a review', *Marine and Petroleum Geology*, vol. 46, pp. 335–354. doi: 10.1016/j.marpetgeo.2013.02.014

Hsu, J.(2007) 'Innovative technologies for education and learning: education and knowledge-oriented applications of blogs, wikis, podcasts, and more', *International Journal of Information and Communication Technology Education*, vol. 3, no. 3, p. 70.

Kirkwood, A. & Price, L. (2014) 'Technology-enhanced learning and teaching in higher education: what is "enhanced" and how do we know? A critical literature review', *Learning, Media and Technology*, vol. 39, no. 1, pp. 6–36. doi: 10.1080/17439884.2013.770404

Kennedy, G. E. & Cutts, Q. I. (2005) 'The association between students' use of an electronic voting system and their learning outcomes', *Journal of Computer Assisted Learning*, vol. 21, no. 4, pp. 260–268. doi: 10.1111/j.1365-2729.2005.00133.x

Kolb, D. A. (2014) *Experiential Learning: Experience as the Source of Learning and Development*, Pearson, FT Press.

Lang, N. P., Lang, K. T. & Camodeca, B. M. (2012) 'A geology-focused virtual field trip to Tenerife, Spain', *Geological Society of America Special Papers*, vol. 492, pp. 323–334. doi: 10.1130/2012.2492(23)

Lin, C. R. & Loftin, R. B. (1998, November) 'Application of virtual reality in the interpretation of geoscience data', *Proceedings of the ACM Symposium on Virtual Reality Software and Technology*, ACM, New York, pp. 187–194. doi: 10.1145/293701.293736

Litherland, K. & Stott, T. A. (2012) 'Virtual field sites: losses and gains in authenticity with semantic technologies', *Technology, Pedagogy and Education*, vol. 21, no. 2, pp. 213–230. doi: 10.1080/1475939X.2012.697773

Lui, M. & Slotta, J. D. (2014) 'Immersive simulations for smart classrooms: exploring evolutionary concepts in secondary science', *Technology, Pedagogy and Education*, vol. 23, no. 1, pp. 57–80. doi: 10.1080/1475939X.2013.838452

Maag, M. (2006) 'Podcasting and MP3 players: emerging education technologies', *CIN: Computers, Informatics, Nursing*, vol. 24, no. 1, pp. 9–13.

Martínez-Graña, A. M., Goy, J. L. & Cimarra, C. A. (2013) 'A virtual tour of geological heritage: valourising geodiversity using Google Earth and QR code', *Computers & Geosciences*, vol. 61, pp. 83–93. doi: 10.1016/j.cageo.2013.07.020

Mather, A. E. *et al*. (2015) 'Ten years on: what can Google Earth offer the geoscience community?', *Geology Today*, vol. 31, no. 6, pp. 216–221. doi: 10.1111/gto.12119

McCaffrey, K. J. W. *et al*. (2008) 'Visualization of folding in marble outcrops, Connemara, western Ireland: an application of virtual outcrop technology', *Geosphere*, vol. 4, no. 3, pp. 588–599. doi: 10.1130/GES00147.1

McLoughlin, C. & Lee, M. (2007) 'Social software and participatory learning: pedagogical choices with technology affordances in the Web 2.0 era', *Proceedings Ascilite Singapore* [online] Available at: http://researchbank.acu.edu.au/cgi/viewcontent.cgi?article=3049&context=fea_pub

McLoughlin, C. & Lee, M. J. (2010) 'Personalised and self-regulated learning in the Web 2.0 era: international exemplars of innovative pedagogy using social software', *Australasian Journal of Educational Technology*, vol. 26, no. 1, pp. 664–675. doi: 10.14742/ajet.1100

Means, B. (1993) *Using Technology to Support Education Reform*, Superintendent of Documents, US Government Printing Office, Washington, DC.

Means, B. (ed) (1994) *Technology and Education Reform*, Jossey-Bass, San Francisco, CA.

Meyer, J. H. F. & Land, R. (2003) 'Threshold concepts and troublesome knowledge: linkages to ways of thinking and practising within the disciplines', in *Improving Student Learning: Improving Student Learning Theory and Practice – Ten Years On*, ed C. Rust, Oxford Centre for Staff and Learning Development, Oxford, pp. 373–388.

Meyer, J. H. F. & Land, R. (2005) 'Threshold concepts and troublesome knowledge (2): epistemological considerations and a conceptual framework for teaching and learning', *Higher Education*, vol. 49, no. 3, pp. 373–388. doi: 10.1007/s10734-004-6779-5

Moysey, S. M. *et al*. (2015, December) 'Enabling field experiences in introductory geoscience classes through the use of immersive virtual reality', in *AGU Fall Meeting Abstracts*.

O'Callaghan, F. V. *et al*. (2017) 'The use of lecture recordings in higher education: a review of institutional, student, and lecturer issues', *Education and Information Technologies*, vol. 22, no. 1, pp. 399–415. doi: 10.1007/s10639-015-9451-z

Selwyn, N. (2007) 'The use of computer technology in university teaching and learning: a critical perspective', *Journal of Computer Assisted Learning*,vol. 23, no. 2, pp. 83–94. doi: 10.1111/j.1365-2729.2006.00204.x

Schroeder, A., Minocha, S. & Schneider, C. (2010) 'The strengths, weaknesses, opportunities and threats of using social software in higher and further education teaching and learning', *Journal of Computer Assisted Learning*, vol. 26, no. 3, pp. 159–174. doi: 10.1111/j.1365-2729.2010.00347.x

Simpson, V. & Oliver, M.(2007) 'Electronic voting systems for lectures then and now: a comparison of research and practice', *Australasian Journal of Educational Technology*, vol. 23, no. 2, pp. 187–208. doi: 10.14742/ajet.1264

Tobin, K. G. (2012) *The Practice of Constructivism in Science Education*, Psychology Press, Routlidge, New York. doi: 10.4324/9780203053409

Trinks, I. *et al*. (2005) 'Mapping and analysing virtual outcrops', *Visual Geosciences*, vol. 10, no. 1, pp. 13–19. doi: 10.1007/s10069-005-0026-9

Webster, R. (2015) 'Declarative knowledge acquisition in immersive virtual learning environments', *Interactive Learning Environments*, vol. 24, no. 6, pp. 1319–1333. doi: 10.1080/10494820.2014.994533

Wu, Q. & Xu, H. (2003) 'An approach to computer modelling and visualization of geological faults in 3D', *Computers & Geosciences*, vol. 29, no. 4, pp. 503–509. doi: 10.1016/S1006-1266(07)60048-0