Mobile virtual reality for environmental education

How to cite:

© 2018 The Authors

https://creativecommons.org/licenses/by-nc-nd/4.0/

Version: Version of Record

Link(s) to article on publisher’s website:
https://ejournal.urockcliffe.com/index.php/jovs/issue/view/14/18
Mobile virtual reality for environmental education

Ana-Despina Tudor  
School of Computing and Communications  
Faculty of Science, Technology, Engineering and Mathematics  
The Open University, UK  
ana.tudor@open.ac.uk

Shailey Minocha  
School of Computing and Communications  
Faculty of Science, Technology, Engineering and Mathematics  
The Open University, UK  
shailey.minocha@open.ac.uk

Melanie Collins  
Geography Department  
Pipers Corner School, UK  
mcollins@piperscorner.co.uk

Steve Tilling  
UCL Institute of Education  
Department of Curriculum, Pedagogy and Assessment  
University College London, UK  
stephen.tilling@ucl.ac.uk

Abstract

We report students’ experiences of using a mobile virtual reality application to learn about the environmental impact of large scale developments on nature reserves, by comparing the physical field trip location to a location in virtual reality, which they accessed while in the field on a geography field trip. We present our research with 64 secondary school students who used Google Expeditions, a smartphone-based virtual reality application, on a geography field trip to their local nature reserve in south-east England. Google Expeditions (GEs) consists of over 700 expeditions or guided field trips that students experience on a smartphone through a virtual reality viewer. An expedition comprises of 360-degree photospheres of locations like the Queen Elizabeth Olympic Park in London, the Grand Canyon, Antarctica and Iceland. Through the use of virtual reality in the field and the affordances of the GE app, students became aware of the issues created by large-scale development on the environment, acquired knowledge about its implication for the ecosystem, and suggested actions for protection of the environment. Following the field trip, students sent letters to the Chiltern Society (a voluntary organization dedicated to conserving of Chilterns’ landscape in the UK) that discussed the implications of large scale development plans close to their local nature reserve in the ChilTERNs.
Introduction

Fieldwork has a long tradition in geography and in certain sciences, notably geology, biology and environmental sciences (Stokes & Boyle, 2009; Stokes, Magnier & Weaver, 2011). Fieldwork involves leaving the classroom and engaging in learning and teaching through first-hand experience of phenomena in outdoor settings (Association for Science Education, 2011; Tilling, 2016). Exploration in natural habitats introduces students to the complexity and messiness of the real world (Lambert and Reiss, 2015), stimulates their curiosity, and increases their interest in scientific inquiry (Foskett, 2000; Remmen & Frøyland, 2014).

Teaching and learning in a field setting enhances environmental literacy, instills social responsibility towards preservation of biodiversity, and raises awareness of ethical questions about other living beings (Scott, Goulder, Wheeler, Scott, Tobin, & Marsham, 2015). 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 (Cooley, Burns, & Cumming, 2015).

Technology-enabled virtual field trips (Stoddard, 2009) through photographs, videos, live expert seminars, web-based interactive experiments, and three-dimensional (3D) simulations (Argles, Minocha, & Burden, 2015; Park, Shin, Cui, & Hwang, 2008) have been promoted as a means for improving the effectiveness of the physical fieldwork experience (Robinson, 2009). However, 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 (Maskall & Stokes, 2008; Stoddard, 2009).

Virtual reality

Virtual reality (VR) generates realistic images, sounds and other sensations to replicate a real environment, or to create a non-realistic setting. The characteristics of VR are 3D images, virtual objects that behave like their real-life counterparts, and features that enable interactivity with the virtual environment. VR has been used as an educational and training platform for simulating object behaviors (e.g. in manufacturing (Nee & Ong, 2013) or for visualizing difficult concepts (Foskett, 2000) (e.g. a solar system).

Virtual reality is being delivered in various ways – ranging from smartphone-driven VR using VR headsets such as Google Cardboard and Samsung Gear VR, to desktop-driven VR with head-mounted displays such as in HTC Vive, Oculus Rift and Sony PlayStation VR. Further, 3D virtual environments can be accessed on desktops and mobile devices that may not require a VR headset as in the case of 3D virtual world Second Life (or in Sansar, a social VR platform), or in 3D virtual environments developed in game development platforms such as Unity 3D. For example, the UK’s Open University’s 3D virtual geology field trip, a simulation of the Skiddaw mountains in UK’s Lake District, was developed in Unity 3D (Argles et al., 2015).

The Google Expedition application

Google Expeditions (GEs) are guided field trips to places that students experience on a smartphone through a VR viewer called Google Cardboard. The GE app (available for Android and iOS platforms) has more than 700 expeditions. An expedition comprises of 360-degree photospheres and 360-degree videos of real or simulated places for educational purposes. For example, there are 360-photospheres of places such as Galapagos Islands or Great Wall of China, or WaterAid’s VR documentary ‘Aftershock’, which has 360-degree videos to highlight Nepal’s challenges to restore water access after devastating earthquakes in 2015. Further, VR can provide experiences of unrealistic events, such as bringing dinosaurs to life in 360-degree videos, a collaboration between Google Arts and Culture and The Natural History Museum.
the human heart, the respiratory system (Figure 1), 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 2 (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).

In the research study being reported in this paper,
we discuss the role of VFTs, as in GEs, in imparting
environmental education. Through an analysis of
students’ experiences, we show how VFTs, as in Google
Expeditions, connect the learning from an international
context to a local context in geography fieldwork.

Fieldwork case study

The Chilterns, located north west of London in the UK,
cover 650 square miles, and almost half of the Chilterns
is an officially designated Area of Outstanding Natural
Beauty, parts of which will be adversely affected due to
High-Speed railway construction (referred to as HS2)
throughout the Chilterns. Local residents’ groups, along
with the support of the Chiltern Society, have worked
together to establish HS2 Watch, an independent group
monitoring the progress of the railway’s construction
throughout the Chilterns.

We describe the experiences of students using the
expedition “Environmental Change in Borneo” on a set
of smartphones and virtual reality headsets provided
by the research team during a field trip to Prestwood
nature reserve in the Chilterns area of the UK. At the
end of the field trip, once students returned to school,
they were required to reflect on their experience of using
virtual reality in the field through a question: “How
did virtual reality help you to understand about the
impact of large-scale developments on the Chilterns?”. We
discuss their reflections by using the Awareness
and Action continuum (Barnes & College, 2013) as a
framework. Through an analysis of students’ post-field
narratives, we show how mobile VR as in GEs bridges
virtual fieldwork with physical field trips, improves
the value of fieldwork education and facilitates experiential
learning.

Theoretical background for Environmental Educa-
tion

Fieldwork is an example of experiential learning, or
“learning by doing” following Kolb’s learning model
(Kolb, 1984). Fieldwork has three phases (Maskall &
Stokes, 2008): pre-field trip preparation; fieldwork;
and post-field trip debriefing. The preparatory phase
involving pre-trip induction, and development
of inquiry (questions for investigation) and data
collection procedures is analogous to Kolb’s abstract
conceptualization; the fieldwork or doing phase is
analogous to Kolb’s active experimentation and concrete
experience phases; and the reflective post-trip phase is
synonymous with Kolb’s reflective observation (Scott et
al., 2012). Here we focus on the experimentation and
concrete experience phase occurring in the field.
During the past 50 years, teaching strategies in fieldwork (Caton, 2006) have evolved from an educator-led field excursion to an active student-driven inquiry-based fieldwork, a process driven by questioning, investigating, analyzing information and developing new meanings and understandings (Jansen, 2011). The key ingredients of an inquiry-based learning approach are that learning is stimulated by a question or problem, and students learn through active engagement in the process of seeking knowledge and new understanding to fulfil the inquiry (Ord & Leather, 2011).

Environmental education represents an integral part of school education (Manzanal, Barreiro, & Jiménez, 1999). Through fieldwork, students can learn about the environment, while being outdoors, where the environment is “used as a vehicle for the development of knowledge” and where their experience of fieldwork and the knowledge acquired is proved to influence beliefs about ecosystems (Manzanal et al., 1999). Among the goals of environmental education are attitude and behavioral change reflected through actions (Gayford, 1996). In our study, the educator aimed to sensitize students to potential environmental changes in their local nature reserve triggered by the construction of a HS2 railway. The action required was to write letters to the Chiltern Society, explaining the impact of such large-scale development on the nature reserve.

We refer to the Awareness to Action (AA) continuum (Barnes & College, 2013) as a framework for environmental education and for our analysis. The Awareness to Action represents a learning process with several stages:

- Awareness and appreciation, which allows students to experience nature and its beauty;
- Knowledge and understanding through which students understand how natural systems work and how they are interconnected with human systems and activity;
- Attitudes and values through which students learn about respect and concern towards the planet and feel ethically motivated to participate to environmental preservation
- Problem solving skills that students acquire to identify, analyze and contribute to resolving environmental issues, and
- Personal responsibility and action, through which moral responsibility turns into ecologically sensitive behaviors.

**Affordances of Google Expeditions**

To explain how VR technology facilitated fieldwork education, we present the affordances of the Google Expeditions app. As a part of our wider research program, which is the first extensive user-centered research program on the pedagogical effectiveness of GEs in science and geography education, we have derived the educational affordances of the virtual reality application (Minocha, Tudor & Tilling, 2017) and their role in fieldwork education, inquiry-based learning and learning via simulations.

The term affordance refers to the perceived and actual properties of an object that determine how the object could possibly be used; a chair affords (“is for”) support and, therefore, affords sitting. The design of an object has to be “perceived” to be of use to the potential user – hence, the emphasis on “perceived affordance” by Norman (1988). We have followed Gibson’s (Soegaard, 2017) and Norman’s (1988) interpretation of educational affordance as it is the participants’ (educators and students) perceptions of the affordances of GEs, and how these affordances support their learning and teaching and influence their experiences with virtual reality.

For each of the affordances that we have derived (see Table 1), we discuss the perceptions and experiences of participants, and how the affordances influence learning and teaching.

**Description of the Research Study**

In this research study, we describe how a virtual field trip in the GEs app was used during outdoor geography fieldwork to help students draw comparisons between the local area they were visiting and locations in the rain forest in Borneo. The simplicity of the equipment associated with the mobile or smartphone-driven VR of GEs (as compared with VR headsets tethered to high-spec machines) enabled us (the research team) to use VR in the field. We were able to power the router (for creating the wireless network between the tablet and
<table>
<thead>
<tr>
<th>Affordance</th>
<th>Meaning of the affordance and implications for learning and teaching</th>
</tr>
</thead>
<tbody>
<tr>
<td>360-degree visual authenticity</td>
<td>The 360-degree photospheres of physical places in GEs capture every possible viewing direction, thereby, providing a wide field of view. The perceptions of participants towards this affordance and which support learning were: accurate physical representation of the space (Fowler, 2015); spatial relationships between the rain forest and the Chilterns area (Gersmehl &amp; Gersmehl, 2011), sense of spatial presence, and experienced immersion.</td>
</tr>
<tr>
<td>360-degree navigation</td>
<td>Students are able to move their head left to right, but also up and down to see the scene all around them within the Google Expedition (Figure 3). This enables them to orient themselves and to apprehend the characteristics of the place they are visiting. The perceptions of participants towards this affordance are: spatial understanding (Gersmehl &amp; Gersmehl, 2011) understanding the proportions of the elements in a scene and how they compare against one another, e.g. how large the rain forest was; being able to observe and understand the characteristics of a physical location; and spatial relationships.</td>
</tr>
<tr>
<td>3D view</td>
<td>The lenses of the VR viewer focus and reshape the images in a GE for each eye and create a stereoscopic 3D image. The 3D view affordance is particularly relevant for visualizing and for understanding perspectives. The perceptions of participants were: sense of orientation in a place, sense of presence and sense of immersion within VR.</td>
</tr>
<tr>
<td>Emphasis</td>
<td>This affordance is specific to the educator or guide-driven mode of GEs on the tablet. The educator can highlight aspects of a scene in an expedition by selecting pre-defined viewpoints or by creating new ones through tapping on the tablet’s screen. The students follow or look at the viewpoint while being guided by an arrow on the smartphone VR scene. In the field trip, students followed the points of interest selected by the educator (Figure 4).</td>
</tr>
</tbody>
</table>

Figure 3. Students viewing the expeditions via the VR viewers during the field trip

Figure 4: (a) Circle marking the point of interest selected by the educator in “guide” mode; (b) arrow pointing students to the point of interest in “follower” mode. GE: Environmental Change in Borneo, scene “Pristine rain-forest”
In a lesson, an educator can use scenes from more than one GE, or use GEs alongside other resources such as videos, or sounds. The perceptions related to this affordance were integrability (use more than one expedition at once) and combine-ability (combine GE with other resources). During the field trip reported in this paper, the educator used several scenes within the same expedition and showed different perspectives on the rain forest.

<table>
<thead>
<tr>
<th>Synthesis</th>
<th>Table 1: Affordances and their implications for learning and teaching</th>
</tr>
</thead>
</table>

Fieldwork setup

Sixty-Four Year 7 students explored the GE of ‘Environmental Change in Borneo’ during their field trip to a local nature reserve in the Chilterns area of South East England. The aim of this virtual field trip was to help students understand the impact on nature produced by deforestation, land clearance and development of buildings, and to sensitize them to the potential magnitude of impact on their local nature reserve that may be caused by the development of HS2 railway nearby.

The students looked at the following scenes from the “Environmental Change in Borneo” Expedition:
- “Pristine Rainforest” – describing the plant and animal diversity in Borneo (Figure 4);
- “Land Clearance and Deforestation” – showing how the forest is cleared and how former forest areas turn into open space (Figure 5);
- “Land Encroachment” – showing how land is being cut through to create space for new real estate development (Figure 6);
- “Sandakan Development” – showing modern touristic coastal developments at the beach (Figure 7).

During the field trip to their local nature reserve, students came in a group of 8-10 students at one time to the GEs table (set up on a picnic table) and spent about 10 minutes touring the “Environmental Change in Borneo” expedition.
Borneo” Expedition under the guidance of the educator (Figure 8).

![Figure 8: Students exploring GE “Environmental Change in Borneo”]

Fieldwork data collection

During the field trip and after the tour of the GE, the students were asked to reflect on how the virtual field trip made them feel differently about the large-scale development planned near the local nature reserve. After the field trip and during the debriefing session of 30 minutes, they wrote their reflections in response to this guiding question: “How did virtual reality help you to understand about the impact of large-scale developments on the Chilterns?” After this debriefing session, we (research team) conducted a face-to-face group interview with two educators who had led the physical field trip.

The ethical considerations and the research design of this research study was approved by The Open University’s Human Research Ethics Committee.

Data analysis

The audio-recordings of the educator-interviews were transcribed verbatim. These transcripts were analysed inductively and deductively in NVivo 11 software for iOS through thematic and axial coding (Corbin & Strauss, 2008). For the analysis of student written reflections, we asked the educator who organised and conducted the field trip to look at the scripts and comment on the how they relate to the learning outcome of the lesson.

During this initial analysis, the educator noticed that students had become aware of the effects of large scale developments and deforestation; that they had gained knowledge and understanding of the implications and even thought of possible actions that they could take to prevent similar situations in the Chilterns or anywhere else. Based on the educators’ comments and her understanding of what students intended to learn, we developed inductively a list of categories to analyse students’ reflections. We then assigned these comments to our category list, in a second iteration of the analysis.

Upon consulting literature sources, we realised that the categories that we had developed were very much similar to the ones proposed by Barnes and College (2013) in the Awareness to Action continuum, and outlined in Section 2 of this paper. Following this, we consulted the AA continuum and our category list, checked for duplicates and realised that some of our initially developed categories could be subsumed to the broader ones in the AA continuum. For instance, for the “Awareness and appreciation” category in the AA, we added two subcategories of “awareness of issue” and “awareness of location and its characteristics”. Once we created a new integrated category list, we performed a third iteration of analysis and coded all reflections again by using the new enhanced model. Due to the nature of the fieldwork and the learning outcomes planned by the geography educator, we were able to map our findings to four out of five stages of the continuum. There wasn’t a scope for analyzing the change in acquisition of students’ problem-solving skills (one of the stages of this continuum) within this research study involving a single physical field trip. We present our findings in the next section.

Study Results

Students were able to connect their understanding and relate the changes in Borneo rain forests to their local nature reserve and to map the broader context of infrastructural 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.”
Awareness and appreciation

In our data analysis, we identified two types of awareness fostered by the experience of VR in the field. The first type of awareness refers to the environmental challenges created by large-scale development in Borneo and the local nature reserve, respectively. By exploring the scenes in Google Expeditions (Figures 4-7), students could visualize how the rain forests in Borneo had been affected by deforestation, palm oil plantations and real estate developments: “It really helped me learn about the devastation of the world now and in the future”.

The second type of awareness refers to learning about the characteristics of the places in virtual reality and of the one that they were visiting as a part of their field trip: “it helped me [to understand] because I saw a beautiful jungle full of green and life. Then in virtual form we saw a building site, sparse trees. If that happened to the Chilterns, with e.g. HS2, it would be devastating.”

The affordances that contributed to students’ awareness were:

- 360-degree visual authenticity and synthesis – seeing a faraway place and accessing various perspectives though several scenes within the same expedition: “It helped us understand as it showed us lovely beautiful forest that was untouched by humans. Then, it showed us a picture of a barren, ugly place where trees had been chopped down. This made us think that we are cutting down too many trees [for] housing more than we should”.

- emphasis – although students were free to explore the photospheres alone, they were guided to look at relevant points and focus on specific content: “it helped me because you could actually see what you were learning, not just talking about it. I found it fun and a new way of learning. It was helpful that they gave you an arrow to show what you are looking for.”

Knowledge and understanding

Through their comments, students demonstrated that they acquired knowledge and understanding of the issues that come along with large scale developments and their impact. One student commented: “it helped me understand because it gave me an idea of how big the impact was and the large scale of the setting. It also helped me because some things in the settings were not seen in everyday life e.g. higher [rain forest] trees”. Further, students showed a good understanding of the geographical concept of scale. This was supported by the affordances of 360-visual authenticity, 360-degree navigation and 3D view, which gave them the bird’s eye view over the rain forest: “it showed me all different things and how things like HS2 can really impact. You could see it on a large-scale so you got to see things [on] an overall scale.”

The educator commented that students were able to compare and contrast their local nature reserve to Borneo rain forests in VR: “it is that taking the local into global […] or the global into local.” The possibility to actually visualize impact of development on nature is an experience that would be difficult to acquire without a comparison of places. Using virtual reality while in the field gave students an unique experience that educators found very useful for their actual understanding of the issue: “one stage would be ‘yes, we’ve done the fieldwork, we’ve been to see ‘this is the area that would be destroyed perhaps, if something big like that was to happen through it’ and then secondly, when you look at that ‘yeah, that could be pretty horrible’ but then to see that [Borneo] and see actually it really would be pretty horrible, it all makes it make sense again”.

Students inferred the broader impact on ecosystems and predicted the change brought by human intervention through their comments on the effects of flora and fauna that lives in their local nature reserve and how the construction of the railway would affect biodiversity, tourism and living standards of locals: “It made me understand that there would be a big change in the Chilterns and not necessarily a good change. Also, it will ruin it for the wildlife and animals which help the Chilterns grow and expand. I hope the Chilterns won’t change.”

Attitudes and values, personal responsibility and action

The attitude of students towards the environmental changes depicted in the GE was expressed in negative statements. Students described the environmental impact as being worse than they had expected and devastating for the health of the rain forest: “It made
it easier to actually get a view on what tragedies might happen in the near future. I always thought that people were being dramatic, but now I understand the long-term impact it will have on the world/woods.

The affordances of GEs such as 360-degree visual authenticity, 360-degree navigation and 3D allowed students to see more of the rain forest as well as understand the degree of impact: “When you look through it you can see much more than you could in a normal picture also as you can see 360 degrees around it make it a lot clearer and see the big impact on the environment closer up” and “it helped me understand because it was a 360 degree view and you can see the impact that we have on the environment around us.”

The personal responsibility and action component of the Awareness to Action continuum were reflected in other comments. Several students acknowledged that there is a shared responsibility for protecting nature and there is a need for action to prevent the destruction of nature reserves: “We all have to share our part of helping in the world”; “we need to try and stop destroying the wildlife and do something about it”.

The planned outcome of the field trip and of the virtual reality experience via the VFT was to support students in writing a letter to the Chiltern Society to address their concerns about the development of the HS2 in the Chilterns area where the Prestwood nature reserve is located. Following the fieldwork, students composed the letter and the most relevant ones were passed on to the Chiltern Society. The best written and most comprehensive letter was awarded a prize.

Discussion

In this paper, we have shown how using VR in a field trip to the local nature reserve supports environmental education by following the Awareness to Action continuum: from students becoming aware about the changes brought by large scale development projects to taking action in the form of a letter to the Chiltern Society.

Students were able to connect their understanding and 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.”

The affordances of GEs such as 360-degree visual authenticity, 360-degree navigation, 3D view, and synthesis enabled students to familiarize themselves with the 360-degree space within the GE and see beyond what a flat view in a video or a book or a photo may provide. This perception of space contributed to their spatial understanding and sense of scale of the context that they are visualizing in an expedition – and, in this case, the scale of the environmental change caused by man-made interventions. Students explained this experience of scale and understanding the extent of change via the GE: “It was useful. It made you understand how habitats can change from human technology and wants. It gave you a before and after picture and it was scary how it can change”.

With the support of GE, students were able to cover the stages of the Awareness to Action continuum of environmental education during a field trip. Furthermore, our findings complement those of Manzanal et al. (1999) that direct experience acquired in the field helps students to understand habitats and environmental issues. A review of environmental education literature by Stern, Powell & Hill (2014) concluded that field trips support environmental education through “active and experiential engagement with real-world environmental problems”. Our interactions with students and the educators who organized the field trip in this research study have shown the role of virtual reality and VFTs as a means of extending and enhancing the field trip experience beyond the physical field trip. Students visited their local nature reserve and, through virtual reality, accessed remote areas, and engaged with VFTs to support their learning in the field.

Students became aware of nature’s beauty both in Prestwood and in Borneo as well as understood the threats these areas are facing. They acquired knowledge about the ecological issues that large scale-development pose in both locations; they manifested negative
attitudes; and called for action to preserve ecosystems in Borneo rain forests as well as in the Chilterns area.

The geography educator who led the fieldwork commented that the major benefit of using VR in the field was to achieve contextualized comparisons between places and to inspire students to think of potential action that they would take to protect the environment: “I think they saw the whole Borneo “visit” in a kind of context of what we were looking at there [in the field], which is I think was the purpose [of this activity]. Through this, students were able to acquire environmental literacy as well as learn spatial skills, such as the scale of impact and spatio-temporal changes.

**Challenges and future work**

Some of the challenges of using VR in the field are posed by accessing the technology safely in various weather conditions, keeping the smartphones and tablet charged for the duration of the field trip, as well as being able to set up a good connectivity between smartphones and the tablets with the help of a battery-powered router.

The focus in this research study was on geography; however, other subjects with tradition in fieldwork, such as ecology, biology and environmental sciences could also benefit from including virtual reality within fieldwork education. VFTs as in GEs are a useful way to experience places that they may not be able to experience in real life such as the flora and fauna on Galapagos Islands, or the volcanic landscapes in Indonesia; or which may be dangerous to visit such as areas of high tides or near an active volcano. Furthermore, VR can be used across all the stages of fieldwork: from supporting educators and students to prepare ahead of a field trip; during a field trip to compare and contrast physical locations with VFTs embedded with mobile VR; and revisiting locations in VR for de-briefing after a physical field trip.

The adoption of technologies 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. Any technology-enabled learning initiative including the VR-based GEs that we have focused on, can be effective only if the educator justifies its usage to students and embeds it within the curriculum.

**References**


Stoddard, J. (2009). Toward a virtual field trip model

