8th International Conference on Higher Education Advances (HEAd'22)
Universitat Politècnica de València, València, 2022
DOI: http://dx.doi.org/10.4995/HEAd22.2022.14487

Using Augmented Reality to improve understanding of the Carbon cycle

Carme Huguet[1], Jillian Pearse[1], Alvaro Marcel Lozano Tarazona[2]
[1]Geoscience Department, Los Andes University, Colombia, [2]Conectate, Los Andes University, Colombia.

Abstract

We designed an activity to improve students' knowledge and understanding of the Carbon cycle, which is typically a difficult concept. We wanted users to understand the main Carbon repositories and how the element circulates, as well as how human activity is impacting it. Originally designed for an advanced biogeochemistry course on paper, it was later redesigned using augmented reality (AR) to reach a wider audience and increase accessibility to both specialized and nonspecialized audiences. The reason for using augmented reality (AR) coupled to inquiry-based learning was to motivate students to complete the activity independently and make it more appealing to a wider audience. The Carbon cycle was divided into 7 stations that will be placed throughout the university campus, and which can be accessed by anybody using an android smartphone. They can choose to complete the whole cycle and answer a questionnaire, or just browse freely. We expect that the activity will improve understanding of the Carbon cycle in a didactic, playful and non-threatening way, and motivate users to learn autonomously. We also expect it to improve long-term retention.

Keywords: *Augmented reality; Carbon cycle; Active learning; carbon repositories; flows of carbon.*

1. Introduction

Since its first use in 1992, Augmented Reality (AR) has gained popularity in educational processes due to its recognized efficacy for teaching and learning (Chen et al., 2012; Ibáñez & Delgado-Kloos 2018; Wang et al., 2018; Garzón et al., 2020). AR uses virtual objects or information overlaid on natural physical environments in a meaningful way that can improve the learning experience (Chen et al., 2012 and references therein). While originally the relatively high cost did not allow for wide dissemination, the advent of mobile devices made it possible for AR to become widespread (Garzón at el., 2019). This increased accessibility and affordability of AR has made it possible to design activities that reach a wider audience.

By layering virtual information over the real physical world, AR provides an exciting array of enhanced learning and engagement educational possibilities (e.g. Wang et al., 2018). In fact, AR has been linked to increased concept understanding, long term concept retention and motivation (Chen et al., 2012; Ibáñez & Delgado-Kloos 2018; Wang et al., 2018; Garzón et al., 2020). While the use of AR seems to have a medium-high impact on learning gains, when coupled with the right pedagogical approach, a higher impact can be achieved. Typically, Inquiry-based learning (IBL) is used in AR applications for natural sciences (Garzon et al., 2020). IBL is an active pedagogical approach where students learn by doing, and allows them to construct knowledge independently as well as improve retention (Edelson et al., 1999).

The Carbon cycle describes the process in which carbon atoms continually travel between the atmosphere, hydrosphere, biosphere and geosphere (e.g. Killops and Killops 2005). Carbon is the foundation of all life on Earth, required to form complex molecules like proteins and DNA. The carbon cycle is also key to understanding the climate system and its imbalance, which makes it very pertinent not only in academia but for the society at large. While it is often challenging to comprehend the carbon cycle form and function as well as how we fit into it, we expect that AR will facilitate this knowledge integration.

As it has been argued that people learn more deeply from words and pictures, we expect this activity will become a great asset for the university community that will have access to clear and didactic information on the carbon cycle (e.g. Mayer, 2005). Furthermore, we added short supporting texts that provide enough information to navigate the carbon cycle and to complete the questions designed to guide users to a deeper knowledge, if they so wish.

While originally designed for advanced geoscience students to improve their understanding of the subject, we saw early on in the development that it provided a great opportunity to engage other members of the university community in the activity, regardless of their educational background. We expect that the use of AR in the exploration of the Carbon cycle will motivate individuals to engage with the activity without feeling it is too complicated or out of reach.

2. Methods

2.1. Activity design

The carbon cycle is key for life on earth; however, the cycle is complex, and thus we used a simplified carbon cycle to design the activity (e.g. Killops and Killops 2005; Fig. 1). The activity has 2 main objectives:

a. Increase understanding of the Carbon cycle

a.1. Understand the reservoirs and fluxes.

a.2. Comprehend the notion of imbalance of the system and human interference.

b- Motivate a wider audience to learn about the Carbon cycle and how we fit into it.

To achieve the objectives, the carbon cycle was divided into 7 stations corresponding to 1) Atmosphere, 2) Soil, 3) Surface ocean, 4) Land biota, 5) Deep ocean, 6) Ocean biota, and 7) Lithosphere. In each station we have a process, reservoir and flux tap that will show the most relevant process in augmented reality as well as a supporting text box with additional information (Figs. 1-3).

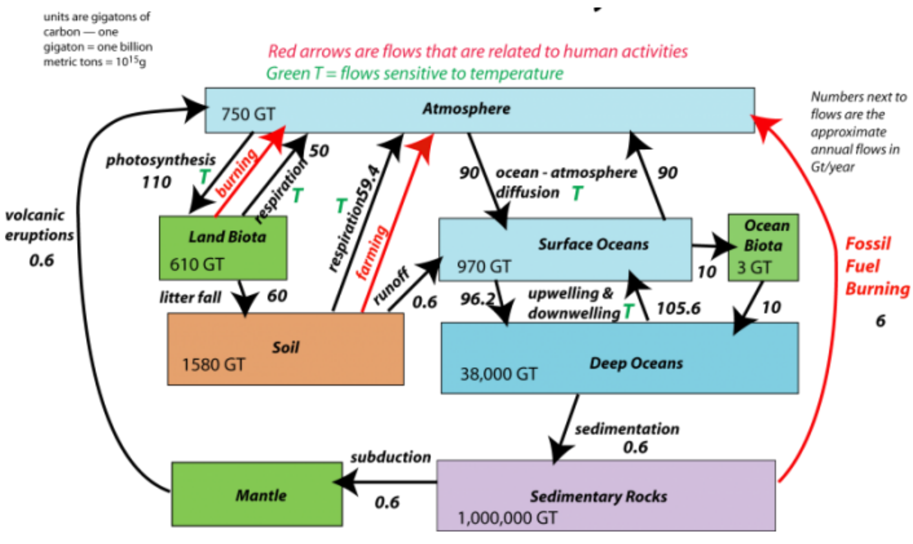

Figure 1. The global carbon cycle used to design the activity. The different reservoirs for carbon and the exchanges between reservoirs in gigatons (GT) per year are shown. The imbalances are indicated with red arrows (figure reproduced from: David Bice © Penn State University is licensed under CC BY-NC-SA 4.0).

2.2. Augmented reality environment design

The Vuforia Engine is the most widely-used software development kit for mobile devices that enables the creation of augmented reality applications. The Vuforia Engine was used for the AR development using the free version programming library (https://library.vuforia.com/). This allows users to freely select the image they want to use as a marker, and the objects (images, sounds, videos, 3D models) that will be displayed when the device's camera recognizes the mark (see Fig. 2 for example of the marker used).

The 3D models were made from scratch by two design students using the Blender application (https://www.blender.org/). The 3D models and animations were optimized so that the application works smoothly. The use of AR allows the models to be viewed from different angles and positions, as long as the activator is visible to the device. To interact with the buttons and switch between Process, Reservoir, and Flow, the touch screen of the mobile devices must be used (Fig. 2).

2.3. Application design

To develop the augmented reality application, the Unity video game engine was used (https://unity.com/). Unity is the world's leading platform for developing virtual and augmented reality experiences. A video game engine allows you to assemble all the components that a video game has, such as programming, graphic design and 3D models. It also allows you to wrap your app for Android phones 5.0 and up using the APK format.

To install the app in the phone you need the following link:

https://drive.google.com/file/d/17uNaCRkskThrT5zAFQwqu_-mz4mOEXqw/view?usp=sharing

Once installed you can scan the marker of each station and access the information (Fig. 2).

Figure 2. Images of a) Icon of the app and opening screen with the 3 tap for process, reservoir and flux designed with https://unity.com/; b) example of the markers for Station 1: Atmosphere (https://library.vuforia.com/).

3. Designed activity and expected learning outcomes

With this AR activity we are addressing intrinsic motivation, as we are targeting the audience's propensity to learn by providing interesting, relevant and enjoyable information (Ryan & Deci, 2000). We are made of Carbon; we breath, eat and have built our civilizations and economies on it, and so a working knowledge of the Carbon cycle is crucial for anybody that wishes to understand our planet (Killops and Killops 2005). As the AR has animations it is easier to see the flow and extent of the carbon circulation between the reservoirs. The inclusion of explicative panels supports the animations and gives extra information to go beyond the simpler processes proving a deeper understanding.

Since the Carbon cycle is a multilayer, complex concept, to make the activity easier and more didactic we parcelled the cycle into 7 stations that represent the main reservoirs of the cycle (Fig. 3). In each reservoir users can access the size, processes and fluxes away from the reservoir by switching between the buttons (Fig. 2). We wanted to show the flow of Carbon from each reservoir: for example, we show the fluxes from the atmosphere to the ocean and land reservoirs (Fig. 3a). It was also key to explain the impact of the human activity on atmospheric CO_2 concentrations and thus enhanced greenhouse effect (Fig. 3b). From the original activity we identified that it is crucial for learners to be included in the Carbon cycle to increase motivation and comprehension. For this reason, one station deals with land biota showing photosynthesis (Fig. 3c) as well as respiration and organic matter flux to the soil. Of course, a little less known is how the oceans also incorporate carbon through photosynthesis, mostly surpassing the capacity of land biota to do so. Moreover, the oceans are great regulators of the cycle, with 90 GT of carbon entering surface waters by simple diffusion and then being incorporated through the bicarbonate chemical reaction in the oceans (Fig. 3d). Although often disregarded, soils are one of the main carbon reservoirs (Fig. 3e). Surface and deep oceans act as separate boxes in our model (Fig. 1) and we can see that the carbon will flow from the surface to the atmosphere, biosphere and deep ocean (Fig. 3f).

The university community can navigate one or all the stations, but only by completing the circuit can they obtain all the necessary information to answer the activity questionnaire:

a. Complete the blank carbon cycle with the arrows both back (natural) and red (anthropogenic) carbon fluxes (Answer is in Fig. 1).

b. Answer the following questions:

    b.1. Indicate the reservoir size in GT (1015g) and put the reservoir sizes in order from the biggest to smallest.

    b. 2. Where do you fit into the carbon cycle?

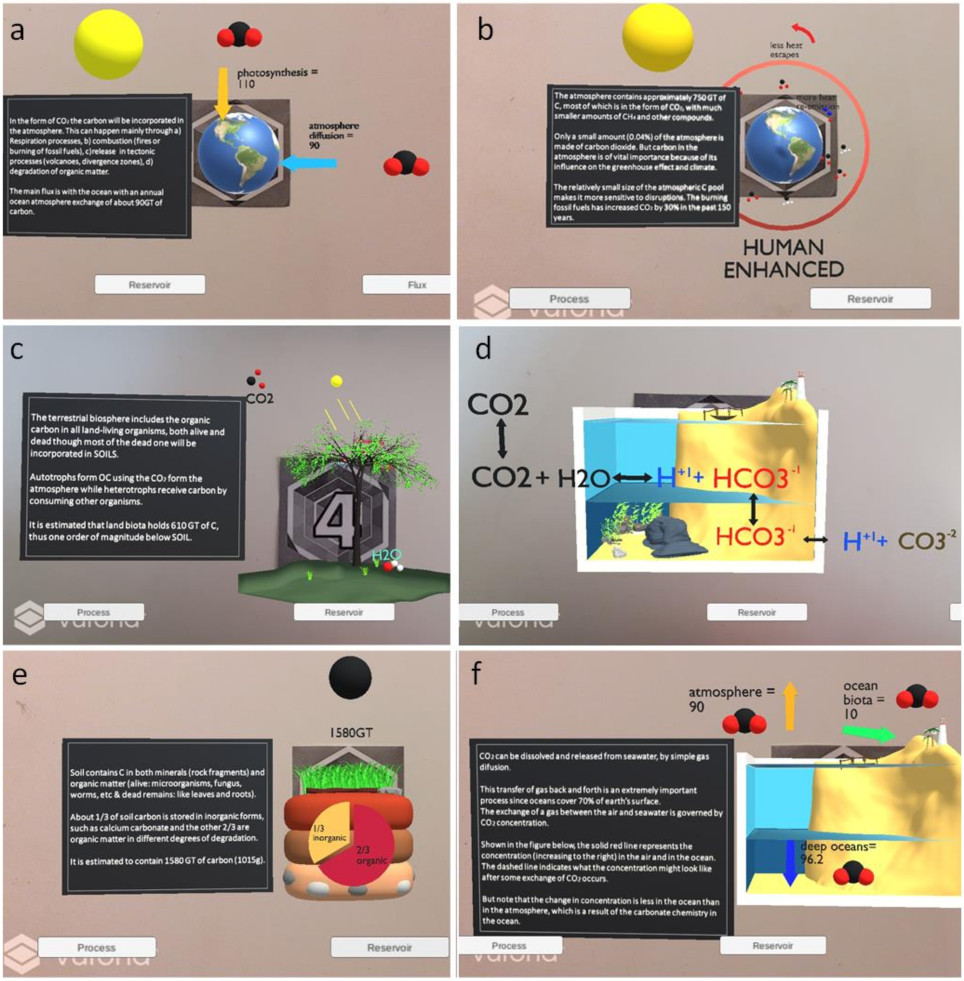

Figure 3. Screen shots of the AR activity corresponding to a) fluxes of Carbon from the atmosphere to the oceans and continents, b) impacts of humans on atmosphere CO_2 concentrations, and thus climate, c) process of photosynthesis by land biota, d) process of Carbon capture by the oceans, e) soil Carbon reservoir and f) fluxes of Carbon from surface oceans to the atmosphere, ocean biota and deep oceans.

The activity is framed within the IBL active approach, where students have to construct knowledge alone or in groups, increasing motivation and retention (Edelson et al., 1999; Garzon et al., 2020). Students have to go through all the stations to find out the necessary information to fill in the blank cycle and answer the questions.

Although the AR activity is designed to be coupled to the IBL approach, even if the users do not complete the activity, we still expect they will be motivated to learn more about the

Carbon cycle. Moreover, we anticipate that the use of AR will motivate non-specialized audiences to complete the activity.

4. Impact of the activity

We expect that the activity will not only reach (geo)science students but engage a wide audience to learn more and understand the dynamics of the carbon cycle. Often both learners and facilitators are afraid to tackle complex concepts for fear of frustration or lack of understanding. That is why the present AR activity was designed so that anybody could engage with and follow the Carbon cycle, becoming aware of where carbon is stored and how it cycles through the different planetary spheres.

We expect that having to circulate between stations and see what are usually abstract concepts overlaid in natural settings will improve understanding of the basic carbon cycle and related concepts. Psychology specialists in the Dean of Students office, after seeing a presentation of the activity, highlighted the active component of the activity as being motivating and conducive to learning. As AR incorporates the surrounding environment, the user can really visualize how we are part of the carbon cycle. We hope that giving all members of the university community the opportunity to live the carbon cycle as an activity, and see the magnitude of the impact human activity has on it, will result in more people taking an interest in what we can do to reduce or mitigate the impact we are having on our planet.

While a full implementation has not yet been possible due to COVID restrictions, the targeted geoscience students and teachers' group that used it during the testing phase reported it to be clear and engaging. The activity was also presented in a specialised group of professors from various faculties participating in a challenge for the development of digital educational resources, where it received very positive feedback. We hope to be able to provide campus availability within the following months.

The impact of the activity on geoscience students will be tested later on in the semester within the environemental geochemistry course to see the impacts on learning outcomes. This will give us the opportunity to test the coupling of intrinsic and extrinsic motivation (Ryan & Deci, 2000). While there is no way to test the number of users on the campus, those that want to complete the activity will need to contact us for the questionnaire, which will help us keep tabs on the usage of the app. We also plan to design an online survey using QualtricsXM (https://www.qualtrics.com/) where users can report usefulness of the activity in improving their knowledge of the Carbon cycle as well as its influence on motivation and long-term retention.

References

Bice, D. Professor of Geosciences, College of Earth and Mineral Science, The Pennsylvania State University, https://www.e-education.psu.edu/earth103/node/1019.

Chen P., Liu X., Cheng W., Huang R. (2017) A review of using Augmented Reality in Education from 2011 to 2016. In: Popescu E. et al. (eds) Innovations in Smart Learning. Lecture Notes in Educational Technology. Springer, Singapore. https://doi.org/10.1007/978-981-10-2419-1_2

Edelson, D. C., Gordin, D. N., & Pea, R. D. (1999). Addressing the challenges of inquiry-based learning through technology and curriculum design. The Journal of the Learning Sciences, 8(3–4), 391–450.

Garzón, J., Pavón, J., & Baldiris, S. (2019). Systematic review and meta-analysis of augmented reality in educational settings. Virtual Reality, 23(4), 447–459.

Garzón, J., Baldiris, S., Gutiérrez, J., & Pavón, J. (2020). How do pedagogical approaches affect the impact of augmented reality on education? A meta-analysis and research synthesis. Educational Research Review, 31, 100334.

Ibáñez, M. B., & Delgado-Kloos, C. (2018). Augmented reality for STEM learning: A systematic review. Computers & Education, 123, 109-123.

Killops, S., & Killops, V. (2005). Introduction to Organic Geochemistry, 2nd edn (paperback).

Mayer, R. (2005). The Cambridge handbook of multimedia learning. Cambridge: Cambridge university press.

Ryan, R. M., & Deci, E. L. (2000). Intrinsic and extrinsic motivations: Classic definitions and new directions. Contemporary Educational Psychology, 25, 54–67.

Wang, M., Callaghan, V., Bernhardt, J., White, K., & Peña-Rios, A. (2018). Augmented reality in education and training: pedagogical approaches and illustrative case studies. Journal of ambient intelligence and humanized computing, 9(5), 1391-1402.