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Augmented Reality Sandbox and Constructivist Approach for Geoscience Teaching and Learning

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***Abstract*—**Augmented reality sandbox adds new dimensions to education and learning process. It can be a core component of geoscience teaching and learning to understand the geographic contexts and landform processes. Augmented reality sandbox is a useful tool not only to create an interactive learning environment through spatial visualization but also it can provide an active learning experience to students and enhances the cognition process of learning. Augmented reality sandbox can be used as an interactive learning tool to teach geomorphic and landform processes. This article explains the augmented reality sandbox and the constructivism approach for geoscience teaching and learning, and endeavours to explore the ways to teach the geographic processes using the three-dimensional digital environment for the deep learning of the geoscience concepts interactively.

***Keywords*—**Augmented Reality Sandbox, constructivism, deep learning, geoscience.

I. Introduction

GEOSCIENCE is the scientific study of the planet earth. Understanding how our planet works is important for everyone. This is achieved through investigating how it changed over time, what stages it did through. The findings are critical as they define the way we need live in balance with the environment and sustain life on the planet. Therefore, modern Geoscience is founded with the core purpose to solve environmental problems. Geoscience is an applied multidisciplinary subject which draws upon all other sciences to unlock the Earth's mysteries. We are now more aware of the significant issues we humans need to address, such as climate change, natural hazards, soul and water and optimal use of natural resources and energy. In order to address and manage these and to continue to add and improve to existing geoscience knowledge, we need to prepare a new generation of geoscience experts who can efficiently leverage on existing knowledge, add new understanding and also train the next generation of geoscientists to come

Geoscience teaching and learning covers a wide range of topics on Earth and its landscape which include mountain building, structure, surface processes, subsurface resources, climate evolution and natural hazards Teaching and learning in the geosciences has benefited significantly through the application of contemporary pedagogy, and in particular the use of information communication technologies. Through computer-generated animations, students are able to visualize the dimensions that were not possible to view before. For example, different views of our earth's interior or the paleoclimate reconstruction of our earth's surface are now possible to visualize using geo-computing and tree-dimensional visualization capabilities.

To an educator, learning is evaluated in terms of learning outcomes which include content knowledge, critical thinking, analytical skills and representation or communication of complex concepts or issues. To achieve higher learning, instructors are increasingly exploring teaching approaches that involve active engagement [1]. Conventional classroom lectures and tutorials are now being complemented by field trips and virtual field trips [2]. Traditionally, Geoscience education has incorporated Science Technology Engineering and Math (STEM) approaches. Modern theories of learning claim that the construction of knowledge occurs as students build understanding through experiences [3]. The constructivist approach and constructivist learning is recognized as a valuable technique to increase deep understanding of scientific ideas which is achieved through students building their own knowledge using inquiry-based exercises [4]. Learning is better when learners are taught by using the constructivist methods [5].

We argue that augmented reality sandbox can be used as a tool to implement constructivist approach in classroom for Geoscience teaching and learning. This article aims to describe the augmented reality sandbox for constructivist approach in Geoscience teaching and learning and endeavours to connect constructivism with other learning theories. It also draws upon augmented reality as an emerging ICT tool in, advancing constructivism in Geoscience education and argues that constructivism can be better implemented through augmented reality sandbox for achieving deep learning.

II. Learning Theories and Constructivism

Learning theories are conceptual frameworks describing how information is absorbed, processed, and retained during the learning process. Learning theories revolve around behaviourism, cognitivism, constructivism, experimentalism and connectivism (social and contextual).

Behaviourism approach states that basically students learn through practice, reshaping what they learn and/or from their positive experiences. According to behaviorist thinkers like Skinner [6], Pavlov [7] and Thorndike [8] learning is a change

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in behaviour caused by external stimuli in the environment.

Cognitive learning is based on how a person processes and reasons information. The underlying concepts of cognitivism involve how we think and gain knowledge. Cognitivists such as Jean Piaget [9] and Jerome Bruner [10] argue that learning is demonstrated through a change in knowledge and understanding.

Constructivism also known as learner centered learning. According to constructivists such as Cooper [11] and Wilson [12], learners interpret information from the unique personal perspective of their previous experience. They learn through observation, processing and interpretation: personalizing the information into knowledge. Boethel and Dimock argue that learning takes place through stimulation of one's ideas and how it reflects on them [13].

Constructivism is different to experimentalism, as the latter is the philosophical belief that the way to truth is through experiments and empiricism. Kolb, one of the key theorists of experiential learning formally recognised that people learn from experience and described learning as four stage cycle of concrete experience, observation and reflection, abstract conceptualisation and testing concepts in new situations [14]

Another modern-day approach is connectivism. Also, known as digital age learning, it is a learning theory that emphasizes the role of social and cultural connectivity [15].

Connectivist such as Siemens and Downes argue that the learning is not an internal and individualistic activity. It is largely affected by the networks in which people work. Connections, technology shape the learning [16]-[17]. However, there is a heap of criticism on connectivism as a new theory. Constructivist such as Kop and Hill recognize a paradigm shift in learning and emergence of new epstomology but they don't take connectivism as a new or separate learning theory [18].

There are several studies that recognize and access the impact of constructivist approach upon learning in Geoscience [19]-[24]. They draw upon general agreement that learners learn from their experience with reference to their prior knowledge.

III. Augmented Reality

Caudell and Mizell [25] coined the term "Augmented Reality (AR)" to describe overlaying computer-generated and computer-presented information onto the real world. AR has been defined as "blending (augmenting) virtual data—information, rich media, and even live action—with what we see in the real world, for the purpose of enhancing the information we can perceive with our senses" [26]. It is fast emerging technology that augments on top of the real world with continuous and implicit user control of the point of view and interactivity [27]. AR has been successfully used in military, medicine, engineering design, robotics, manufacturing and consumer design [28].

Fig. 1 Milgram's reality virtuality continuum [29]

A. Enabling Technologies

AR utilizes several approaches to integrate the virtual world to the real world which makes the use of several developing and emerging technologies. Four such technologies which are very relevant to rich AR applications, identified [30] are; localization technologies, natural user interfaces, connected cloud computing environment and portable mobile devices. Posture and location of objects in three dimensions is enables by localizing technologies like Global Positioning Systems (GPS). An increasing number of AR applications use gesture and kinesthetic control [31], [32] which are integrated into the natural user interfaces which people commonly identify with. Size, weight and processor speeds of these interfaces make is more usable and richness of data fed to the interactivity is provided by connected environment.

B. AR in Education

Educational content can be experienced through a wide variety of media, ranging from non-interactive books to highly interactive digital experiences which fully engage our senses [33]. With AR technology getting more mature and accessible to many through smartphone applications, its inclusion as an educational medium is getting prevalent at many places. Use of AR technology in education has been reported to improve content understanding, spatial cognition, psychomotor skills, motivation and collaboration, all of which instill deep learning with long retention.

IV. Augmented Reality (AR) Sandbox

Born out of a National Science Foundation project, the prototype of the AR Sandbox was developed at the Keck Center for Active Visualization in Earth Science at the University of California. The Augmented Reality Sandbox is a sandbox exhibit on which a physical topography can be shaped and surface processes can be simulated and virtually overlaid and visualized dynamically in real time. It utilizes a depth sensing camera which senses the temporal state of the sand topography, that is fed into the computer for computation and generation of color coded contours which is beamed it back on to topography via a screen projector.

Augmented reality sandbox uses a projector and a Kinect 3D camera mounted above a sandbox. The Kinect 3D camera detects the distance to the sand below, and a visualization/an elevation model with contour lines and a colour map assigned by elevation is cast from an overhead projector onto the surface of the sand. As the sand moves, the Kinect 3D camera perceives changes in the distance to the sand surface, and the projected colours and contour lines change accordingly. When an object (represent of cloud) is sensed at a particular height (~ 60cm.) above the surface of the sand, virtual rain appears as a blue, shimmering visualization on the surface below. The water appears to flow down the slopes to lower surfaces. The contour lines and colours can be adjusted to convey different principles and/or to be optimized for different physical setups.

Augmented reality sandbox allows a digitally enhanced view of the real world. Learners use a rake to scrape sand in a sandbox, creating land features such as mountains and lakes.

Camers reads the distance and projects contours onto the scene, cool colors for depressions, and warm colors for peaks. The visualisation software was developed for Active Visualization in Earth Science at the University of California [34].

AR Sandboxes has been developed and used and their numbers have exceeded 150 globally (Fig. 2). The most recent one was built in Singapore, at the Department of Geography, National University of Singapore (NUS) to support modern approach to geoscience education.

Fig. 2 AR Sandboxes around the world and Singapore (in red). Source: EOS [35]

V. Constructivism and the AR Sandbox

Incorporated with a modified design to accommodate mechanisms to perform simulations of natural events like rain and volcanic flows, the AR sandbox offers an opportunity to embed constructivist approaches to learning geoscience. Pedagogic materials, including tutorial and laboratory manuals, for Physical Geography and Geoscience were prepared with an aim to bring experiential learning to the Geoscience classroom. The AR Sandbox is functional and plans are in place for testing its educational utility and efficacy at NUS. Student surveys are currently being designed which shall be used to collect student feedback after its use for learning, in the upcoming cohort. It is expected that the findings shall encourage the use of the AR sandbox beyond the Department of Geography to other faculties like School of Design, Environment and computing for both education and research.

Since 2012, supported by availability of online resources on constructing an AR Sandbox [36]-[39], more than 150 AR Sandboxes have been built in Europe and Americas. These are hosted at schools, universities, research centers, government organizations, museums, and science centers but their use was primarily for providing an experiential visualization of earth processes like precipitation, flooding and volcanic hazards. [35].

As a tool for implementing constructive teaching and learning in Geoscience, the AR Sandbox is still in its infancy. This is primarily because of its closed architecture and programmatic limitations which limits its integration with other state of the art Geographic Information Systems (GIS). It has got tremendous potential for constructivist approach in teaching and learning through an open integrated AR-GIS framework which is receptive to developments in GIS and Geospatial Simulation technologies. Ishii et al. [40] proposed the 'Sandscape' a decade ago which is a spatial system based on infrared depth sensing. The AR sandbox that designed by Kreylos [35] in its current form, provides an elementary constructivist experience of the change landscapes through real-time modelling and visualization for the geoscience student.

VI. Conclusion

We opine that the AR sandbox has all the potential to scaffold geoscience education with the constructivist approach making it an effective tool for developing visualization constructs for earth system processes which is not possible using other learning approaches. Constructivist approaches can be embedded through the capabilities of an AR sandbox which unlike experimentalism and connectivism is not limited within the temporal confines of a geoscience educational program.

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