2017 IEEE 17th International Conference on Advanced Learning Technologies

Science Education and Augmented Reality content: The case of the Water Circle

Tharrenos Bratitsis, Pinelopi Bardanika, Michalis Ioannou
Early Childhood Education Department
University of Western Macedonia
Florina, Greece
bratitsis@uowm.gr, pinelopibardanika9@gmail.com, michalissioannou@yahoo.gr

***Abstract*— Augmented Reality (AR) is a live, direct or indirect projection of the physical-real world which allows users to experience the surrounding environment as it is, in real-time, enhanced with digital and/or interactive content. It seems that AR can be exploited for teaching various disciplines. In this paper, the preliminary results of a study regarding a teaching intervention about science education in primary school and specifically the topic of the water circle are presented. The AR content was deployed through the ENTITI creator application.**

Keywords: augmented reality, primary school, water circle, ENTITI creator, science education

I. INTRODUCTION

Augmented Reality (AR) is a technology, applicable in various fields, among which lately education is arising. Interactivity, a fundamental aspect of AR, is a constant aim of educators when exploiting technology. Direct, location-based information provision to the user and the combination of reality with multimedia content, animated or not, are some of the advantages of AR. Moreover, the development of mobile applications and the evolvement of mobile devices, especially graphics' related, now provide the opportunity to develop innovative learning applications which utilize AR.

In this paper, an intervention for teaching the Water Circle as part of Science Education in Primary School, is presented. It utilizes the ENTITI creator application (www.wakingapp.com) for the development of AR material. It is part of an undergraduate thesis research study. Based on the positive indications which derive from the preliminary results, a discussion is raised about the exploitation of such technologies in other disciplinary areas as well, but also the need to design corresponding frameworks and approaches.

The paper is structured as follows; initially, the theoretical framework is presented, followed by the description of the study and the research methodology. Then, some preliminary results are presented, followed by a concluding discussion.

II. THEORETICAL BACKGROUND

From a very early age children formulate theories and ideas about everything around them which play a significant role in their learning experience. Even before they become part of any educational system, they form ideas for various physics' phenomena and construct definitions. Moreover, children through community and social interactions look up for definitions of the world they live in [1].

Traditionally, the "Deductive Approach" is used in schools. Teachers present concepts and provide application examples. Following this approach, children must be able to handle abstract notions, thus making it difficult deal with science education in depth before secondary education. On the contrary, the "Inductive Approach" involves observation, experimentation and teacher-guided construction of own knowledge by the child. Today, the Inductive Approach in Science Education is often referred to as Inquiry-Based Science Education [2].

Inquiry, as a term, is used throughout science education literature to describe goals for science learners, as well as approaches for science teaching [3]. It is the intentional process of diagnosing problems, making observations, critiquing experiments and distinguishing alternatives, planning investigations, researching conjectures, posing questions, searching for information, constructing models, debating with peers, and forming coherent arguments [2, 4]. Students who use inquiry to learn science are engaged in activities and thinking processes, similar to those of scientists. Engaging students in inquiry-based activities should contribute to greater understanding of scientific concepts, appreciation of "how we know" what we know in science, understanding of the nature of science, development of skills necessary to become independent inquirers about the natural world, and disposition to use the skills, abilities, and attitudes associated with science [4].

The evolvement of ICTs is affecting everyday life, including education. Besides, children as "digital natives" [5] are already familiar with technologies. AR, nowadays easily deployed via mobile devices, is a variation of virtual reality. While the latter completely immerses a user in an artificial environment, AR allows the user to see the real world, with virtual objects superimposed upon or composited with the real world. It supplements reality and ideally the user can see virtual and real objects coexisting in space [6]. In an AR interface, the user views the world through a handheld or head mounted display that either is see-through or overlays graphics on a video of the surrounding environment. AR also enhances the real world experience [7].

Science Education incorporates technology more, over the past few years, in all educational levels, utilizing the pedagogical advantages which derive from it. Furthermore, experiential and inquiry learning have been established as an

2161-377X/17 $31.00 © 2017 IEEE
DOI 10.1109/ICALT.2017.64

appropriate way of learning science related topics, as opposed to traditional teaching and creating abstract experimental structures. In this paper, AR is exploited for deploying multimedia material in the context of science education in order to enhance students' engagement in the learning activity, regarding the Water/Hydrological Circle.

The latter can be defined as the continuous and uninterrupted movement and recycling of water in the hydrosphere, the atmosphere, soil and subsoil [8]. Within this "mobility", Earth's water is constantly changing state from solid ice to liquid and gaseous water vapor. This is achieved due to the heat effect of the Sun on Earth, via solar radiation. In the Greek Official Curriculum [9] and the Renewed Study Framework [10] for Primary School, the hydrological cycle is mentioned in the Environmental Study section in which Physical Sciences are integrated. The Water Cycle chapter states that the children should be able to "connect the various water states and the water cycle with the weather conditions", "connect the weather conditions with the living conditions and the life quality of human beings". In this study, this topic was selected while designing an intervention for 2nd Grade students.

Another significant pillar of this study is that of Digital Storytelling (DS). It is the combination of traditional, oral narration with multimedia and communication tools [11]. It is a form of art which combines various types of multimedia material, including images, text, video clips, audio narration and music to tell a short story on a particular topic or theme [12]. Digital stories can be stored or published on the internet, allowing people to review critique and discuss upon them, thus enhancing their educational value and their life span [11]. As a teaching approach, it can be exploited for almost all types and levels of education, but also for many disciplines [13]. It is a powerful approach which can engage students in deep and substantial learning [14]. Teachers incorporating DS can enhance and facilitate more effectively students' engagement in fruitful discussions, information retention, content understanding and acquisition, for several disciplines and complex notions [15].

Lastly, the educational community appears to have great interest for the exploitation of mobile devices during the past few years [16]. Sandberg et al. [17] believe that there are two decisive factors which define research in this domain. The first is that informal learning is equally important as formal learning and the second is that the constant technological evolution of mobile devices has equipped them with position recognition and multimodal information representation capabilities, along with internet access. These advantages can nowadays be exploited by AR applications, deployed via mobile devices, thus enhancing the real world with digitalized information. Augmented reality (AR) is currently considered as having potential for pedagogical applications. However, in science education, research regarding AR-aided learning is in its infancy [18] and only a few studies are available [e.g. 19].

III. RESEARCH STUDY

This study aimed at recording children's existing perceptions about the Water Cycle, but also attempted to investigate if these perceptions can be transformed through the proposed approach in order to shift further towards the corresponding scientific knowledge. Usually teachers cover this topic by demonstrative experiments, combined with some sort of lecture. Often, the conduction of such an experiment in a plenary session is considered adequate for realizing at which extend the children have acquired the necessary knowledge about this phenomenon.

In this paper, the implementation of an alternative, innovative teaching intervention, is presented. The core teaching methodology used is that of the didactic transformation of the Water Cycle into a digital story-fairytale, using the ENTITI creator application, aiming at assisting the children to discover the Water Cycle and the corresponding stages on their own.

The study was conducted with the participation of 15 Grade 2 students of a Greek, public primary school. It was divided into 4 phases, over 2 consecutive days. In Phase A, a big paper board with the word WATER written in the center was attached on the wall. Children were asked to provide their ideas and knowledge about water, its states and uses, in a 10 minute plenary brainstorming session. Then, similar worksheets were distributed and children had to create individual concept maps. After about 10 minutes, a combinatorial concept map was created on the paper board through a researcher facilitated discussion. However, next to this map, nine facilitative questions were posted on the wall for the students to see. With these, the researcher wanted to provoke a discussion which would reveal the children's perceptions about the Water Cycle. These are discussed in detail in the results' section. The researcher wrote down the children's answers, thus creating the overall concept map.

In Phase B, the ENTITI application (creator–player) was exploited for teaching the Water Cycle topic through an AR, DS approach. Initially, a short digital story in the form of a video was presented. The main character was a water drop (referred to as Drop hereinafter) which greeted the children and explained that not a long time ago, she experienced a very intriguing adventure. Considering that her memory was not very strong, she asked the children to help her find the stops of her adventure in order to help her recreate her story. After the completion of the video, the researcher revealed a present sent by Drop earlier in order to assist them while pursuing information about her adventure stops. The package contained a smartphone running ENTITI and an explanatory letter in order to initiate the search.

Additional short digital stories, each one corresponding to one stage of the Water Cycle, were connected triggering images in ENTITI. The images were randomly distributed in the classroom and the children were required to find them and scan them with the smartphone. They formed 3 groups of 5 and wandered in the classroom in order to spot anything unusual. By scanning the images, the stories were overlaid as videos, usually in the form of a first person narrative. They contained information about the Water Cycle stage depicted in the trigger-image. The images were natural representations of the water stage (e.g. rain, snow, river, ocean) but some "traps" were included as well. For example a dripping tap or a water fountain was included which are not part of the

Water Cycle representation, as they are parts of closed artificial water systems. These images triggered an oral exhortation for the children to "look elsewhere". The aim was to demonstrate that not all water related pictures can fit the Water Cycle representation. After completing the stages' discovery, the children were asked to find their sequence, exploiting the digital stories as clues, in order to recreate the Water Cycle. For that matter, smaller copies of the trigger images were distributed to the children in order to individually create their sequences.

In Phase C, an experiment about the Water Cycle was conducted. The researcher had brought all the necessary materials for the children to recreate a physical model of the Water Cycle and thus deeper understand the cycle notion, working in groups. Each group conducted the experiment and then had to explain it to the rest of the class, after all the groups had finished. The experiment involved the creation of a "mountain" with dirt. A split plastic bottle was used to represent a river which connected the mountain with the sea, which was a pot. Using pliers, they held ice cubes over the mountain and purred hot water from plastic bottles on them. The cubes melted on the "river" and the water gradually reached the "sea". A metal pot cover was positioned over the "sea" which collected water vapor on its cold surface which was directly over the "sea: Each group tried to observe and explain the water stages while attempting to provide a name for the corresponding phenomenon. During this activity, additional information was provided about the melting and coagulation processes. The activity included worksheets to be filled, mainly image based, regarding the phenomena of evaporation, compaction, melting and coagulation. At the end of this phase, a new concept map was created, having the same facilitating questions attached next to the paper board.

Lastly, in Phase D the children formed 4 groups, each one corresponding to one of the Water Cycle stages. For example, one group was the cousin of Drop and another group was a Snow Flake. Each group had to create a new story based on their corresponding stage, but they had to also include the whole Water Cycle. In this manner, they were required to recreate the Water Cycle from a different initiation point. For that they had to understand the stages and their sequence, instead of memorizing them, as they had to provide the perspective of another character through their story. Then, they presented their story to the rest of the classroom as a small theatrical play.

The data collection tools were the researcher's journal, the concept maps, the worksheets, video and audio recordings. The analysis approach was of a qualitative nature, applying an interpretative understanding of the children's reactions, arguments, interaction and behaviors, following the participatory observation research approach. Four main research questions were formulated:

1. Can children understand the sequence of the Water Cycle stages through this approach?
2. Can children ascertain that water is not lost/vanished, but it is recycled by altering stages in the process?
3. Are children able to describe the Water Cycle on their own, unassisted?
4. Did the experiential activity (Phase D) further facilitate the Water Cycle process understanding?

IV. Results

In this section, only preliminary results are presented. In Phase A, the concept map revealed that for most of the children (12/15), the first thing coming to mind when seeing the word WATER was its usefulness and how important it was for humans. At some extend this didn't come as a surprise, as these were issues the children were familiar with form their previous school years. Nevertheless, a significant portion (9/15) mentioned the word "sea". A smaller portion (6/15) brought up the word "snow", whereas only 5/15 came up with "rain". Also, 5/15 thought of the word "lake", 4/14 mentioned the "waterfall" and only 1 child mentioned the words "river", "sewer", "tap" and "earth".

When the facilitative questions were posted on the wall, it became clear that some of the children's perceptions were correct and some not. For example, for the question "Is water important for humans? Why?" the answers focused more on water's usefulness in everyday life (e.g. washing hands). In the question "Where can we find water in nature?", the children mentioned the river, the waterfall, the tap, the lake and the natural spring". When asked if they knew "where rain comes from and how is it formed" they answered that it comes from the sky when a cloud gets thicker (inflated might be a more accurate translation of the Greek word they used) and almost black … "then it rains from the clouds". As to "where does the rain water go" the answers included: "in/on the plants", "around the world" and "in the sewer". Their explanations on why does it rain relied again on the usefulness of the water (e.g. it rains so that we have water to drink and wash our hands). Regarding the composition of the clouds, they mentioned "smoke", "cotton" and "water". One question was about constructing a snowman and leaving it under the sun for a long time, if it would retain its form. The children answered that "it will turn into water because the sun will melt it". The next question regarded the possible states of water and the children had significant difficulties in understanding the question. The last question was "how did the water get on the sky?" and the children replied that "this happens when the water is inflated". Eventually, it turned out that in questions 2, 3, 4, 6, 8 and 9 the children's answers were based on their existing perceptions.

In Phase B, all 3 groups fell for the "traps", as they seemed to draw their attention more and they were considered more interesting. Group A chose the fountain, Group B selected the natatorium and the soda bottle, whereas Group C selected the water tap. After completing this activity, the researcher distributed smaller copies of the images which corresponded to portions of the Drop's adventure. The children were asked to recall the stages and put the images in the correct sequence. Indeed, they were able to recreate the sequence, but they put the images in a row and not in a circular manner. Additionally, some of the students (5/15) where slightly confused when they had to place the snow flake image. In order to facilitate the process, the researcher positioned the images on the classroom blackboard and asked "how can we place them in order to be

able to understand that Drop left her home and returned back to it after her great adventure?". One child stood up and positioned them in a horizontal sequence. When the researcher insisted, "are you all ok with this, did she get back to her home?", one girl took the initiative to propose that "we should put them in a circle, because the starting and ending points are the same". The rest of the class immediately agreed and said "Yes, yes, we should put them in a circle" a child said, "let's call it the circle of water".

After that, the girl who brought the idea into the class stood up and created the circle. But she was having trouble in positioning the snow flake image, so the researcher asked, "who can tell me how snow is created?". Almost all the students were eager to answer and the first who was assigned the task mentioned "it comes from the clouds". The researcher facilitated a discussion which reached the conclusion that "when it is very cold, all the water drops in the clouds come close together to get warmer from one another. Then they become too heavy for the cloud to hold and they drop down to the ground in the form of snowflakes". So the researcher asked "does this remind you of something?" and one child replied "the clouds!", whereas another one intervened and said "we should put snow with the rain because they are the same, they come from the clouds". And so, the Water Circle was realized and the researcher further added connecting lines between the images and wrote the physical phenomenon which occurred in each stage transition (evaporation, condensation, liquefaction, concentration). For each word, the students explained what the corresponding phenomenon was and where it should be positioned on the Water Circle. Out of all 4 phenomena, they faced difficulties in explaining "condensation", as they were not very familiarized with it. Thus, during this phase the children managed to understand that the water runs a cycle of various staged in nature, represent it successfully and adequately explain the transitions between the stages.

In Phase C the children were very excited with the the experiment. All the groups were able to observe everything that happened during the conduction of experiment. In the end, each group presented observations they made. Group A said that "the ice cube melts when hot water touches it". Group B mentioned that "the ice cube with hot water turns into water and then it evaporates". Groups C said that "the ice cube melted. The water evaporated". Furthermore, the children were able to name and explain the stages and the phenomena, facilitated by the researcher when needed.

Additionally, worksheets were distributed, consisting of A4 size papers with the words "evaporation, condensation, liquefaction, concentration" written on them. Also images of water drops, red of blue thermometers, ice cubes, snowflakes, etc. were provided. They had to attach the proper images on each paper. For example, a water drop with low temperature (blue thermometer) turns into ice or snow. They could easily complete the evaporation, melting and coagulation phenomena, but faced some difficulties regarding condensation. Group C couldn't complete the coagulation task, but with the facilitation of the researcher all the groups completed all the tasks eventually.

Also after the end of this activity the second concept map was created. The aim was to examine if the children's perceptions were altered in any way, utilizing the same set of 9 questions which were used during Phase A. It took them just 5 minutes to create the concept map and their answers were all accurate and correct. No misconceptions were noticed, whatsoever and the answers provided were significantly different than in Phase A (they were more up to the point and precise).

Lastly, in Phase D each group corresponded to one stage of the Water Circle. They had to create their story which had their "stage" as the initiation point for the Circle and create a drawing for it. After holding group meetings, they assigned roles among them. While painting they thought of and rehearsed their "lines" to be used when narrating the story later on. When this stage was completed, each group presented its story by having the members taking turns, depending on the orientation of "their Water Circle" and narrating that part of their story. The activity was overall very successful and the children were very excited.

V. Discussion

The study, presented in this paper is an attempt to introduce the Water Circle to 2nd Grade students in an alternative and innovative manner. The aim was to examine if the exploitation of AR and DS can facilitate the understanding of the designated Science topic at its extend, equally or better when compared with the traditional teaching approach and with the factor of amusement increased or not. It was an experiential – inquiry learning approach which incorporated the DS advantages [13]. Through this intervention the children should be able to recognize that temperature is the cause for water's stage transformations, but also to be able to use the newly acquired knowledge in their everyday life.

The results indicate that the children fully understood the sequence in the Water Cycle. They realized that water is not vanishing, but it is being recycled, following certain stages. They were able to accurately describe the stages on their own. What is more important is that the Water Circle was never presented to them, nor any hint was provided throughout the ongoing discussion that a circle should be formed. Even through some minor facilitation, the children were able to understand and propose on their own that Drop's adventure formed a circle. Moreover they were able to follow the same path with different initiation points during Phase D. This is an indication that they deeply understood the circular notion in this case, but also everything related to the transitions among stages. Furthermore, they explained all the involved physical phenomena and could rather easily fulfill the tasks in the worksheets.

Of course there are many limitations in this study, as it was conducted in only one school with a rather small population. It was a typical Grade 2 class of an urban area, specifically a medium sized city in Greece. Thus, the composition of the classroom was representative of a typical

class of the country. The children were familiarized with aspects related to water from their Kindergarten years, when they start talking about water usefulness and environmental protection. Thus, this can explain their answers in the brainstorming session. On the other hand, the 4 physical phenomena were never introduced to them, nor was the Water Circle. The fact that they were able to understand it and propose spontaneously that the images from Drop's adventure should form a circle is considered by the authors a very significant and promising observation.

Also the fact that the intervention was contextualized as a digital story further facilitated this understanding, as the children at this age can connect to story characters and become engaged by feeling emotionally attached to them. As the literature states, these are some of the advantages of DS as a teaching approach [13], which were verified in this case. In this study, the AR application was exploited in order to provided more added value to the DS approach, as it further facilitated the children's attachment with the hero of the story and her emotional state, but also it made it easier for the children to connect each story with the Water Circle stages in a more straight forward manner. The authors do not claim that the overall approach led to a better understanding of the subject nor that the incorporation of AR provided a totally novel educational experience. But it is important to mention that the children discovered the new knowledge on their own during Phase B, which was further assimilated during Phase C and assessed by the researcher during Phase D. Furthermore, it was more enjoyable for the children.

The children had no difficulty in handling the smartphone, as they were all familiar with such devices. What came as a surprise for them, a rather pleasant one, was the fact that the digital story just popped out of nowhere when they aimed at the triggering images and moreover, they "didn't have to press any buttons or on the screen". They mentioned frequently that they had never been taught in this way ever before, using such devices and methods. Also they asked too many times if the researcher was planning on returning in the near future for more learning activities like this. Consequently, the children drew significant pleasure form the intervention. They felt engaged and excited.

It should be noted that for similar interventions to be implemented, only 1 mobile device with internet connection or mobile data is required. Thus they can be easily implemented in almost any school with minimal cost, apart from the time needed to design and create the digital stories. The ENTiTi application was also free and easy to use.

Concluding, this small scale study provided interesting and positive observations regarding the incorporation of AR applications in the classroom. The children seemed to fully understand a Science topic which his often fully understood in consequent grades. Of course the acquired knowledge was not examined if it was retained fully after a longer time period. But the fact that this intervention took place in a fully functional, typical classroom and not a laboratory setting provides some added value to the results.

Future plans include the design and implementation of additional studies about other disciplines and topics, but also regarding other age groups. The aim is to fully examine how AR applications, preferably combined with DS can be incorporated in education and further examine if and how Open Educational Resources of this type can be created and fully shared with the educational community.

VI. REFERENCES

[1] R. Driver, "Children's Ideas in Science", Open University Press, Mikton Keynes, Philadelphia, 2000.

[2] European Commission, Science education now: a renewed pedagogy for the future of Europe, Belgium, 2007.

[3] National Research Council (NRC), Inquiry and the National Science Education Standards: a guide for teaching and learning, Washington, DC: National Academies Press, 2000.

[4] National Research Council (NRC), National Science Education Standards, Washington, DC: National Academies Press, 1996.

[5] M. Prensky, "Digital game-based learning", ACM Computers in Entertaiment – Theoretical and Practical Computer Applications in Entertainment, vol. 1(1), 2003, pp. 1-4.

[6] R. T. Azuma, "A Survey of Augmented Reality", MIT Press Journals, vol. 6(4), 1997, pp. 355-385.

[7] M. Billinghurst, "Augmented Reality in Education", New Horizons for Learning, 2002.

[8] K. Pavlopoulos and A. Galani, Geology – Geography, A' Gymnasium, Students book, Athens: National Institution for Publishing School Books (OEDB), 2012.

[9] Curriculum for Enviromental Studies, Athens: Greek Ministry of Education, Research and Religious Affairs, 2012.

[10] Interdisciplinary curriculum Framework for ICT, Athens: Greek Ministry of Education, Research and Religious Affairs, 2003.

[11] S. A. Lathem, "Learning communities and digital storytelling: new media for ancient tradition", Proc. Society for Information Technology & Teacher Education International Conference, Chesapeake, VA: AACE, 2005, pp. 2286-2291.

[12] B. R. Robin and S. G. McNeil, "What educators should know about teaching digital storytelling", Digital Education Review, vol. 22, 2012, pp. 37-51.

[13] T. Bratitsis, "Digital Storytelling, Creative Writing and 21st Century Literacy", Bulletin of Educational Reflection and Communication, I.M Panagiotopoulou School, vol. 55, 2015, pp. 15-19

[14] N. Smeda, E. Dakich and N. Sharda, "The effectiveness of digital storytelling in the classrooms: a case study, Proc. Advanced Learning Technologies (ICALT), IEEE 13th International Conference on Andvanced Learning Technologies, Jul. 2013, pp. 491-492.

[15] B. Robin, "Digital storytelling: a powerful technology tool for the 21st century classroom", Theory Into Practice, vol. 47(3), 2008, pp. 220-228.

[16] J. Gikas and M. Grant, "Mobile computing devices in higher education: student perspectives on learning with cellphones, smartphones, and social media", Internet and Higher Education, vol. 19, 2013, pp. 18-26.

[17] J. Sandberg, M. Maris and K. de Geus, "Mobile English learning: an evidence-based study with fifth grders", Computers & Education, vol. 57, 2011, pp. 1334-1347.

[18] Cheng, KH. & Tsai, CC. "Affordances of Augmented Reality in Science Learning: Suggestions for Future Research", Journal of Science Education and Technology, Vol. 22(4), 2013, pp 449–462

[19] Chiang, T., Yang, S. & Hwang, G. "An Augmented Reality-based Mobile Learning System to Improve Students' Learning Achievements and Motivations in Natural Science Inquiry Activities", Educational Technology & Society, Vol 17 (4), 2014, 352–365.