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AIBLE: An Inquiry-Based Augmented Reality Environment for Teaching Astronomical Phenomena

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ABSTRACT

We present an inquiry-based augmented reality (AR) learning environment (AIBLE) designed for teaching basic astronomical phenomena in elementary classroom (children of 8-11 years old). The novelty of this environment lies in the combination of both Inquiry Based Sciences Education and didactics principles with AR features. This environment was user tested by 69 pupils in order to assess its impact on learning. The main results indicate that AIBLE provides new opportunities for the identification of learners' problem solving strategies.

Index Terms Human-Centered Computing [Human-Computer Interaction]: HCI design and evaluation methods

1 INTRODUCTION

In augmented reality (AR) environments, users can interact with realistic, complex, symbolic, textual and/or spatial information. Thus, we believe that AR environments, especially those with tangible markers, are tailored to Inquiry-Based Sciences Education (IBSE). IBSE is a learner-centered/constructivist pedagogy [4] that is internationally recommended for sciences education [2]. In IBSE, students are encouraged to take active control of their learning, make predictions, hypotheses and test them by conducting experiments. As such, it provides pedagogical situations that lead children to become conscious of their entrenched beliefs in order to change them. During IBSE, learners investigate and manipulate in order to become conscious of complex phenomena and so to construct scientific knowledge (see e.g. [5]). In the real life, manipulations in astronomy are naturally impossible. Therefore, it is difficult for children to observe the inconsistencies between everyday and scientific explanations and their understanding [3]. Very few targeted teaching material for astronomy is available for teachers and learners in elementary schools. So, there is a real need for a new form of didactic materials. In this paper, we present AIBLE, an Augmented, Inquiry-Based, Learning Environment, for teaching astronomy to young learners (8-11 years old).

The aim of this study is to discuss how an inquiry-based AR environment can assist in learning astronomical phenomena. In a previous study [1], we demonstrated the advantages of the system compared over a classical support. Results showed significant statistical differences between the experimental (AIBLE users) and control groups (physical model users) in pre-test/post-test assessment tasks. The work we present here is based on a new user study that attempts to explore in detail the characteristics of the environment which facilitate learning.

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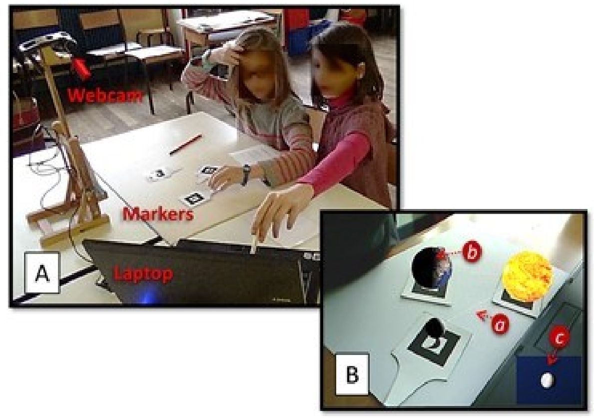

Figure. 1: Descriptions of the AIBLE. A- Example of typical children interactions. B- Example of first person perspective of the AR environment. Visual guides proposed to support learners: (a) dashed-lines between bodies' centers (b) a terrestrial observer – removable (c) vignette showing the terrestrial observer's view in real-time (optionally proposed).

2 AIBLE TO LEARN ASTRONOMY IN FORMAL EDUCATION

Designing an AR environment according to IBSE principles requires pupils to experiment by interacting with and physically manipulating the content. Thus, we combined the enhanced display possibilities of AR with physical manipulations of tangible markers to didactical principles associated to astronomy learning. Here, the virtual celestial objects can be freely moved "as for real". Virtual Sun, Earth and Moon are associated to specific patterns to be easily identified. Sun, Earth and Moon appear realistic as they are represented using textured 3D spheres (textures were obtained from space images). The light properties are taken into account and self-shadows of Earth and Moon are directly produced by an omnidirectional light source associated to the Sun. An optional vignette (Fig.1-B (c)) can be displayed to see the subjective view of a virtual terrestrial observer (Fig.1-B (b)) in real-time in order to scaffold spatial perception. Moreover, it is possible to adjust the difficulty level according to education objectives, and to adapt the level of investigation.

This environment takes into account professional reality so as to encourage the integration of a new digital support in the classroom: AIBLE is cheap, quick-to-install and easy-to-use (Fig.1-A). It only requires a fixed webcam, a laptop computer and three printable markers.

With the use of AR, direct manipulations of the virtual representations the Sun, the Moon and the Earth become possible. Users can investigated so as to find origins of Moon phase's evolution, alternation of day and night, seasons or Moon/Sun eclipses.

3 THE IMPACT OF AIBLE ON LEARNING

3.1 Setting and procedure

In order to characterize how users interacted during their inquiries, AIBLE was tested in-situ, with the same IBSE pedagogical sequence as in [1]. 69 pupils were recruited from grades 4 and 5 (8 to 11 years old) in two French schools. The characteristics of the participants were equivalent to those of the previous study. Pupils were asked to use the AR tool in two-person teams (one team was a trio) to answer this question: *Why Moon phases are daily changing?* Using AIBLE, pupils had to spatially arrange the Sun/Earth/Moon system, which is viewed from space (allocentric view), in order to recover the Moon's relative position when i) full Moon, ii) new Moon, iii) first quarter or iv) waning crescent are observed from Earth (geocentric view). The setup was located in a computer room. The research team conducted the pedagogical sequences. Each experiment lasted 45 minutes on average for each of the 34 pairs and was videotaped. This study is based on pre and post-tests evaluations questionnaires, videotape analysis and analyses of digital logs of the markers motion.

3.2 Main results and discussion

All pairs but one succeeded in solving the astronomical problems after testing their various hypotheses and discussing together their protocols and results. Investigations dropouts were very limited and essentially associated to school life activities. As in the previous study, Pre and post-test assessments after 1 week indicated that using AIBLE enables the pupils to learn and overcome their misconceptions. We explored in details which interactions could facilitate these learnings in IBSE context.

- Children systematically manipulated the markers without looking at their hands. They continuously gazed at the monitor. Their visual attention was dedicated to the assessment of (i) spatial positions or to (ii) their investigation hypotheses (Fig.1-A). Children worked together towards the same purpose (e.g. one moved the Moon marker or the terrestrial observer while the second provided screen control) and manipulated the system alternatively. AR environment provides essential and direct visual feedbacks to children. AIBLE mobilizes perceptive tasks during problem solving.
- Symbols on markers and textured 3D spheres, which broadly participate to the realistic perception of celestial bodies, were unanimously valued. The AR dashed-lines (Fig.1-B (a)) between the bodies' centers were used by 20 pairs as geometrical indicators of celestial bodies' relative positions. In association to this semiotics aspects of AR, physical environment layouts were referred to by children to explain and describe spatial positions of virtual spheres; e.g. "Put the Earth near the camera!"; "Why do you push the Sun toward the window?"; etc. Using AR in IBSE context, children benefited from physical spatial indicators, which were used as landmarks. Identification of celestial bodies and of their relative positions became obvious for the pupils. The co-existence of virtual and real objects provided semiotic, topographic and geometric spatial references. It thus reduced the learning complexity of spatial relationships.
- The pupils systematically used the vignette (Fig.1-B (c)), which help them assess their hypotheses. By providing evidences, children could find meaning in their investigations and in their manipulations. Real-time view of the terrestrial observer scaffold users' investigations. Pupils immediately interrelated their manipulations made in the allocentric view to the Moon shape in the geocentric view, with their own terrestrial perception of moon. Thus, AIBLE enables awareness of allocentric explanations during inquiry, conducive to a scientific conception of the Moon's phases evolution.
- Almost all children spontaneously used tangible markers for problem solving and initiated gesture strategies for solving problem on their own initiative. Thus, tangible interactions associated to IBSE encouraged pupils to test their own hypotheses using intuitive manipulations and to evaluate them using sensorimotor, kinesthetic feedbacks. Markers motions reflect hand movements. As such they can serve as evidence of underlying representations in memory and of the processes by which such representations are derived and utilized. Analyses of digital logs of the markers motions enabled five different typologies of gesture strategies to be characterized. They were classed according to (i) accuracy level to arrange markers, (ii) motion types, and (iii) groping level for solving the problem. They highlighted children's hypotheses and their metacognitive mental models. 77% of the pupils who acquired required skills and knowledge used two specific strategies. Those metacognitive models can be clearly associated to scientific learning. By providing use of individual strategies and encouraging students to make their own ideas overt, AIBLE enabled learners to overcome their initial conceptions.

4 CONCLUSION

Usually, children cannot access large-scale space to solve astronomical problems. However, they have to construct a mental image of spatial relationships from an allocentric point of view to contradict their ego/geocentric one. The combination of AR and IBSE, provides many benefits to overcome beliefs. It enhances perceptive tasks mobilisation, focussing pupils on active learning. Mixed reality affords perception of spatial indicators. For young learner, it facilitates spatial encoding and learning of spatial layout. So, AIBLE provides elements to young learners to plan process of problem solving in 3D. AIBLE affords also intuitive manipulations which contributed to spatial abilities development. Thus, pupils, as expected in IBSE principles, develop their own intuitive gesture strategies which provide interaction experiences. So, pupils have elements to control their investigation on complex problems. They can construct scientific explanations using their own mental schema. This study states that AIBLE really allows heuristic investigations and scaffolds spatial cognition, which fosters consciousness of the origin of astronomical phenomena. Moreover, this study contributes to the establishment of a frame of references of astronomical skills used by young learners.

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