AR Learning Environment Integrated with EIA Inquiry Mode

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Augmented reality (AR), the technology of integrating virtual objects with the real world, has the following three defining characteristics: (a) Combines real and virtual objects in a real environment; (b) Runs interactively and synchronously; (c) Registers real and virtual objects with each other. Based on these characteristics, AR has been proven to have great potential educational affordances which are especially useful in the sciences, including spatial ability, practical skills, scientific inquiry learning, and conceptual understanding.

Keywords: AR learning environment ; EIA model

1. AR Experimental Environment of Primary School Science

In recent years, AR has attracted attention from a wide range of researchers in the domain of teaching primary school science, and such literature covers many sub-fields, such as Physical Sciences [1][2], Life Sciences [3][4][5], and Earth and Space Sciences [6][7]. In these different sub-fields, AR tends to play different roles. For example, in the area of Physical Sciences, AR is used to support some unavailable experiments, such as microscopic particles and the magnetic field [8][9][10][11]. In the Life Sciences, multiple articles investigate the effects of using AR to guide students to explore a real outdoor space with AR-generated clues [3][5][12]. When it comes to Earth and Space Sciences, AR assists students to record and analyze their long-term observations of phenomena [6][7]. In addition, these studies consider many supportive strategies suitable for AR teaching, including text reminders [13], collaborative scaffolds [8], repertory grids [14], and concept maps [4].

According to the literatures, it is clear that AR can be a helpful tool in empowering students' comprehensive scientific literacies, such as observation, inquiry, and analysis, when they are engaged in science learning. Compared to other traditional classroom technologies such as Flash or video clips, AR can be used in conjunction with other support tools, meaning that AR is powerful when comes to constructing learning spaces.

Thus, it is obvious that the field has studied out-of-classroom learning spaces and specific abilities to a good extent. As AR becomes more well-known and pertinent to everyday teaching and learning, it is natural to move from more fundamental, ability-specific inquiries to a more integrated, rounded perspective to examine such technology. One good candidate for the requirements is to consider students' scientific literacies, so that this can potentially collaborate with AR to transform the classroom into a more suitable learning space for the students themselves. Therefore, it is now appropriate to introduce the idea of primary students' scientific literacy.

2. Scientific Literacy

Scientific literacy is the ability to engage with science-related issues; in other words, this suggests that a scientifically literate person is able to understand science, the nature of scientific knowledge and the relationship of science with society and environment, to know basic scientific concepts, laws, theories and principles, and to use science process skills [15]. Scientific literacy has been globally recognized as a major goal of science education [16], and many educators that specialize in evaluation and assessment pay close attention to such an issue and tend to approach it from multiple dimensions. For example, the PISA (Program for International Student Assessment) evaluates test-takers' scientific literacy from three aspects: (a) to explain a phenomenon scientifically; (b) to evaluate and design scientific enquiry; and (c) to interpret data and evidence scientifically [17]. It is then reasonable to infer that according to educators and developers for PISA, these aspects are considered pillars to understand and engage in critical discussions on issues that involve science and technology. Science curriculum scholars from China have put forward eight inquiry activities related to scientific literacy: posing questions, raising hypothesis, making plans, collecting evidence, processing information, drawing conclusions, communicating and presenting, and evaluating and reflecting [18]. These foundational and policywise pieces of literature are valuable references when considering and designing AR-based scientific inquiry, as the activities above could be taken on in the process.

3. Cognitive Load

Cognitive load is another important factor that needs further discussion in the scientific activities on the basis of AR [19]. Since our working memory is limited, there is a finite range for the amount of information we can deal with simultaneously and the time that the information can be retained, and information exceeding the limit could lead to cognitive load [20]. Cognitive load also occurs when we adopt a new technology for learning with an inappropriate order of relevant activities [21]. Thus, learning content and activities sequences should be taken into consideration according to AR's characteristics to reduce students' cognitive load. The cognitive load can be measured from two dimensions, namely "mental load" and "mental effort", respectively relating to intrinsic cognitive load and extraneous cognitive load [22]. A man with low mental load and high mental effort has a positive performance on cognitive load [14]. If the AR tool promotes distraction by presenting a lot of information, it will increase cognitive load for students [23]. Students will feel it is difficult to understand the learning content, and they may need to put great effort into completing the learning tasks or achieving the learning objectives in this learning activity [22]. Therefore, assistance in selecting and interpreting information in AR-based learning environments is required [23]. If the scaffolding mechanism can support better metacognitive processes, it might help with the aforementioned drawbacks of AR technology.

4. Scientific Inquiry Model

It is indisputable that primary science courses are essential in developing students' scientific literacy. In order to promote effective instructions in teaching primary science, researchers have proposed a variety of teaching and learning models, each with their own focuses. The learning psychologist and constructivist-driven 5E instructional model proposed by the BSCS (Biological Science Curriculum Study) has been widely applied and reiterated in the past 30 years or so [24][25]. 5E model's five discrete elements (engage, explore, explain, elaborate, and evaluate) have been used for references by many successors to build their own models. Eisenkraft [26] later added two activities, elicit and extend, to form the 7E model and emphasize the transfer of learning. Schwarz and Gwekwerere [27] constructed the EIMA model, standing for engaging topic, helping investigation, creating models and applying models to explain novel situations. Marshall, et al. [28] then built on top of EIMA and came up with the 4E×2 model, highlighting the formative assessment and metacognitive reflection and reserving four inquiry activities: engage, explore, explain, and extend. Gunckel [29] designed the Inquiry–Application Instructional Model to support teachers focusing primarily on scientific inquiry, but also including aspects of conceptual change and cognitive apprenticeship.

In the case for China, scholars theorized during the national curriculum reform of Primary and Secondary Schools in 2001 that students' methods of approaching learning should be rooted in Independence, Investigation, and Collaboration, in which teachers pursue an inquiry teaching model such that it integrates educational technology and curriculum and instruction [30]. In that inquiry model, the teaching process is divided into five steps: (1) situational contextualization, (2) inspirational thinking, (3) independent investigation, (4) cooperation and communication, and (5) summarization and improvement. Each phase of this model has specific corresponding resources, methods and activities [30].

In general, these models have their own advantages, yet it is difficult for them to seamlessly adapt into an AR-based environment for primary science's teaching and learning. Some major reasons include that current pedagogy is more focused on teacher–student interaction than participant–environment interactions. Moreover, the current pedagogy lacks mechanisms to promote active learning initiated by the students. Since student actions in AR-based learning environments are no longer in one-to-one correspondence with the teacher, student learning in such environments can take the paths of learning from the environment [1][3], learning from peers [2], and learning from their own construction [31]. Therefore, a good inquiry model that intends to suit AR learning environments must consider multiple factors, such as teacher role, classroom ecology, and situational context in addition to supporting the diversity and flexibility in students' individual learning.

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