Authoring Augmented Reality Learning Experiences as Learning Objects

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***Abstract*—Engineers and educators alike have prototyped a variety of augmented reality learning experiences (ARLEs). However, adapting ARLEs in educational practice would require an interdisciplinary approach that considers learning theory, pedagogy and instructional design. To address this requirement, we model ARLEs as learning objects by outlining the necessary components, and we propose a participatory design to demonstrate the authoring process of an augmented reality learning object (ARLO). ARLOs can be made useful in many scenarios if teachers are empowered to edit its context elements, content and instructional activity. Lastly, we point to the research questions entailed in modeling ARLEs as ARLOs.**

Keywords-augmented reality; augmented reality learning experience; authoring; learning object; participatory design;

I. Introduction

Researchers have used augmented reality – the integration of virtual objects in a real environment, made interactive in real-time – to create compelling experiences that facilitate effective learning. Although many such augmented reality learning experiences (ARLEs) exist in the current literature, only few are made by interdisciplinary groups with pedagogy and instructional design in mind [1]. The enabling technologies of augmented reality (displays, tracking algorithms, etc.) have matured to the point that we can already create usable ARLEs in the education setting. From AR proof-of-concepts, we can now proceed to adapting it for the use of a teacher in a school.

II. ARLEs Modeled as ARLO

Learning object refers to "any entity, digital or non-digital, that can be used, reused, or referenced during technology supported learning" according to the IEEE Learning Standard Committee [2]. Learning objects are reusable because of their inherent characteristics: self-contained, interoperable and adaptable. This modular quality of learning objects suggests that learning can be facilitated by using small, reusable units of learning. However, Chiappe et al. [3] suggests that we should not think of learning objects as indivisible units with internal components that cannot be changed. Instead, they recommend an instructional design model for learning objects to accommodate change in at least three overlapping internal components: context elements, content and instructional activities. These components are already defined and exemplified in the literature, especially for web applications and virtual learning environments.

The concept of learning objects can be extended to ARLEs to create augmented reality learning objects (ARLOs). ARLOs inherit the components of learning objects. However, ARLOs also have context elements, content and instructional activities that are specific to ARLEs as summarized in Fig. 1. Important context elements would be the teacher's objectives and the instructional setting (lecture, laboratory, self-study, homework) [4]. In ARLE, another important context is the *context of visualization*. Augmented reality inherently affords contextual visualization: the presentation of virtual information in the rich context of a real environment. Examples would be viewing a butterfly in the school garden [5], or seeing magnetic field lines on a magnet [6]. Contextual visualization leads to beneficial effects in learning because of two reasons. First, virtual information is aligned with real objects, thus reducing the need to switch attention between different media. Second, multimodal cues found in a familiar, real environment are used, thus, helping the students relate and construct their knowledge. For students to benefit from contextual learning, teachers must be able to adapt ARLO to objects and environments that are accessible and familiar to students.

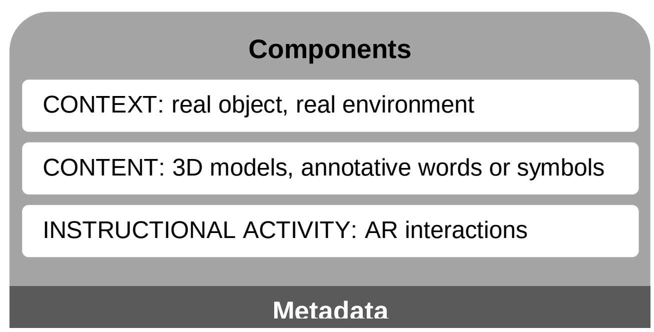

Figure 1. ARLO-specific components that should accommodate changes.

Content in learning object may refer to the interface, the information (text, image, sound) and its characteristics such as length, language and word choice. In ARLEs, information takes the form of 3D computer graphic models, and annotative words or symbols like numbers, circles and arrows. ARLO must allow the teachers to scale, translate or even add or delete the 3D models and annotations used. This

ARLO feature ensures the seamless integration of the virtual elements to the real environment, and allows the adjustment of the ARLO to the teacher objectives and student needs.

Instructional activity in learning objects may refer to the individual steps in the process of teaching using the learning object, with or without other learning materials. Examples are explaining to students the objectives of a learning object, and asking students to change some values in an equation to note changes in a graph. ARLEs can enable novel instructional activities through various AR interactions. For example, in [5] teachers can instruct students to take a picture of the butterfly every day. In [6], teachers can ask students to move pieces of magnet closer or farther from each other to see changes in the magnetic field lines. Currently, all useful AR interactions cannot yet be listed exhaustively. However, it is clear in the literature that AR is not only a static, visual display. AR can afford highly embodied interactivity that teachers need to adjust depending on their teaching requirements.

III. Participatory Design of ARLO

We propose a participatory design approach for creating an ARLO by involving educational technology experts, curriculum designers, teachers and students in the design and evaluation of the ARLO (Fig. 2). Early in the design phase, paper-prototyping and AR demonstrations can be used to gather insights from curriculum designers and teachers. Interviews and focused group discussions will be conducted to explore the following: the usability of state-of-the AR technology and accompanying interactions, perceived usefulness of ARLEs, and how ARLEs can fit in the current practice of the teachers. Engineers will then base the first prototype on these requirements. The ARLO can be improved iteratively by having curriculum designers do an expert evaluation and by having the teachers use them in class.

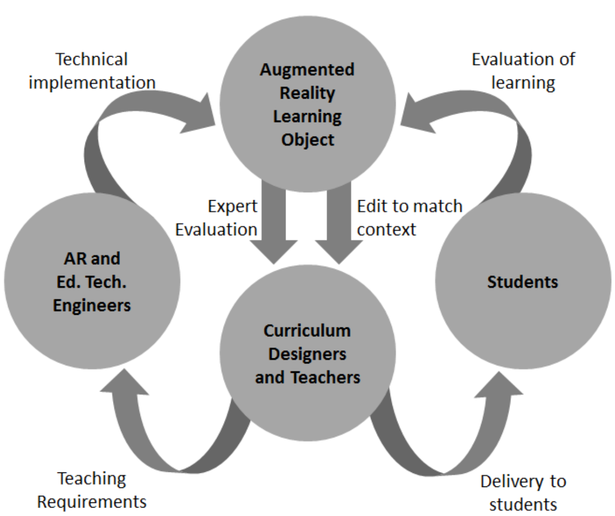

Figure 2. Participatory Design of Augmented Reality Learning Object

Our participatory design involves two kinds of authoring: creating and editing.

A. *Authoring 1: Creating the ARLO*

The first type of authoring corresponds to the cycle “Engineer → ARLO → Curriculum Designer/Teacher → Engineer” in Fig. 2. This type of authoring requires the joint effort of engineers, curriculum designers and teachers to create an ARLO. This includes incorporating features that would enable a teacher to change the context, content and instructional activity of an ARLO.

B. *Authoring 2: Editing the ARLO for Specific Use Cases*

The second type of authoring corresponds to the cycle “ARLO → Teacher → Student → ARLO” in Fig. 2. This authoring occurs when the teacher edits the ARLO based on intended objectives, and the background of the students. For ARLEs, teachers should be able to fit the AR contents (3D models, annotations, etc.) to the target real object or environment of their choice. The ARLO can also be adjusted iteratively after the teacher gets feedback from the students.

IV. Conclusion

ARLOs are AR-based learning objects that have their own unique components (in terms of context, content and instructional activity) that should be editable by teachers to guarantee reusability. ARLEs can be applied to educational practice by modeling them as ARLOs, thus leading to the following research questions:

1. How do you model an ARLE as a learning object?
2. How do you author ARLOs to guarantee reusability?
3. What are the roles of the stakeholders (engineers, curriculum designers, teachers, parents, students) in the creation of ARLOs?
4. What unique instructional activities can ARLOs afford and how do these affect learning outcomes?

To answer these questions, we assume a participatory design approach wherein the stakeholders can collaborate freely to create a proof-of-concept ARLO. Experiences in this research can answer the four research questions above, and inform the design of future ARLEs.

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