Design of a Cognitive Artifact based on Augmented Reality to Support Multiple Learning Approaches

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Abstract: Multiple learning approaches require different strategies, when teachers prepare instructional material and conduct the learning process. On the other hand, students need flexibility, when explore the educational contents. Augmented reality can contribute to the development of innovative instructional resources, which provide more effective learning. This paper presents the design and using of an Augmented Reality Cognitive Artifact (ARCA), which is an educational tool useful for teachers and students. Teachers can create specific contents, according with their objectives, and students can extensively interact with the application to learn on these contents. Due to its structure, ARCA can be adaptable for different learning approaches, including objectivists, constructionists and blended ones.

Introduction

Effective teaching and learning needs an adequate planning, so the adoption of a systematic process, covering from the content creation through the use, applied to teaching and learning using technological interfaces, may achieve some learning principles, such as objectivism and constructivism. (Chen, 2007)

Objectivists and instructional theorists such as (Gagné, 1984) argue that a specified sequential process facilitates the internal cognitive structures during the learning process, leading to a successful results. However, some constructivists, such (Jonassen, 1999), argue that the knowledge is individually constructed through real world experiences, by collaboration and social negotiation. In order to expand the cognitive abilities, some learning methodologies use symbols and artifacts, provided by external devices, called cognitive artifacts (Norman, 1994).

Several devices used to extend and stimulate thinking capabilities in the problem solving, attention and information processing can be considered as cognitive artifacts. It is important to point out that these artifacts do not change the human mind capabilities; instead of this, they change the way to interact with knowledge (Zhang & Norman, 1994).

The cognitive artifacts characteristics fits to the Augmented Reality (AR), that is a technology defined as: “an interface based on computer generated information combination (static and dynamic images, spatial sounds and haptic sensations) with the real user environment, provided by a technological device and using natural interaction on the real world” (Kirner, 2011). In this way, a single Augmented Reality Cognitive Artifact (ARCA), suitable for education, could satisfy multiple learning approaches, by changing the software feedback.

An ARCA for education has to fulfill the following requirements, stated by (Kirner & Kirner, 2011)

- It has cognitive potential, multimodal and natural interaction.
- Its construction must use ordinary materials and an easy process, to obtain availability and low cost.
- Its logical parts must use AR technology.
- The cognitive experiences must be simple and easily customized by teachers.
- The user interface must consider usability characteristics (easy to understand, learn and use), human factors (usable, effective and well accepted) and ergonomics (safe and efficient).

The ARCA, as a sequential content provider, helps teachers to control the learning, by structuring the considered environment. The design and goals of the ARCA conducts to a process of knowledge acquisition that fulfills the requirements of objectivist theories. In addition, an exploratory content provider lets the students control the learning process, in cases when the environment is free and flexible to exploration. In these cases, the objectives are set by the learner, which can decide about the content to explore, multiplying perspectives or collaborating, which is compatible with constructivist theories. This discussion was presented in (Chen, 2007) and summarized in Table 1.

Objectivist Approach	Constructivist Approach
Teacher controls learning process	Student controls learning process
Instructional strategies are well-defined and selected based on the domain and type of learning goals/objectives	Learning is embedded in complex, problem-based real-world tasks
Learning environment is structured and sequenced properly	Learning environment is open and flexible
Goals and objectives are set by the designer or teacher	Goals and objectives are set by the learner
Assessment is aligned with the goals and objectives and conducted at the end of instruction	Assessment is continuous and embedded in learning tasks
Cognitive process of knowledge acquisition is emphasized	Multiple perspective and social negotiation is emphasized

Table 1: Objectivist and constructivist characteristics (Chen, 2007).

The ARCA proposed in this paper provides multiple approaches, customized by the teacher, to meet with the adopted learning process. It can be used as an evaluation resource, on sequential activities, aiming at motivating the adoption of innovative interaction to explore the contents and achieve the proposed goals.

To make ease the AR environment construction, an authoring tool, called basAR (Behavioral Authoring System for Augmented Reality), was used to create intelligent AR environments based on a virtual structure of action zones. These zones can react to the user interaction, giving feedback to him, based on a described behavior (Cerqueira & Kirner, 2011). A visual software interface, placed over the basAR level of structure and behavior, helps the teacher to easily insert contents and choose the approach that is most appropriate for the considered context.

The objective of this paper is to present the ARCA, a tool that intends to be useful by teachers and students. Teachers can create specific contents, according with their objectives, and students can extensively interact with the application to learn on these contents. Due to its structure, the use of ARCA can be adaptable for different learning approaches, objectivists, constructionists and blended ones. First, the paper points out related work which were relevant to develop the project. Then, it focuses on the conceptual proposal of the tool. After that, it discusses the behavior incorporated into the artifact. Following that, it presents a visual interface to ease the development and use and two scenarios of the application use. Finally, the conclusions are summarized.

Related Work

ARCA can be used in software and hardware applications that involve the combination of computer generated multimedia and physical structures. An example of this approach is presented in an AR game, by (Kirner & Kirner, 2011), where the game static physical structure uses Styrofoam and the movable parts are paper crafted cars. The game tests the player's knowledge by asking some specific questions, depending on the user interaction with cars positions. Figure 1 shows the activation of the question and the answer.

Figure 1: Game artifact with augmented reality.

Another example of cognitive artifact is the AR-Artifact, developed to help cognitive disabled people to restore cognitive functions, such as: follow instructions, select and evaluate situations, reasoning, making decisions, constructing and describing things, etc. (Kirner & Kirner, 2011). This application shows point patterns and pictures, provided by the AR software to enable a therapist to implement cognitive tests for their disabled patients. Figure 2 shows an example of pattern matching and comparison test.

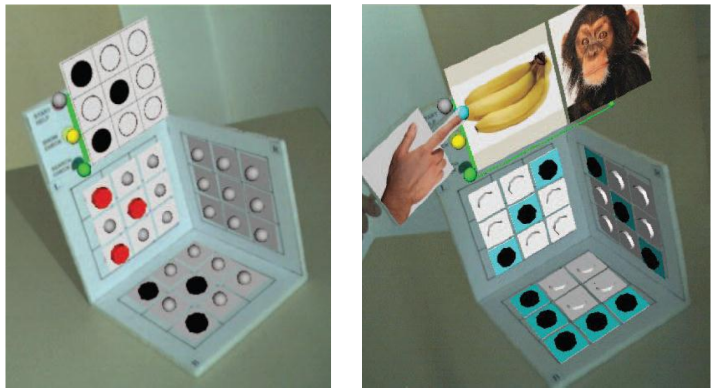

Figure 2: Cognitive rehabilitation using augmented reality artifact.

Design of the Cognitive Artifact

The development of an ARCA requires the following steps, which are represented in layers:

- Conceptual Definition: This layer defines the artifact requirements for the applications.
- Physical Structure: This layer defines the artifact construction and the interaction zones placement.
- Infrastructure: This layer defines the placement of a correlation item between real and virtual world. AR usually uses a computer vision library that tracks a fiducial marker to correlate the worlds.
- Virtual Structure: This layer defines the action zones distribution matching with the physical structure point placement.
- Content: This layer defines the virtual objects to provide the application abstraction.
- Behavior: This layer defines how the application reacts to user interactions.

Conceptual Definition

The artifact has to place two content windows to show questions and answers or multi-level content, three buttons to answer the questions or to navigate into the levels, one 3D model activation button, one next level activation button and one reset button.

Physical structure, infrastructure, virtual structure and content placement

The artifact base is composed of a piece of Styrofoam with an attached sheet of paper, with the artifact requirement buttons printed on it (Fig. 3a). On this sheet of paper, is also placed the infrastructure marker to correlate the worlds.

The virtual structure is relatively placed on the infrastructure source (fiducial marker) and it should match the physical structure buttons positions to create the buttons virtual behavior. The content is attached to the virtual structure (Fig. 3b).

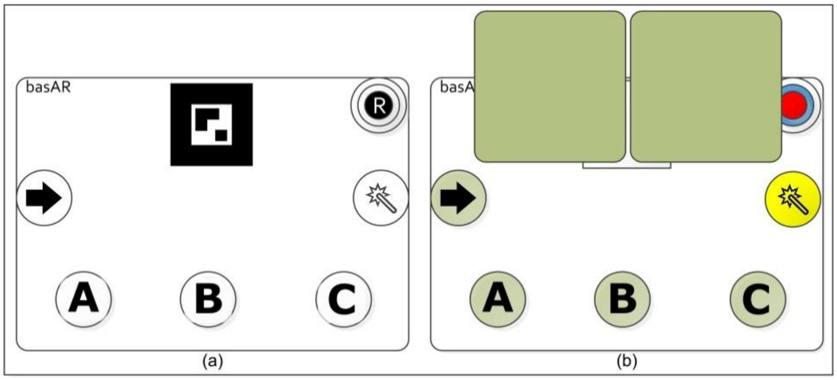

Figure 3: (a) Physical structure; (b) Content placement of the ARCA

A cube actuator artifact with a fiducial marker (Fig. 4) performs the interaction with the virtual structure. It is an origami cube template, provided by the basAR, which is easily folded and distributed.

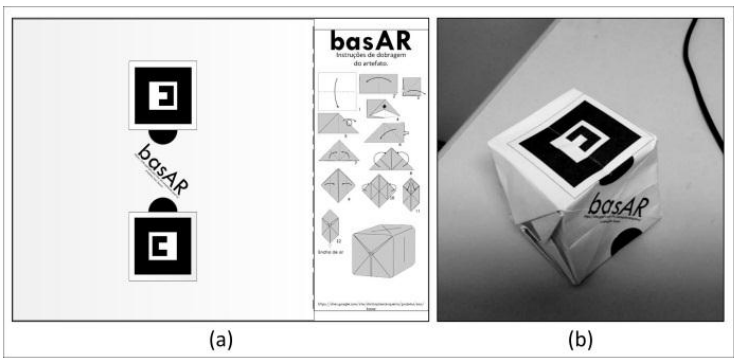

Figure 4: Cubic actuator artifact. (a) Sheet distributed to fold the artifact; (b) cube folded and ready to use.

Behavior

The behavior layer is described at a configuration file on the Data folder (*config_behavior*), which is part of the basAR file structure. This behavior file is not compiled; it is a structured sequence of states that set each action zone behavior, occurring in a certain instant time. Specific details on how to configure the basAR behavior is given in (basAR, 2011).

Artifact Behavior

The structured sequence of states can be visually represented by state machines. This representation shows the behavior concept that is used. Different behaviors concepts are incorporated in the ARCA, allowing different uses of the artifact. These behaviors are categorized as follows:

- Straight Quiz (SQ)
- Driven Exploration (DE)
- Flexible Quiz Game (FQG)
- Flexible Free Exploration (FFE)

These types of behaviors are compatible with the objectivist and constructivist learning approaches, presented in Table 1.

Straight Quiz

In the SQ content approach, the behavior shows a given content and, after the user selecting the sub-content, the behavior increases a correct counter or a wrong counter, depending on the sub content selected. It also marks the question which is being explored and activates the next question button. The graphic given in Figure 5 illustrates this sequence of steps. An audio may follows a correct or a wrong sub-content, conducting and giving feedback about the contents' selected choice.

The SQ meets with the objectivist learning, as it allows the teachers to control the assessment sequence of the contents, structuring the quiz. The evaluation of the knowledge acquisition is acquired from the score results related to the application.

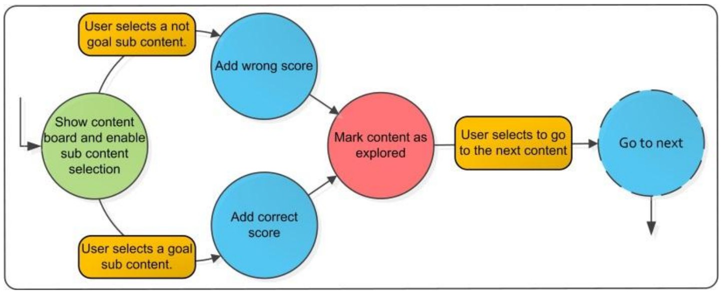

Figure 5: Straight Quiz behavior steps.

Driven Exploration

In the DE content approach, the behavior shows a starting content, which can be a question or a first level content explanation. The user must pass through all shown sub contents. In this way, when the user selects sub content, the behavior plays an audio that is correlated to it. If the teacher has customized the behavior to show a second level explanation board, this behavior is shown at the right side of the question board. The graphic given in Figure 6 illustrates this sequence of steps.

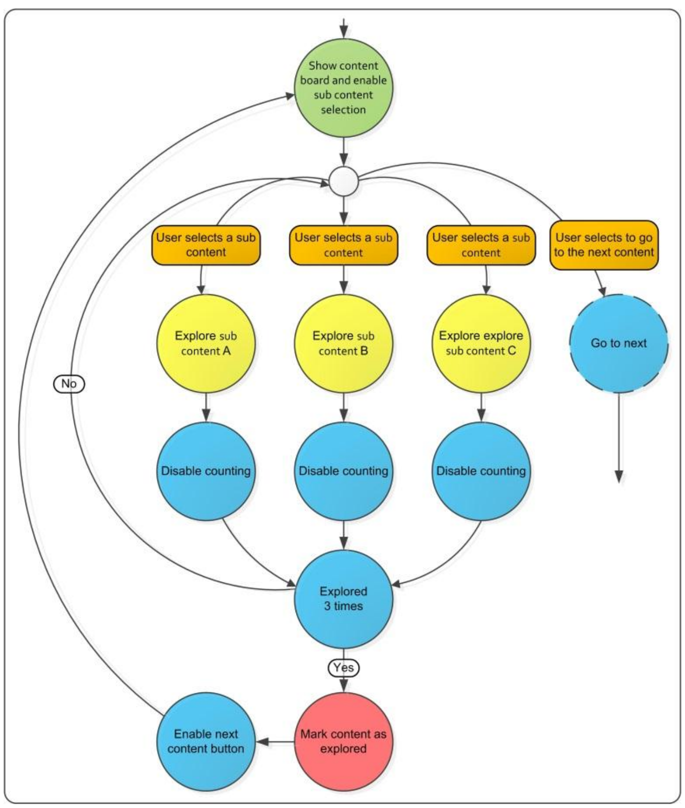

Figure 6: Driven Exploration behavior steps.

After the user passing through all the sub-contents, the behavior enables the next content, marks the content as explored, and allows the user to review the statements, if desired.

The SQ satisfies the principles of the objectivist learning approach, providing a structured learning environment driven to the goals and objectives. The instructional strategy designer sets the main contents horizontally on the first level, and the DE drives the user to go vertically in the level to acquire knowledge. This strategy is shown in Figure 7.

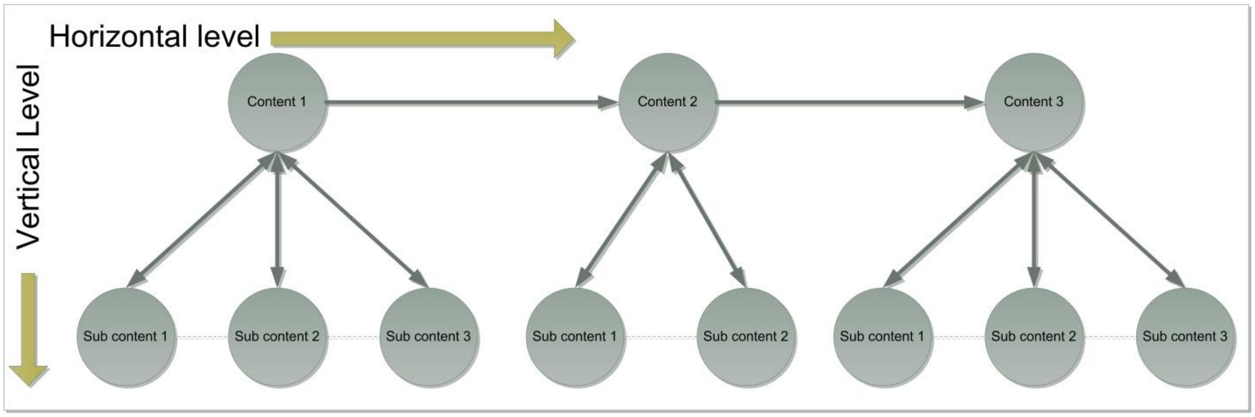

Figure 7: Horizontal and vertical content access.

Flexible Quiz Game

In the FQG content approach, the behavior shows the content and the user explores the sub-contents until he finds the correct one (or the goal, not necessary wrong). After the user selecting the correct sub content, the behavior enables the next content button and the user chooses if he wants to explore other sub-contents or jump to the next content. Figure 8 illustrates this sequence of steps.

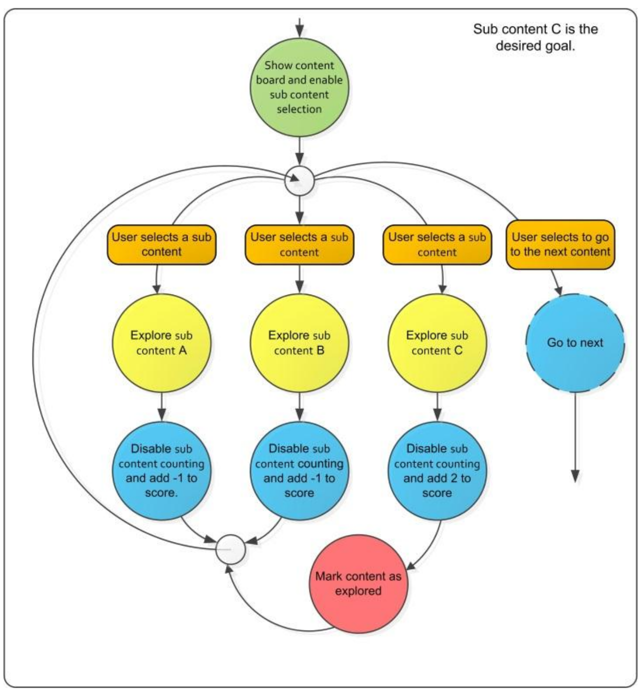

Figure 8: Flexible Quiz Game behavior steps.

The FQG fulfills the characteristics of a hybrid learning approach (objectivist and constructivist), since, first of all, the user has to find the goal statement and then chooses if he wants to explore the remaining statements. That is, the user controls the learning process after the goal is achieved.

Flexible Free Exploration

On FFE content approach, the behavior shows the content and enables a free user exploration to any statement. In this case, the next content is always enabled, so the user can skip the content, seeing whatever is desired. The graphic given in Figure 9 illustrates this sequence of steps.

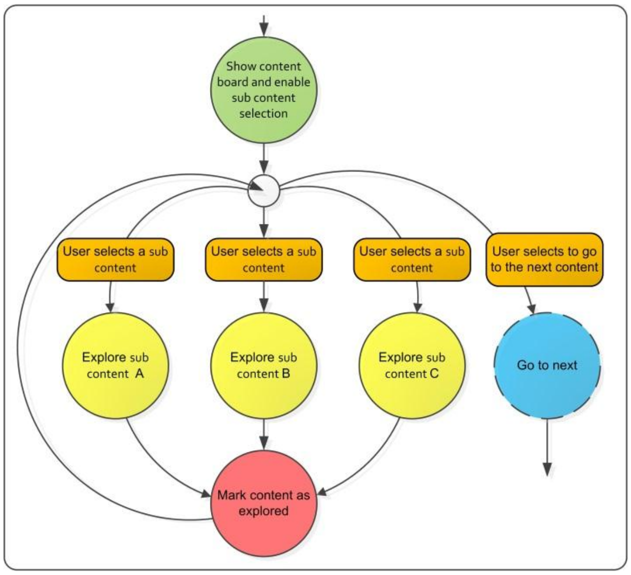

Figure 9: Flexible Free Exploration behavior steps.

The FQG is in accordance with the constructivist learning, since the user controls the learning process, choosing the goals and objectives and freely exploring the environment. Multiple goals are possible, allowing multiple perspectives.

The content approaches, pointed out above, are implemented in the behavior conceptual definition layer. The teacher may choose the way to explore the content. For example, he can start the activity, exposing the topic content using the DE, then testing the knowledge with the SQ approach type. Alternatively, he can start the activity, proposing a free exploration through the content, following FFE, then testing the knowledge with a flexible quiz, using FQG. Figure 10 illustrates both alternative approaches.

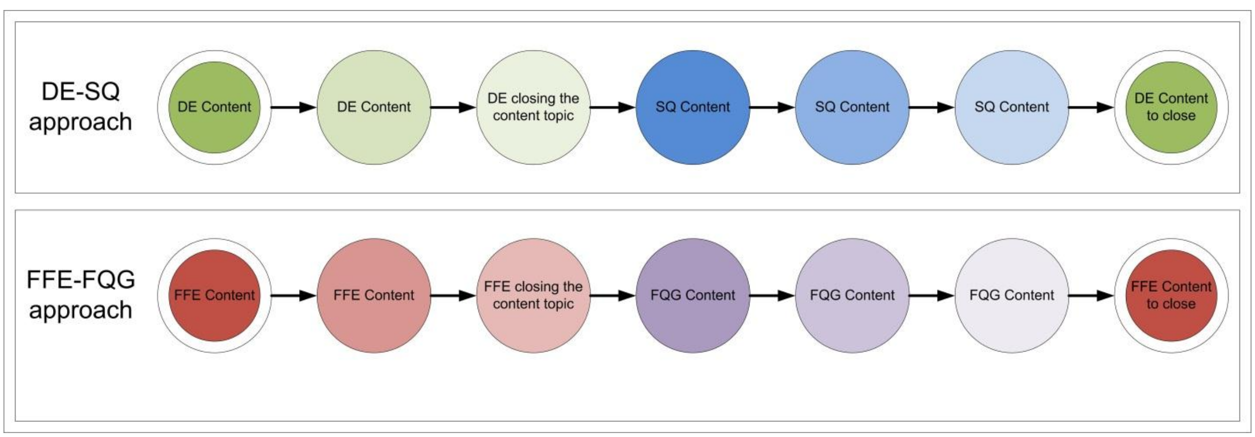

Figure 10: Hybrid approaches allow flexibility to create the activity.

Cognitive artifact applications

This artifact can be used in several activities, such as:

- Question & Answer to different types of learning methodologies.
- Content explorer.
- Quiz games.
- Etc.

Using the basAR, it is possible to customize the artifact reaction, by editing the behavior configuration file; however, for behaviors containing several states, the complexity to manipulate the file increases, so a visual user interface can help the development, giving to the user a subset of possibilities and allowing the visual manipulation of the content. The interface groups the information and mounts the files that the basAR reads to start-up the AR environment. Considering a model in layers, the interface is above the structure of the Multiple Learning Content, where the application developer, if he desires, can edit the behavior configuration file (Fig. 11). The user will interact with the application or even develop their own content and share it with other people.

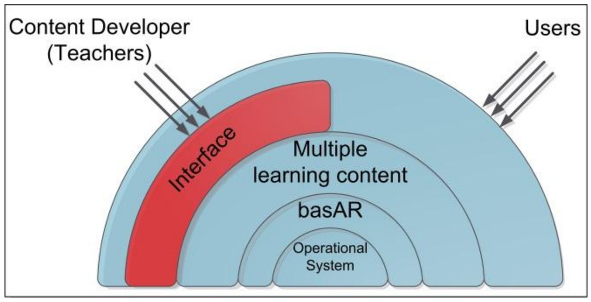

Figure 11: Interface placement on the layer model.

Figure 12 shows an example of the visual interface for content development. According to it, two steps are necessary to create a specific content. In the first step, the developer creates, edits, deletes and saves contents with several options. These options can be: adding audio; choosing a statement that is enabled (or the content goal); selecting the sub-content in which the developer will insert images and 3D models took from a content repository (Fig. 12a). In the second step, the developer chooses the specific contents and adds them to the sequence field, selecting the suitable content structure (SQ, DE, FQG or FFE). In this case, the developer can create, edit, deletes and saves the sequences to share with the users (Fig. 12b).

Figure 12: Interface example. (a) Content development step; (b) Sequence development step.

Figure 13a shows a user testing a Q&A quiz application. The user has to choose the correct answer to the question. The environment includes the artifact placed on the table, a webcam placed on top pointing to down and a monitor showing the virtual content. Figure 13b shows the application in a Free Exploration mode. In this case, the user chooses a statement and the right image appears together the explanation. The user manipulates the artifact in front of a notebook webcam, interacting with the artifact.

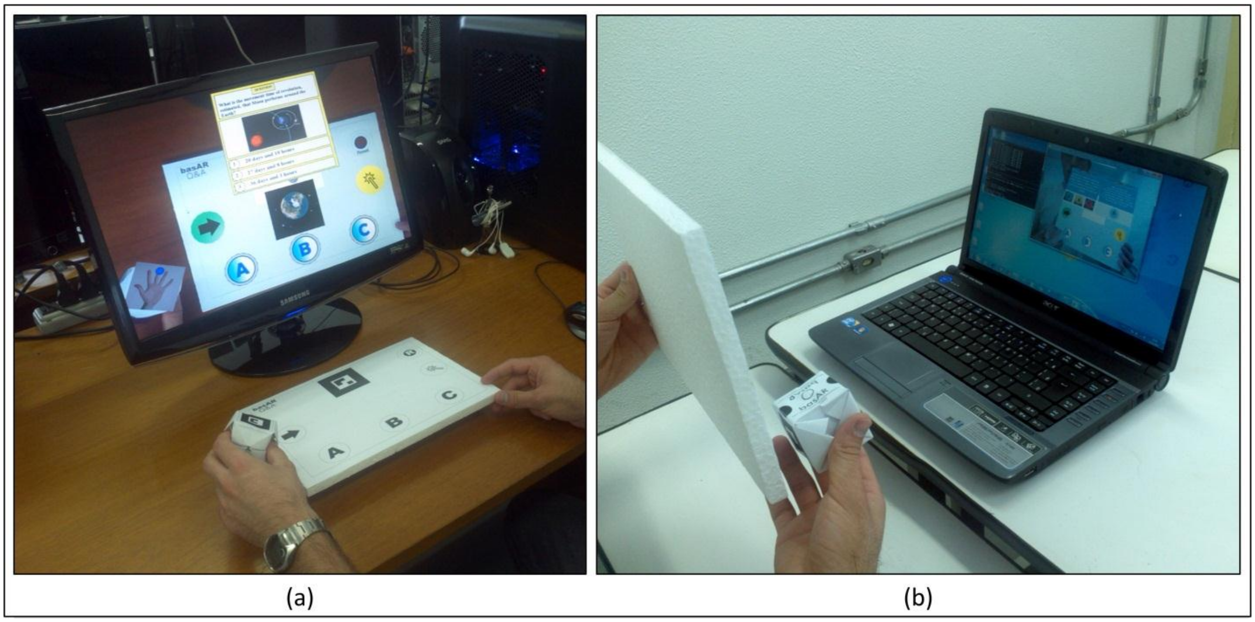

Figure 13: ARCA use. (a) Q&A table setup and (b) learning tool mirror setup.

Conclusions

This paper presented and discussed the authoring of augmented reality applications by non-programmers (like the majority of teachers), using the basAR tool and a visual interface. Using these technological resources, the teacher can customize the learning approach he considers the most adequate for his context, satisfying objectivist and/or constructivist theories or combining both of them, defining a hybrid approach by extracting the best points of each approach.

Besides, it was described the creation of an easily and non-expensive interactive Augmented Reality Cognitive Artifact (ARCA), in which the virtual content will be placed.

A pilot application was tested by undergraduate and graduate students. The graduate students tested the application building a content using the SQ approach and customizing it directly in the file structure, instead of using a simplified interface. After that, the undergraduate students used the application to learn on the subject. This showed the need to develop a tool to make easy the organization of the intended content. These tests and additional observations indicated that the application is attractive and motivate the students stimulating curiosity, by the blend of visual and audio contents included in the augmented reality application.

The main expected contributions from this work include:

- Discuss a simple augmented reality cognitive artifact to use in the teaching and learning process.
- Provide a tool that implements some methods to create objectivist, constructivist and hybrid approaches for educational activities.
- Reinforce the augmented reality usability, by means of the generation of innovative learning scenarios, which could improve the learning achievements.

Future works include:

- Incorporate on-line collaboration features, so that the teachers can interact with the student's artifact or the students could interact with each other's, in the same class or in distance learning cases.
- Implement modules, to serve for the teacher create alternative ways to interact with the contents.

Finally, it is important to stress the potential that the cognitive artifacts based on augmented reality, helping teachers in the effective use of learning approaches and, consequently, contributing to the continuous improvement of learning processes.

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