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How the Type of Content in Educative Augmented Reality Application Affects the Learning Experience

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Abstract

Nowadays, the use of technology to improve teaching and learning experiences in the classroom has been promoted. One of these technologies is augmented reality, which allows overlaying layers of virtual information on real scene with the aim of increasing the perception the user has of reality. In the educational context augmented reality have proved to offer several advantages, i.e. increasing learning engagement and increasing understanding of some topics, especially when spatial skills are involved. Contents deployed in an augmented reality application are of two types, static, i.e. text, or dynamic, i.e. animations. As far as we know no research project has assessed how the type of content, static or dynamic, can affect the student learning experience in augmented reality applications. In this article the development and evaluation of an augmented reality application using static and dynamic content is described. In order to determine how the type of content affects the learning experience of the student, an experimental design in which the student interact with the application, using static and dynamic contents, for learning topics related with an electronic fundamentals course was performed.

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Keywords: static and dynamic contents, augmented reality, fundamentals of electronics.

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1. Introduction

In recent years, the use of technology to improve teaching and learning experiences in the classroom has been promoted[1]. One of these technologies is augmented reality, which allows overlaying layers of virtual information on real scene with the aim of increasing the perception the user has of reality[2]. In the educational context augmented reality offers several advantages as: (i) it has an ability to encourage kinesthetic learning, (ii) it can support students by inspecting the 3D object or class materials from a variety of different perspectives or angles to enhance their understanding, (iii) it increases the student level of engagement and motivation in academic activities, and (iv) it allows to provide contextual information, that is data about real objects of the scene related with the learning activity[3]. The contents deployed in an augmented reality application are of two types, static or dynamic[4]. Texts, visual cues or 3D models whose appearance does not vary during interaction with the user are defined as static contents, besides dynamic contents vary their appearance during interaction with the user, and animation are an example of them. Dynamic visualizations such as animations or videos are depictions that change continuously over time and represent a continuous flow of motion (e.g., of an object), whereas static visualizations do not show any continuous movement, but only specific states taken from such a flow of motion[5]. Which type of content must be deployed in an augmented reality application depends on the topic and the learning experience that will be provided to the student[6,7].

Most of the research projects involving the design and evaluation of the static and dynamic content have considered the framework of the Cognitive Theory of Multimedia Learning and of the Cognitive Load Theory (CTML)[8]. This framework establishes that a learner has to select, organize and integrate new information to fully understand any instructional material. According to CTML, select and organize verbal information involves the construction of a verbal mental model, while the selection and organization of visual information involves the development of a visual mental model. This framework also states that the construction and integration of these two mental models allow a deeper understanding of a specific topic and an improved linking with prior knowledge, which promotes the storage of new knowledge more easily in the long-term memory. For this reason, several studies have explored whether there is a difference in learning when the contents are presented in textual, visual way or integrating both ways[9,10].

Different learning strategies or cognitive activities applied by students when they use text or diagrams-based contents have been explored[11]. For measuring or evaluation of these processes the use of think-aloud protocol and coded cognitive activities such as: inference, background knowledge, vocabulary, among others, has been proposed. From experimental tests performed in learning subjects like biology, the authors found that students perform more elaborate cognitive activities when learned through diagrams than using text, however they did not determine whether the level of learning was better in some of the two modes[11].

Other works have focused on evaluating whether there is an effect on learning when the student uses static or dynamic contents. An analysis of how different abilities, skills and knowledge of student affect the understanding process of dynamic content has been described[12]. Additionally, the authors of this research work reported eight studies in which the understanding of a complex mechanical system using static and animated diagrams is evaluated, with and without verbal instructions. From the results they were able to determine that the space ability has no significant effect on the understanding of the content, and possibly this kind of ability is more useful when the content is textual or verbal and the student has to mentally create a visual representation of it[12]. Finally, the authors determine no significant impact on learning when static or dynamic content is used.

Additionally, the effect of static and dynamic contents on understanding the physical principles of locomotion of fish has been determined[13]. Specifically, three conditions defining how the content is showed have been tested: text only, text with dynamic visualizations, or text with static visualization. In this research work the authors proposed as metrics for measuring the level of learning, the use of think aloud protocol and the grade of exams involving text or graphics. The results obtained is that both visualization conditions are better than text-only when pictorial recall or transfer tasks were evaluated, but not for factual knowledge verbal tasks.

As far as we know no research project has assessed how the type of content, static or dynamic, can affect the student

learning experience when this content is deployed using augmented reality. In this article the development and evaluation of augmented reality applications using static and dynamic content, in order to determine how the type of content affects the learning experience in the classroom are described. For this purpose an augmented reality application that uses pictures as landmarks for deploying the virtual contents was developed. The contents deployed by the application are static or dynamic, including text, images, videos, 3D models and animations. The augmented reality application is executed in mobile devices for its use in the classroom, and the user interaction is based on the touch screen of the device. In order to determine how the type of content affects the learning experience of the student, an experimental design in which several students learn topics related with an electronic fundamentals course, using static and dynamic context was performed.

The rest of the paper is structured in the following way. In Section 2, the design of the content and the augmented reality application developed is described. The experimental design performed in order to determine the level of learning achieved using the augmented reality application and using different types of contents is reported in Section 3. Finally, in the last Section, conclusion and future work will be explained.

2. Description of the learning content and the augmented reality application.

The topics learned through the use of the application, the features of the contents and the augmented reality application developed are described in this section. It is worth mentioning that the development of these components was necessary to perform an experimental test in order to determine whether there are differences in learning when static and dynamic content are used in an augmented reality application.

2.1. Learning topics and contents.

The course chosen for developing the educational content was fundamentals of electronics, and the topics selected, based on the curriculum of the course, to be included in the augmented reality content and application were:

- The atom and its structure: basic concepts of the atom and its function are described in this field, including the major components of its structure, i.e. electrons, protons, neutrons, layers and sub layers are described.
- Charge and discharge phenomenon: how electrons are released from an atom of a specific material to produce the occurrence of the electrical phenomena as the current is described in this topic.
- Current, voltage and resistance: In this last topic the physical principles of phenomena of current, voltage and resistance are described. How they are produced, how they are measured and which factors influence its magnitude.

From these topics and considering the learning objectives in each of the themes defined by the course, the next step was the development of the three educational contents that could be deployed in an augmented reality application. In Figure 1 the three content developed for each of the topics can be observed. The content used to teach the topic titled the atom and its structured can be observed in Fig. 1a. This content was developed as a static 3D model of the atom where each one of its structures can be visualized. An example of the content used to teach the third topic, in this case the voltage can be observed in Fig. 1b. For the third topic, different animations including elements such as arrows, dots and a character representing electrons were used, so this content is dynamic. For each of the concepts taught in this topic, i.e. current, voltage and resistance, a different animation was developed. Finally, the content developed for teaching the topic charge and discharge phenomenon can be observed in Fig. 1c. This content consists in an animation in which how the electrons are separated from the atoms and became free electrons is described. Each of the static and dynamic visual content described are supplemented with audio and text that describes what is being observed in the visualization.

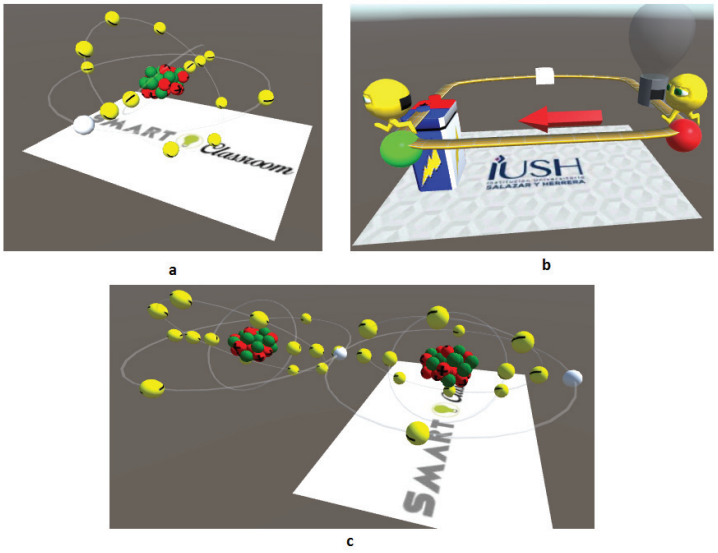

Fig. 1. Contents for learning the three topics included in the experimental design: (a) atom and structure; (b) voltage, current and resistance (c) charge and discharge phenomenon.

2.2. Augmented Reality Application.

The augmented reality application was designed and developed to be deployed on a mobile device. For the development of the application two tools were used: (i) Vuforia and (ii) Unity3D. Vuforia is a framework that provides functionalities for the development of augmented reality applications on mobile using as targets or patterns, images or objects. In the case of our application two images were used as targets, one of which allows displaying the first and second content and the other allows displaying the third content. For the development and deployment of the application to the mobile device Unity3D is used. Unity3D is a game engine that can be integrated with Vuforia allowing the development of augmented reality applications. Using the functionalities provided by Unity3D: (i) the static and dynamic content were associated to the targets, and (ii) the user interface was created consisting of toggle buttons that allowed the student interacting with the content, displaying texts and reproducing explanatory audios and 3D visualizations. For example, through a set of toggle buttons the student can chose a structure of the atom, and the application displays and explains the structure, changing the static or dynamic content, and the audio and text shown. The augmented reality application deployed on the mobile device can be observed in Fig. 2.

3. Evaluation and Experimental Test.

In this section the design and development of an experimental test to determine if there is a significant difference in learning level achieved by a group of students using a dynamic and static content is described. Unlike other research performed and reported in the state of the art, two types of content using an augmented reality application and complementing the description of the visualization using text and audio are evaluated in this paper.

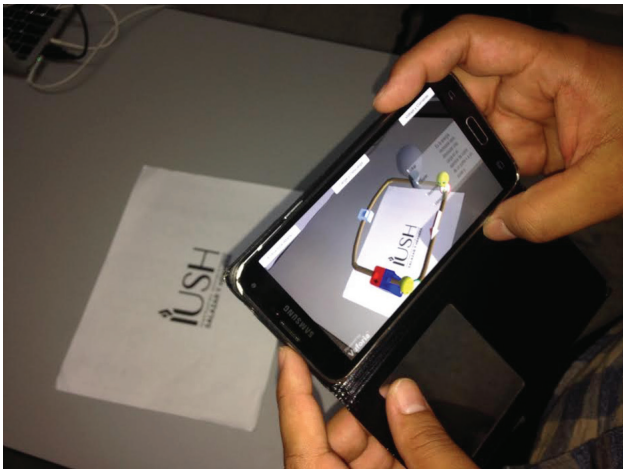

Fig. 2. Student interacting with the augmented reality application developed.

3.1. Experimental Design

Sixteen students took part of the experimental test. The average age of the group of students tested is twenty years. Sixty percent of the students are men and forty percent are women. None of the students had prior knowledge on the topics taught and evaluated, nor experience in the use of augmented reality applications. The experimental test performed by the students was composed of four major steps:

1. Pre-test: the first step of the experimental test was to make a pre-test in which students' prior knowledge is assessed in the subject taught by the augmented reality application. This pre-test consisted of six questions, where four of them were multiple choice text-based questions and two of them were questions based on visualizations.
2. Interaction with the augmented reality application using static and dynamic contents: once the students made the pre-test, a brief explanation about how augmented reality works using image targets and how is possible to interact with the static and dynamic contents through the touch screen was performed. The hardware used for deploying the application was a smart phone Galaxy S5 and a tablet Asus. Each device had a set of headphones to listen clearly the audio explaining the topics. Students had in total a maximum of 10 minutes to interact with the application.
3. Post-test: The third step consisted of making a post-test to determine how much each student learned about each of the topics taught by the application. Like the pre-test, the post-test consisted of six questions, four of them text-based and 2 of them based on visualizations.
4. Survey: Finally, the experimental test concluded when the student performed a survey, based on likert scale question, to assess her/his perception of the learning process and the interaction with augmented reality application during the experiment.

3.2. Results

The results obtained from the experimental test performed are of two types: (i) the level of learning achieved by the students and (ii) the perception of the students considering the learning experience. In the first of them the level of learning achieved by students using the augmented reality application is characterized. Fig. 3 shows the comparison between the grade obtained by the students when they performed the pre-test and the post-test.

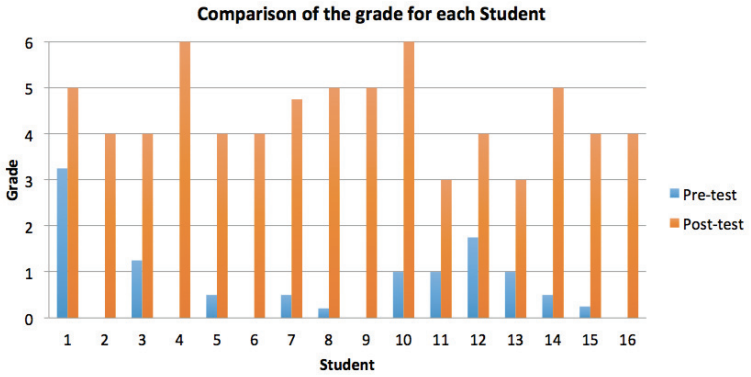

Fig. 3. Plot comparing the grade obtained in the pre-test and post-test by each one of the students.

The increment in the grade between the pre-test and post-test, discriminating questions for the type of content being evaluated either static or dynamic, achieved by the students can be observed in Fig. 4. As mentioned above three questions was used to evaluate the topics learned by the static content and three questions was used to evaluate the topics learned by the dynamic content, the total amount of question in the test was of six, with a maximum grade by question of one.

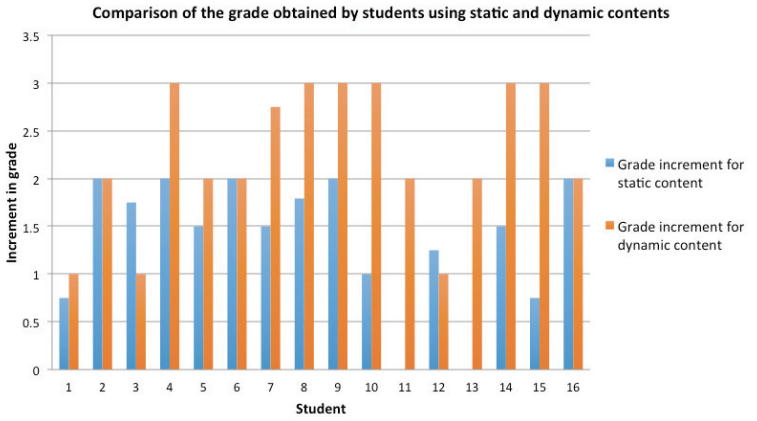

Fig. 4. Plot comparing the increment of the grade obtained by each student when static and dynamic contents were used.

Whereas the second type of results where the student's perception about the learning experience is reported, the results can be observed in Table 1.

Table 1. Survey statements and responses of the students.

No	Statement	1*	2	3	4	5
1	"It was easy to interact with the augmented reality application"	0	0	2	9	5
2	"It was easy to understand the 3D visualizations"	0	0	2	6	8
3	"I consider that the augmented reality application help me to understand more easily the concepts"	0	0	2	8	6
4	"It was easy to understand the text and audio shown in the augmented reality application"	0	0	1	6	9
5	"It was easier to understand the concepts using an animation than a static 3D model"	0	0	3	6	7

* Likert Scale: 1 "strongly disagree"; 2 "disagree"; 3 "no opinion"; 4 "agree"; 5 "strongly agree"

From the results reported in this section, it can be concluded the following about the experiment performed to determine if there are differences in level of learning achieved by students when they use static and dynamic contents:

- Considering Fig. 3, there is a significant increase between the grade obtained by the students in the pre-test and post-test, indicating that the augmented reality application developed and the static and dynamic contents complemented by text and audio, are effective in teaching the concepts described in section 2. Additionally, it is worth to mention that the interaction of students with the application was short and the amount of taught and tested concept was high.
- Considering Fig. 4, although the increment in the grade is not as significant as in Fig. 3, we can observe that in most cases (11 students), the grade obtained by the students when they learned using dynamic content is greater than when they learned using static content. This affirmation may contradict what it is reported in the literature where the authors have compared static and dynamic visualizations, but our approach is different because it uses augmented reality and complements the visualization using audio and text. However, a test involving a increased number of students to perform a hypothesis test that allows us to conclude what we are affirming is required.
- Finally, considering Table 1, the most important thing that it can be stand out is that students feel dynamic content helped her/him understanding the concepts more easily. This would strengthen the affirmation proposed in the previous point.

4. Conclusions.

The design and development of an augmented reality application that allows teaching basic concepts of the electronic fundamentals course, using static and dynamic content supplemented by audio and text is described in this article. Additionally, the design and results of an experimental test performed for determining if there is a difference in the level of learning and perception of the learning experience of students, when static and dynamic content is used in an augmented reality application, is reported. From the results the following can be concluded:

- The augmented reality application using dynamic and static content complemented by audio and text is effective for teaching concepts of the fundamentals of electronics course.
- It can be observed that there is a difference in the learning level of students when they use dynamic and static contents, but this should be tested using a statistical hypothesis test.

- The perception of students is that learning the concepts is more easily when they use dynamic contents than when they use static ones.

From these findings the following is proposed as future work: (i) to perform an experimental test in which an increased number of students are included and (ii) to extend the development and use of the application to the full course of fundamentals of electronics.

Acknowledgements

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