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# Evaluating the Effect on User Perception and Performance of Static and Dynamic Contents Deployed in Augmented Reality based Learning Application

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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 that user has of reality. Augmented reality has proved to offer several advantages in the educational context, 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 perception and performance 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 perception and performance of the student, two experimental designs in which the student interact with the application, using static and dynamic contents, for learning topics related with an electronic fundamentals course was performed.

**Keywords:** Augmented reality; static and dynamic contents; basics of electronics; engineering teaching

## INTRODUCTION

In recent years, the use of technology to improve teaching and learning experiences in the classroom has been promoted (Kesim & Ozarslan, 2012). One of these technologies is



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**State of the literature**

- 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 animations are an example of them.
- Several studies have explored whether there is a difference in learning when the contents are presented in textual, visual representation or integrating both ways.
- Most studies comparing different types of contents have been done in multimedia applications.
- Other works have focused on evaluating whether there is an effect on learning when the student uses static or dynamic contents, however, there is not an established definition of these kinds of contents.

**Contribution of this paper to the literature**

- Two approaches for configuring static and dynamic content in augmented reality applications are proposed in this article. One based on visual features, i.e. how visualizations are shown as dynamic and static, supplemented with audio and text, and the interaction done using common widgets and touchscreen device. In the second approach static and dynamic content is seen holistically, i.e. considering the visual, interactive and verbal as static or dynamic.
- 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.

augmented reality, which allows overlaying layers of virtual information on real scene with the aim of increasing the perception the user has of reality (Azuma et al., 2001). Augmented reality offers several advantages in the educational context as (Cuendet, Bonnard, Do-Lenh & Dillengourg, 2013): (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. The contents deployed in an augmented reality application are of two types, static or dynamic (Nincarean, Ali, Dayana, Abdul & Abdul, 2013). 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 animations 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 (Lowe & Schnotz, 2008). 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 (Aisnworth, 1999) (Aisnworth, 2006).

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 (CTML) and of the Cognitive Load Theory (Mayer, 2009). 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 representation or integrating both ways (Schnotz, 2005) (Bétrancourt, 2005).

Different learning strategies or cognitive activities applied by students when they use text or diagrams-based contents have been explored (Cromley, Snyder-Hogan & Luciw-Dubas, 2010). 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 learning performance or perception was better in some of the two modes (Cromley et al., 2010).

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 (Hegarty & Kritz, 2008). 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 (Hegarty & Kritz, 2008). 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 (Kuhl, Scheiter, Gerjets & Gemball, 2011). 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 performance and perception 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 performance and perception 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, two experimental designs in which several students learn topics related with an electronic fundamentals course, using two approaches for configuring static and dynamic contents was performed. This article is an extension of the results reported in (Diaz, Hincapié & Moreno, 2015). **Table 1** summarizes the research works that have evaluated how different types of contents impact the learning performance and perception.

**Table 1.** List comparing the topics addressed by the related works.

| Research work | Text-based content | Static visual-based content | Text and visual-based content | Dynamic Content | Augmented Reality Applications |
|---|---|---|---|---|---|
| Schnotz, 2005 | X | X | | | |
| Bétrancourt, 2005 | | X | | X | |
| Lowe & Schnotz, 2008 | | X | | X | |
| Cromley, Snyder-Hogan & Luciw-Dubas, 2010 | | | X | | |
| Cromley et al., 2010 | X | X | X | | |
| Hegarty & Kritz, 2008 | | X | | X | |
| Kuhl, Scheiter, Gerjets & Gemball, 2011 | | X | | X | |
| Diaz, Hincapié & Moreno, 2015 | X | X | X | X | X |
| Diaz & Hincapié, 2016 | X | X | X | X | X |

The rest of the paper is structured in the following way. The design of the content and the augmented reality application developed is described in first section. 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 second section. Finally, in the last Section, conclusions and future work will be explained.

## 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.

### *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: the physical principles of current, voltage and resistance phenomena are described. How they are produced, how they are measured and which factors influence its magnitude.
- Battery and generator: In this last topic the chemical and physical principles describing how the electrical energy is produced in a battery and generator are described.

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 four educational contents that could be deployed in an augmented reality application. In **Figure 1** the four 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 **Figure 1**a. 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 **Figure 1**b. 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. The content developed for teaching the topic charge and discharge phenomenon can be observed in **Figure 1**c. This content consists in an animation in which how the electrons are separated from the atoms and became free electrons is described. Finally, the content describing the basic functionality of a battery and generator can be observed in **Figure 1**d. This content consists of an animation describing how the chemical or mechanical phenomena produce electrical energy, for the battery and generator, respectively.

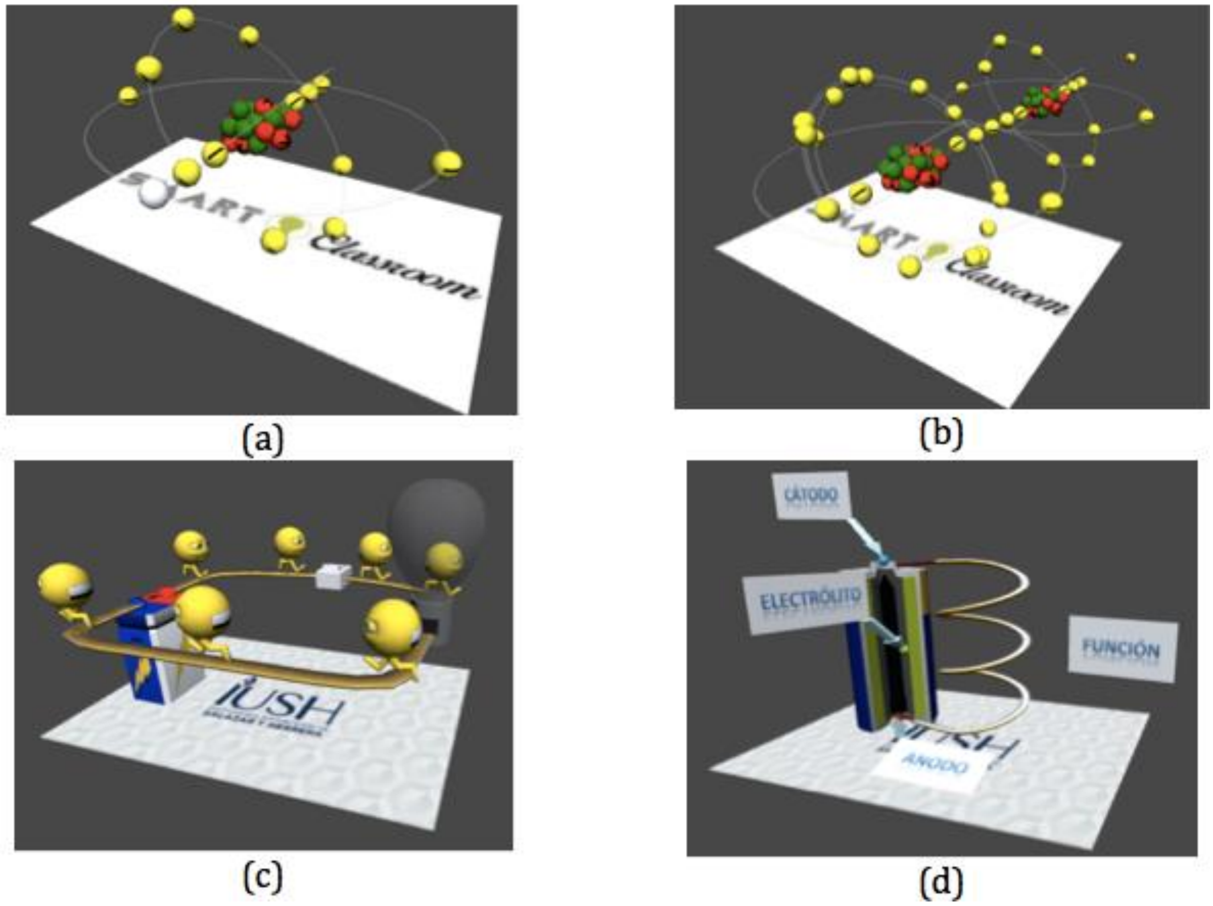


**Figure 1.** Contents for learning the three topics included in the experimental design: (a) atom and structure; (b) voltage, current and resistance; (c) charge and discharge phenomenon; (d) functional description of battery and generator.

Two approaches for configuring static and dynamic content in augmented reality applications are proposed in this article. One based on visual features, i.e. how visualizations are shown as dynamic and static, supplemented with audio and text, and the interaction done using common widgets and touchscreen device. In this first approach the visualization is a 3D model defined as a static content or 3D animation defined as a dynamic content. This first approach is similar to that proposed in the state of the art in other kind of applications. The second approach is based on the experimental results obtained using the first proposal. In this approach static and dynamic content is seen holistically, i.e. considering the visual, interactive and verbal as static or dynamic. **Table 2** shows the configuration differences between static and dynamic content proposed for the first and second approach.

**Table 2.** Description of the two approximations proposed for defining statics and dynamic contents.

| Approach | Type of Content | Sensorial Channel | | Interaction* |
|---|---|---|---|---|
| | | Visual | Verbal | |
| **First approach: Visual based content** | Static | Non animated 3D models | Text and audio based description of the content | Highlighting of different parts of the models using widgets, such as radio buttons. |
| | Dynamic | Animated 3D models | Text and audio description of the content | Highlighting of different parts of the models using widgets, such as radio buttons. |
| **Second approach: Integral based content** | Static | Non animated 3D models | Text-based description of the content | Forwarding of text description using widgets, such as buttons. |
| | Dynamic | Animated 3D models | Audio-based description of the content | Selectable labels in the 3D model for activate the audio based description. |

* All approaches allow the change of the point of view of the visualization changing the camera position of the mobile device regarding the position of the target.

### *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 (Grubert & Grasset, 2013) (Cushnan & El-Habbak, 2013). 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 and fourth 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 (Hocking, 2015) (Murray, 2014). 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 for the first approach or ray casting collision with labels for the second approach, 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 **Figure 2.**

Each one of the software components implemented in the augmented reality application is shown in **Figure 3**. Two computing nodes are observed in the figure, the mobile device and the web server. Software components that allow graphical and interactive deployment of augmented reality content are executed in the mobile device node. The content manager component allows the management of different types of static and dynamic content, through a file in XML format that describes the content. This component uses Unity3D functionality for visual displaying of content using the graphic engine and Vuforia SDK for augmented reality implementation. The interaction manager component allows the use of different forms of interaction with content such as the use of widgets using the touchscreen or selection of 3D parts using raycasting collision detection model. For storage of resources that are part of the static and dynamic content, the application uses obj files for 3D models and animations, mp3 for audio and rtf files for textual description. These resources are handled through the database content. The web service manager allows getting access to stored resources through JSON protocol.

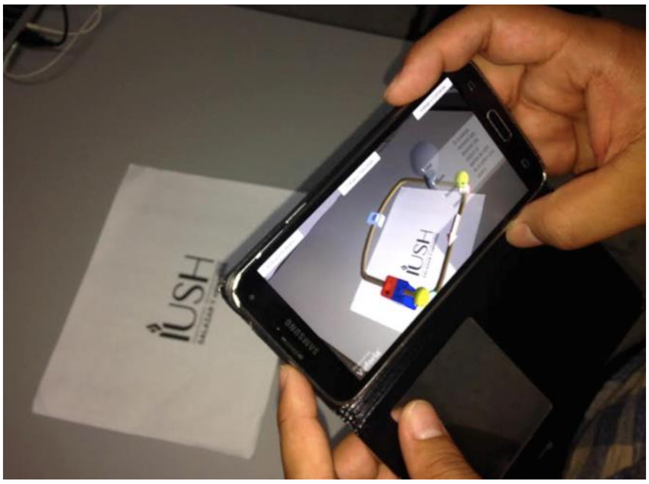

**Figure 2.** Student interacting with the augmented reality application developed.

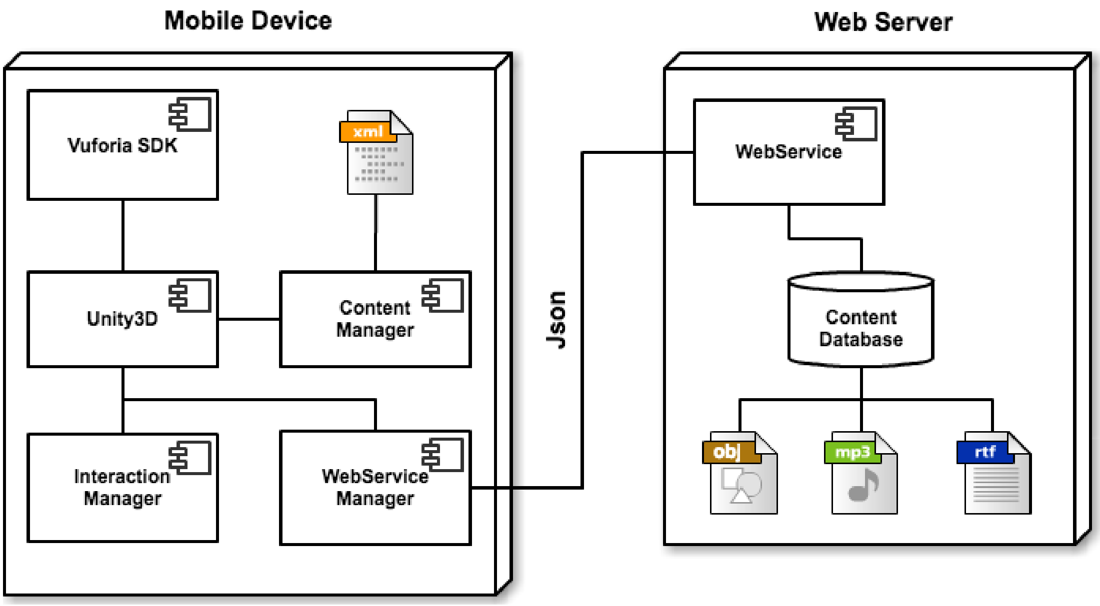


**Figure 3.** Deployment diagram of the augmented reality application proposed.

## Evaluation and Experimental Test

In this section the design and development of two experimental tests to determine if there is a significant difference in learning performance and perception achieved by a group of students using a dynamic and static content are 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 visualization using text and audio are evaluated in this paper. For each experimental design the first and second approaches described in **Table 2** are evaluated and the learning perception and performance resulted from each one is measured.

### *Experimental Design*

Sixteen students took part of the first 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. Twenty-five students took part of the second experimental test. The average age of the group of students tested is twenty-three years. Forty eight percent of the students are men and fifty two percent are women. As in the first experimental test 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, using the first and second approaches, was composed of four major steps:

1. Pre-test: the first step of both experimental tests 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 depending whether the first or second approach was evaluated. Students had in total a maximum of 10 minutes to interact with the application. The students involved with the first experiment use the first approach proposed of static and dynamic content and the students involved with the second experiment use the second approach described in **Table 2**.

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, three of them text-based and three 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.

### *Results*

The results obtained from both experimental tests performed are of two types: (i) the learning performance achieved by the students and (ii) the perception of the students considering the learning experience. In the first of them the learning performance achieved by students using the augmented reality application is characterized. Figure 4 and Figure 5 shows the comparison between the grade obtained by the students when they performed the pre-test and the post-test and used the first and second dynamic and static content approach, respectively.

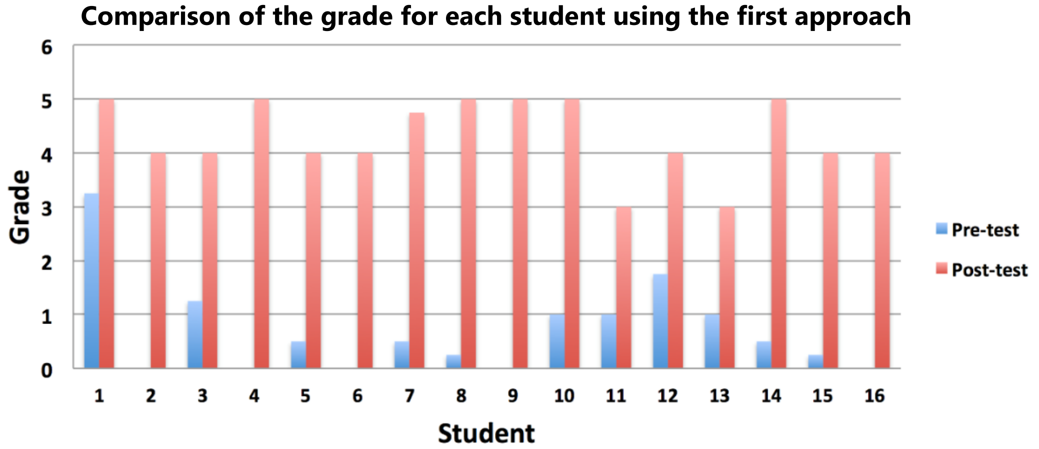


**Figure 4.** Plot comparing the grade obtained in the pre-test and post-test by each one of the students using the first static and dynamic content approach.

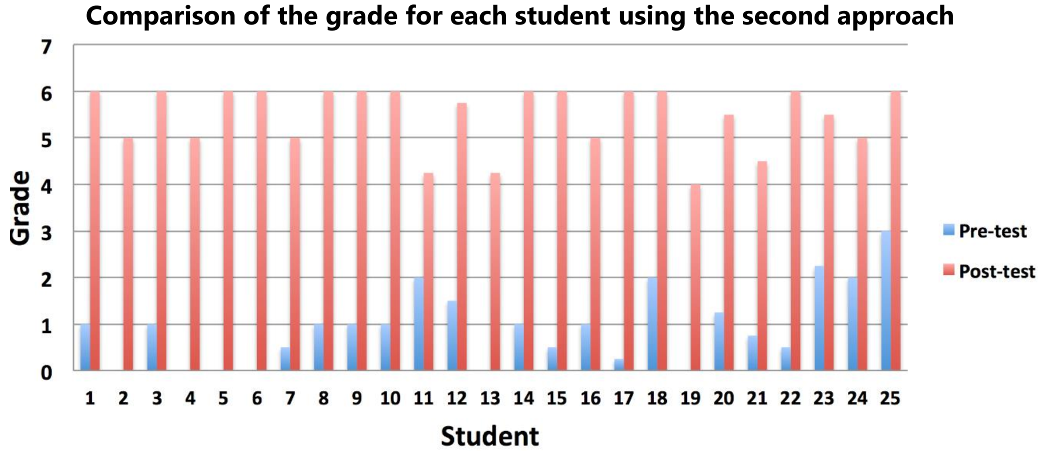


**Figure 5.** Plot comparing the grade obtained in the pre-test and post-test by each one of the students using the second static and dynamic content approach.

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 using the first and second approach proposed, achieved by the students can be observed in **Figure 6** and **Figure 7**, respectively. As mentioned above three questions was used to evaluate the topics learned by the static content and other three questions was used to evaluate the topics learned by the dynamic content, the total amount of question of the test was of six, with a maximum grade by question of one.

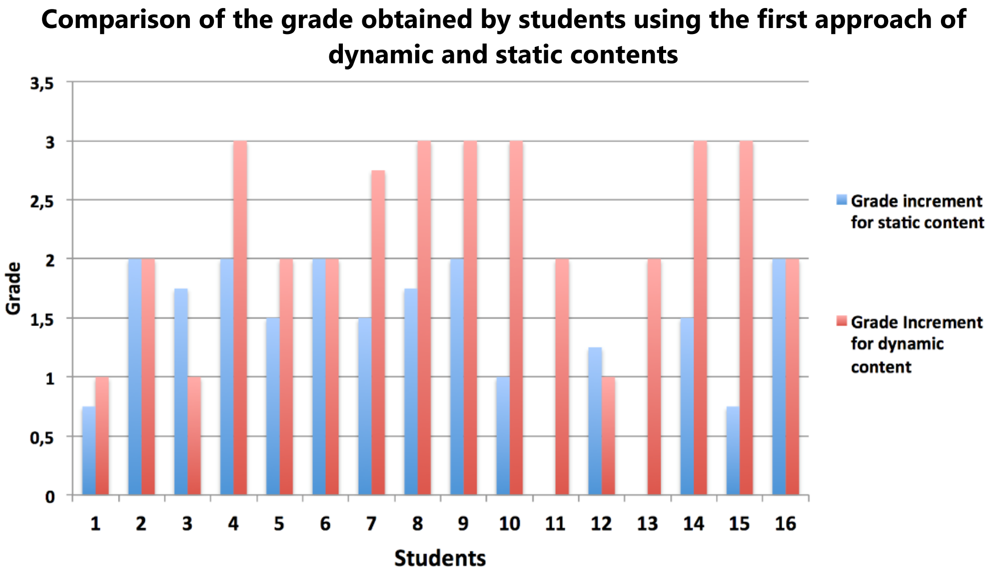


**Figure 6.** Plot comparing the increment of the grade obtained by each student when first approach of static and dynamic contents was used.

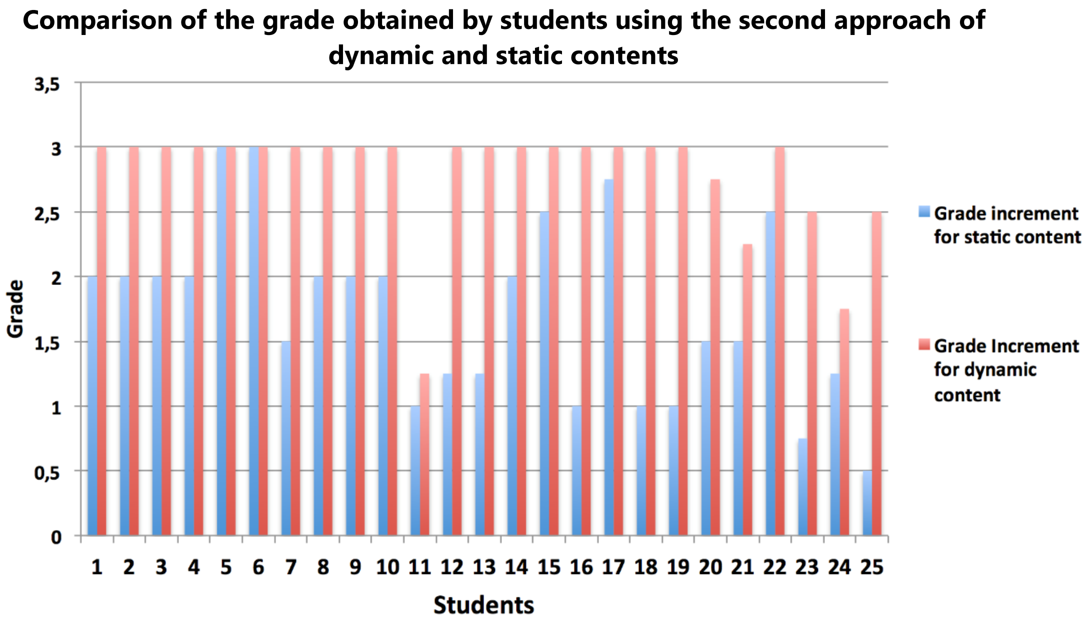


**Figure 7.** Plot comparing the increment of the grade obtained by each student when second approach of static and dynamic contents was used.

**Table 3.** Survey statements and responses of the students using the first approach of static and dynamic contents.

| 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"

Additionally, a statistical analysis was applied for the data collected in the experimental test. Statistical parameters such as mean, median, minimum, maximum, and standard deviation for each experimental variable applying the first and second approach described can be observed in **Table 5**. Whereas the second type of results where the student's perception about the learning experience is reported, the results can be observed in **Table 3** for the first approach and **Table 4** for the second approach.

**Table 4.** Survey statements and responses of the students using the second approach of static and dynamic contents.

| No | Statement | 1* | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| 1 | "It was easy to interact with the augmented reality application" | 0 | 0 | 3 | 7 | 15 |
| 2 | "It was easy to understand the 3D visualizations" | 1 | 0 | 0 | 5 | 20 |
| 3 | "I consider that the augmented reality application help me to understand more easily the concepts" | 1 | 0 | 0 | 6 | 18 |
| 4 | "It was easy to understand the text and audio shown in the augmented reality application" | 0 | 0 | 5 | 10 | 10 |
| 5 | "It was easier to understand the concepts using an animation, audio and touch screen interaction than a static 3D model and text description" | 0 | 0 | 0 | 5 | 20 |

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

There is an increase between the grade obtained by the students in the pre-test and post-test, indicating that the augmented reality application developed and both approaches for static and dynamic contents, are effective in teaching the concepts described in second section as is observed in **Figure 4** and **5**. Additionally, the average increment grade for the second approach is higher (M=4.53, SD=0.971) than the obtained using the first approach (M=3.594, SD=1.102). Besides, 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. In order to determine whether there is a significant increase between the grade obtained by the students in the pre-test and post-test for each approach, a statistical hypothesis test was applied. For first and second approaches a Shapiro test was applied for determining whether the samples came from a normally distributed population. The p-values computed for the variables $FA_{pr}$, $FA_{po}$, $SA_{pr}$, and $SA_{po}$ were respectively 0.0018, 0.003, 0.022, and 8x10$^{-5}$. These p-values suggest, with a confidence interval of 95 %, that the variables do not have a normal distribution. For this reason a paired Wilcoxon test was applied for each approach in order to determine whether there is a significant increase between the grade obtained by the students in the pre-test and post-test. The p-values computed for the first approach and second approach are 4.6 x 10$^{-4}$ and 1.199 x 10$^{-5}$, respectively. These p-values suggest, with a confidence interval of 95 %, that the grades obtained by students in the pre-test and post-test are not similar for both cases, first and second approach. Also, the differences in the mean grades values suggest (see **Table 5**) that when students interact with the augmented reality application using both approaches, there is an increase, among the pre-test and post-test.

**Table 5.** Statistical Analysis for each one of the variables measured in the two experimental tests.

| Abbreviation | Variable | Min | Max | Mean | Median | St. Dev. |
|---|---|---|---|---|---|---|
| $FA_{pr}$ | Pre-test grade using FA* | 0.0 | 3.25 | 0.7031 | 0.5 | 0.8622 |
| $FA_{po}$ | Post-test grade using FA | 3.0 | 5.0 | 4.297 | 4.0 | 0.690 |
| $SA_{pr}$ | Pre-test grade using SA* | 0.0 | 3.0 | 0.94 | 1.0 | 0.820 |
| $SA_{po}$ | Post-test grade using SA | 4.0 | 6.0 | 5.47 | 6.0 | 0.674 |
| $FA_{sc}$ | Grade Increment for static content using FA | 0 | 2 | 1.359 | 1.5 | 0.6829 |
| $FA_{dc}$ | Grade Increment for dynamic content using FA | 1.0 | 3.0 | 2.234 | 2.0 | 0.760 |
| $SA_{sc}$ | Grade Increment for static content using SA | 0.5 | 3 | 1.73 | 2 | 0.6919 |
| $SA_{dc}$ | Grade Increment for dynamic content using SA | 1.25 | 3 | 2.80 | 3 | 0.4448 |
| $FA_{Diff}$ | Difference in pre-test and post-test grade using the FA | 1.750 | 5 | 3.594 | 4 | 1.102 |
| $SA_{Diff}$ | Difference in pre-test and post-test grade using the SA | 2.25 | 6 | 4.53 | 5 | 0.971 |

*FA is the abbreviation of first approach and SA is the abbreviation of second approach

Regarding **Figure 6** and **7**, although the increment in the grade is not as significant as in **Figure 4** and **5**, we can observe that in most cases (11 students for the first approach and 23 for the second approach), the grade obtained by the students when they learned using dynamic content is greater than when they learned using static content. In order to determine whether there is a significant increase between the grade obtained by the students using a static and dynamic content using both approaches, a statistical hypothesis test was applied. For the static and dynamic content using each approach a Shapiro test was applied for determining whether the samples came from a normally distributed population, the p-values obtained for the variables $FA_{sc}$, $FA_{dc}$, $SA_{sc}$, and $SA_{dc}$ were 0.013, 0.00406, 0.2071, and 7.887 x 10$^{-8}$, respectively.

These p-values suggest, with a confidence interval of 95 %, that the variables $FA_{sc}$, $FA_{dc}$, and $SA_{dc}$ do not have a normal distribution, but the variable $SA_{sc}$ has. For this reason a paired Wilcoxon test was applied in order to determine whether there is a significant difference between the grades obtained using static and dynamic content, applying both approaches. The p-value computed for comparing static and dynamic content using the first approach is 0.00566 and for comparing static and dynamic content using the second approach is $2.586 \times 10^{-5}$. These p-values suggest, with a confidence interval of 95 %, that the grades obtained by students using static and dynamic content are not similar for both cases first and second approaches. Besides, the differences in the mean values (see **Table 5**) of the variables suggest that the increase in the grade cause by the dynamic content is higher (M=2.234, SD=0.760 for first approach and M=2.80, SD=0.4448 for second approach) than the increase in the grade cause by the static content (M=1.359, SD=0.6829 for first approach and M=1.73, SD=0.6919 for second approach). 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 in the first approach, and in the second approach uses an integral dynamic content proposal in which the visual, verbal and interaction is dynamic.

In a similar way, another hypothesis test was applied in order to determine whether there is a difference between the grade increased by applying the static content using the first approach or the static content using the second approach. As was mentioned in the above paragraph the samples expressed by the variable $FA_{sc}$ does not have a normal distribution and the variable $SA_{sc}$ has a normal distribution. For this reason a Mann-Whitney U test was applied in order to determine whether there is a significant difference between the grade the grade increased by applying the static content using the first approach or the static content using the second approach. The p-value computed for comparing static content using the first approach is 0.1774. This p-value suggests with a confidence interval of 95 %, that the increase in the grades obtained by students when they use static content are similar for both cases first and second approaches. In contrast, the same test was applied in order to determine whether there is a difference between the grade increased by applying the dynamic content using first or the static content using the second approach. In this case, the p-value computed for comparing the grade obtained when dynamic content is applied using the first and second approaches is 0.006712. This p-value suggests with a confidence interval of 95 %, that the increase in the grades obtained by students when they use dynamic content is not similar. Moreover, the differences in the mean values (see **Table 5**) of variables $FA_{dc}$ and $SA_{dc}$ suggest that the increase in the grade cause by the dynamic content in the first approach is higher than the increase in the grade cause by the dynamic content in the second approach.

As a final test, the comparison of the impact of first and second approaches on student performance was proposed. In this case, two new variables were computed using the grades obtained by the students in the pre-test and post-test for each approach (see **Table 5**). Equation 1 and 2 expresses the variables computed.

$$FA_{Diff} = FA_{po} - FA_{pr} \qquad (1)$$

$$SA_{Diff} = SA_{po} - SA_{pr} \qquad (2)$$

For each variable a Shapiro test was applied for determining whether the sample came from a normally distributed population. The p-values computed for the variables $FA_{Diff}$ and $SA_{Diff}$ were respectively 0.0689, and 0.1930. These p-values suggest, with a confidence interval of 95 %, that $FA_{Diff}$ and $SA_{Diff}$ have a normal distribution. For this reason a t-student test was applied in order to determine whether there is a significant increase between the grade obtained by the students using the first approach and the second approach proposed. The p-value obtained is 0.095. This p-value suggest, with a confidence interval of 95 %, that the increase in the grade after using the augmented reality application applying the first approach is not similar to those using the augmented reality application applying the second approach. Besides, the differences in the mean of $FA_{Diff}$ and $SA_{Diff}$ variables suggest (see **Table 5**) that when students interact with the augmented reality application applying the second approach, there is a higher increase in the grade than the student interact with the augmented reality application applying the second approach.

Finally, considering **Table 3** and **4**, 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. Additionally, considering two of the questions, number 3 and 5, a higher percentage of students using the second approach, 96% for third question and 100% for fifth question, than the percentage using the first approach, 87.5% for the third question and 81.25% for fifth question, are agree about the benefits of augmented reality and dynamic contents.

## CONCLUSION

The design and development of an augmented reality application that allows teaching basic concepts of the electronic fundamentals course, using two approaches for configuring static and dynamic contents is described in this article. Additionally, the design and results of two experimental test performed for determining if there is a difference in the performance 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 can be concluded that the augmented reality application using the two approaches for configuring dynamic and static contents are effective for teaching concepts of the fundamentals of electronics course. Additionally, it can be observed that there is a difference in the learning performance of students when they use dynamic contents, besides better results were obtained using the second approach.

On the other side, the perception of students is that learning the concepts is more easily when they use dynamic contents than when they use static ones. Additionally, a major percentage of students consider that it is easier to understand the concepts using the second approach than using the first approach. This last conclusion is affirmed by the performance results obtained.

From these findings the development and use of the application to the full course of fundamentals of electronics is proposed. Additionally, the integration of the application with the curriculum and its evaluation during the whole course in order to define the impact of static and dynamic contents is defined as future work.

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