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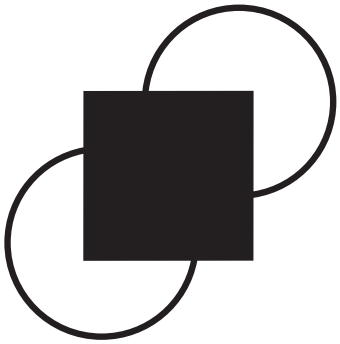

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ANALYSIS OF AUGMENTED REALITY'S INFLUENCE ON REGULAR SYSTEMS TAUGHT IN TECHNICAL GRAPHICS SUBJECTS

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Abstract

The subject named Technical Graphics Communication is taught in different degrees in Jaume I University, among which are Bachelor's degrees in Industrial Technology Engineering, Mechanical Engineering, Electrical Engineering and Chemical Engineering. One of its main aims is to improve the students' spatial vision ability. Nevertheless, three-dimensional shape recognition (3D models) and their later representation in Multiview drawings (two-dimensional information), is one of main issues found by instructors along the years, being a constant for years.

The development of technology and modeling tools allows a broader and more effective presentation of this syllabus. One of these tools is Augmented Reality that integrates digital information into real-world environments and allows users inspecting and analyzing a 3D model in an interactive way, spinning it, scaling it, and resulting in an easier way to understand its features.

Therefore, this article shows the results obtained from an experience developed in Technical Graphics Communication subject where Augmented Reality was applied for improving the 3D model interpretation. Students assign a high level of usability of the Augmented Reality application, also considering it a good teaching resource.

Keywords: Augmented Reality, engineering graphics, 3D modeling, Technical Graphics Communication.

1 INTRODUCTION

A basic subject in Engineering studies is Technical Graphics. The main objective is to train students to develop models and drawings to complete the essential documentation of a technical project. At the end of the course, students must dominate representation systems, control the perception of space and shapes, and be determined to recognize the properties of the model in order to solve certain problems. In order to achieve this aim, a key element is to work on their spatial vision.

Furthermore, spatial vision is critical for understanding the other subjects studied in technical degrees. Different studies show how spatial vision can be improved using 3D models, that is, simultaneously arranging and interacting with 3D objects while carrying out exercises on these objects projected on paper [1]. Obtaining models of real parts is clearly more expensive in time and money than providing virtual models.

Augmented Reality (AR) is a technology that combines digital content with information from the real world. Thus, it overlaps images in real time, with what it is seen in real space, by merging them or being even able to interact with the environment. The concept of AR refers to combining what is not in the real scene with what exists, offering users an increased or improved representation of the world around them [2]. Unlike virtual reality (VR), RA does not need a viewfinder, glasses or additional equipment, but uses the camera of the mobile device (phone or tablet) thought an application. RA has many possible uses or applications, such as simulation, training, navigation, tourist guides, language learning, advertising, manufacturing, etc. [3].

The use of AR, it is an issue that has been introduced in university teaching in recent years. There are several studies focused on teaching with AR, where students learn and explore new content in a more attractive way in different fields of study. In this way, teachers have the support of three-dimensional visualization techniques to represent theories and examples in various fields of knowledge. There are numerous works that show how the implementation of AR in the classroom helps to improve learning and facilitates the teacher's work [4] [5]. We can find introductory works on RA in higher education in

fields as diverse as mathematics [6], anatomy [7], surgery [8], astronomy [9], mechanical systems [10], in science laboratories [11] or electrical engineering [12], among others.

We can also find works where AR is applied in teaching content related to technical graphics [4] [13] [14]. They include positive conclusions: the opinion of the students is that it facilitates the understanding of shapes and volumes of objects, as well as a better understanding of the relative position of some objects against others. RA makes the educational process more interesting and intuitive, the learning process easier and ultimately more effective. It can be used to design material that promotes autonomous learning or that involves collaborative work. Furthermore, it is highlighted that AR can be a low-cost technology that improves teaching and learning.

The main objective of the experience is focused, on the one hand, on analysing the perception of the students regarding the use of AR as a support tool in solving technical graphics exercises and specifically improving spatial vision, and on the other, the usability of AR applications. Thus, this paper is structured as follows: Section 2 presents the design and methodology used in the proposed innovation. Next, section 3 shows the results that have been obtained from the experience and finally, main conclusions of this work are highlighted.

2 METHODOLOGY

The experience was designed following a methodology. Figure 1 shows the phases of the methodology followed, detailing each of them below.

Figure 1. Methodology

2.1 Design of the experience

One of the main problems that students find in the subject of Technical Graphics in Engineering is the difficulty in interpreting models and their corresponding reproduction trough orthographic views. Compared to traditional representation techniques, such as 2D axonometry, this study proposes the use of RA as a support to provide this information. Therefore, the main objective of the experience is to provide students with information about the model using AR, so that they can work from it, turning it and scaling it, until they fully understand its characteristics to be able to properly sketch their orthographic views. Figure 2 shows this process.

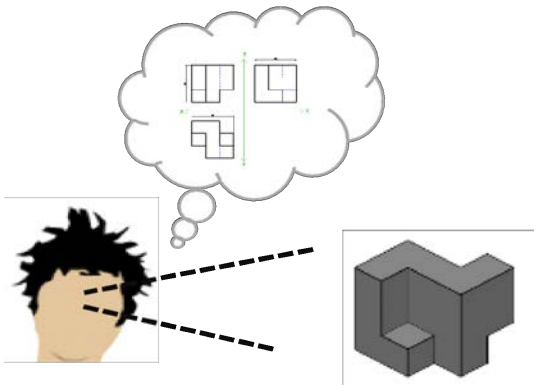

Figure 2. Interpretation of model using augmented reality.

To carry out this process, (1) the AR tool is selected, (2) the models to work are designed, (3) the experience with the students is developed, and finally (4) its usability and perception are evaluated.

2.1.1 Review and selection of augmented reality tools

There is a wide range of AR tools available on the market, both in the professional environment for the presentation and sale of products, and in the educational field. In the field of education, the main objective is to allow users to create their own content. These tools include *Layar* (https://www.layar.com/), *Aurasma* (https://www.aurasma.com/) and *Augment* (https://www.augment.com/es/), among others. All of them allow creating and managing content according to the subject and specific needs of the teacher, who can create both the RA activator (images or codes) and the content to be displayed, which in this case are 3D models.

While *Layar* and *Aurasma* allow users to add interactivity to any model through interactive buttons that trigger different actions, *Augment* allows users to easily host and visualize the 3D model, with the 3D model being exclusively the most important element. Since it is only necessary to host and view models, the use of Augment tool is chosen, considering that it meets the needed specifications. In addition, it is easy to use, both for importing models from other 3D modeling software (such as the one used in the subject, Solidworks®) and for visualize them.

2.1.2 Design of the models to be use

Once the tool is selected, the 3D models are designed. Four models used in the subject with different levels of complexity are selected, ranging from least to most complex from left to right (Figure 3). The objective of the exercise is that students fully understand the geometric characteristics of the models, and then, they will be able to represent, through sketches, both the visible parts or faces (with visible edges) and the hidden parts or faces (with hidden edges). Figure 3 shows the selected models that best fit these aspects.

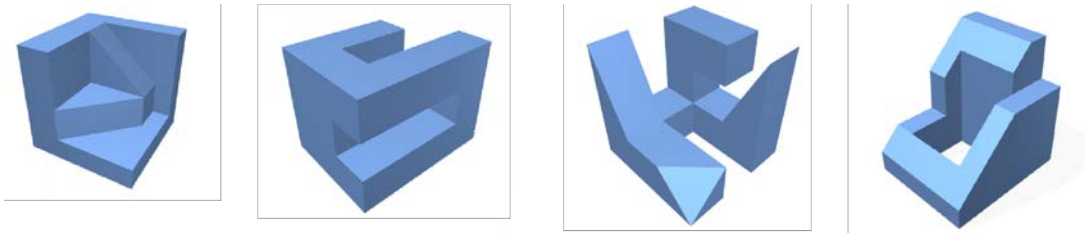

Figure 3. 3D models used in the experience

2.1.3 Design of the evaluation questionnaire

With the aim of evaluating both the usability of the tool and the perception of the students, a questionnaire is designed to be completed by students once the experience is over. Table 1 shows the questions asked. This table is divided into different parts (first column) in order to know: (1) the profile of the students (questions aimed at finding out previous knowledge both in the field of technical drawing (TD) and in the field of the RA); (2) the familiarity or use of RA; (3) the usability of the application; (4) the motivation of the students and (5) the opinion on AR as a learning tool.

Regarding the usability of the application, the usability scale system (SUS) byJohn Brooke [16] has proven to be a reliable method to evaluate it compared to industry standards. It consists of a 10-item questionnaire with a Likert scale. Participants rank each question from "Strongly Agree" to "Strongly Disagree". These responses are subsequently translated into a numerical score, so "Strongly Agree" means 5 points and "Strongly Disagree" 1 point. Applying the SUS calculation method, a usability value is obtained in the range of 0-100. The results do not represent a percentage, but a score to measure the level of usability when users interact with the AR tool. With a score of 80.3 or higher, users express their full satisfaction with the use of the RA tool. If the score is less than 51, the tool must be redesigned to improve user satisfaction.

Table 1. Questions asked to the students in order to know their profile, the perception and usability of the tool, as well as their motivation after using it.

Objetive	*Question*	*Answer*
To know the student's profile	What degree do you belong to?	a) Degree in Engineering in Industrial Technologies b) Degree in Mechanical Engineering c) Degree in Electrical Engineering d) Degree in Chemical Engineering e) Degree in Agrifood and Rural Engineering
	Which is your laboratory group?	Laboratory 1… .16
	Gender	a) Man b) Woman c) Others
	What previous knowledge of technical drawing (TD) do you have?	a) I have never coursed TD b) I have only studied basic concepts at school c) I have only studied TD at the high school d) I have not studied TD but I am familiar with Computer Aided Design (CAD) e) I have previously studied TD and am familiar with Computer Aided Design (CAD)
To know Familiarity or use of AR	Before doing the activity, did you know what Augmented reality was?	a) Yes b) No c) Maybe
	Before doing the activity, did you know augmented reality tools?	a) Yes b) No c) Maybe
To know the usability of the application	I think that I would like to use this system frequently	1. Strongly disagree 2. Disagree 3. Neither agree / disagree 4. Agree 5. Strongly agree
	I found the system unnecessarily complex	
	I thought the system was easy to use	
	I think that I would need the support of a technical person to be able to use this system	
	I found the various functions in this system (turn and scale) were well integrated	
	I thought there was too much inconsistency in this system	
	I would imagine that most people would learn to use this system very quickly	
	I found the system very cumbersome to use	
	I felt very confident using the system	
	I needed to learn a lot of things before I could get going with this system	
	Using AR has allowed me to better understand the model	
	It has been easier for me to represent orthographics views from the AR model, than if this information is provided through an axonometry in a paper	
	I think that its use during exams can be very useful	
	The class is much more enjoyable if you use this type of tools	
	I have paid more attention in this class than in others of this subject	

	I consider that my skills in interpreting views and viewing ability improve with the use of AR	
	I think that AR is a tool that allows you to interact with complex information easily	
To know the motivation of the students	Augmented Reality motivated me to perform the assigned task	1. Strongly disagree 2. Disagree 3. Neither agree / disagree 4. Agree 5. Strongly agree
To know opinion on AR	Characteristics that would define the Augmented Reality tools as a teaching resource: Versatile Adequate Interactive Funny Economic Easy to use Flexible Innovative	1. Strongly disagree 2. Disagree 3. Neither agree / disagree 4. Agree 5. Strongly agree

2.2 Development of the experience

Once the experience is defined as well as the corresponding theory groups to be developed. Figure 4 shows a summary of the steps developed during the experience. Firstly, the students are grouped into pairs. Only one of them has to downloaded the application. Using the scan option, the QR codes (Quick Response code) that act as triggers for the augmented reality model are read. Once scanned, a 3D model will appear on the actual physical surface where the code has been positioned. Using the climbing and turning tools, students can work with the model, understanding their shape from all perspectives. Once these characteristics are understood, both students sketch the orthographic views. After the activity, the teacher shows the solution.

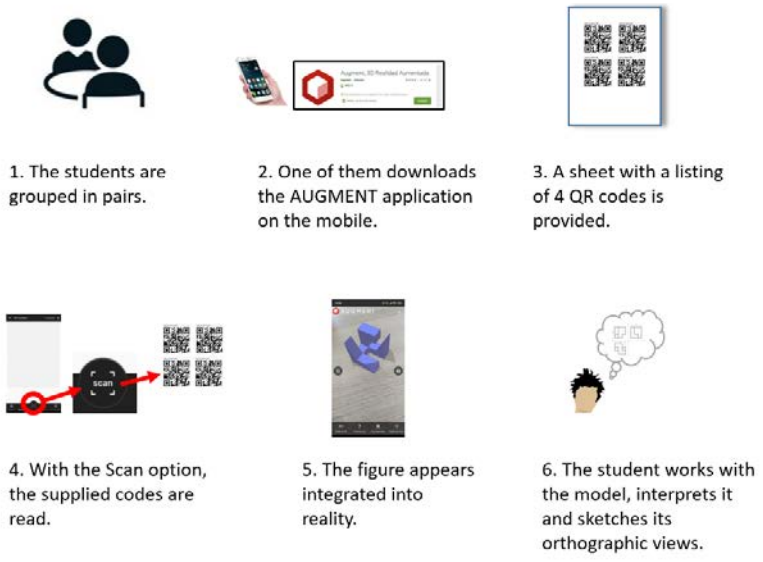

Figure 4. Development of the experience

2.3 Analysis of results

Once the experience has been completed, students are provided, through the university's virtual classroom, with an evaluation questionnaire to fill out. The results are analyzed descriptively, detailing the results of each part of the questionnaire.

3 RESULTS

The study was carried out by 74 undergraduate students (70.3% men and 29.7% women) with the aim of evaluating the influence of the use of AR as a learning tool compared to the usual teaching system of the subject. The participants were enrolled in the degrees in Engineering in Industrial Technologies (29.7%), Mechanical Engineering (22.7%), Agri-Food and rural Engineering (18.9%), Chemical Engineering (16.2%) and Electrical Engineering (9,5%).

Before evaluating the usefulness of the AR application, information was obtained from the participants regarding their prior knowledge in the field of TD and in the field of AR (Table 1). With regard to prior knowledge in the field of TD, students answered whether they had studied related concepts in any period before enrolling in their degree. The responses obtained are detailed in Table 2.

Table 2. Percentage of students who studied subjects related to TD in each period.

Students (%)	***Time***
14,9	I have never learned TD
17,6	I have only studied basic concepts at school
45,8	I have only studied basic concepts at highschool
2,7	I have never studied TD but I am familiarized with CAD
16,2	I have previously study TD and I am familiarized with TD.
1,4	have only studied basic concepts at highschool/school
1,4	I have studied TD in high school and am familiar with CAD (Solidworks®)

Regarding the familiarization/use of AR, they are asked about their previous knowledge of AR and about the different available application tools. Table 3 shows the percentage of familiarity of the participants with the tool. The results show that, in general, there is a lack of knowledge of AR tools.

Table 3. Percentage of participants' familiarity with AR.

Questions	***Answers (%)***		
	Yes	***No***	***Maybe***
Did you know what AR was?	54,8	27,4	17,8
Did you know some AR tools?	27,4	56,2	16,4

Regarding the usability of the application, a total of 17 questions were asked (Table 1). From questions 1 to question 10, where related to the SUS model [16]. The SUS usability measurement system uses 10 items which are evaluated on a scale from 1 to 5, (1 Strongly Disagree to 5 Strongly Agree). The items (table 1) are:

- I think that I would like to use this system frequently
- I found the system unnecessarily complex
- I thought the system was easy to use
- I think that I would need the support of a technical person to be able to use this system
- I found the various functions in this system (turn and scale) were well integrated
- I thought there was too much inconsistency in this system
- I would imagine that most people would learn to use this system very quickly
- I found the system very cumbersome to use
- I felt very confident using the system
- I needed to learn a lot of things before I could get going with this system
- Using AR has allowed me to better understand the model

With a score of 80.3 or higher, users express their full satisfaction with using the AR tool. If the score is less than 51, the tool should be redesigned to improve user satisfaction. In addition, the SUS model considers that a score greater than 68 points is above the average to establish the level of usability of an application. In this case, following the SUS score calculation methodology, the value obtained is 64.1. This value indicates that the usability of the application is below average, but, despite this, it is very close to that established by the measurement system.

The remaining seven questions and the percentage of responses are represented in Table 4. Columns 1 to 5 indicate the response scale, being: 1, Strongly disagree; 2, Disagree; 3, Neither agree / nor disagree; 4, Agree; 5, Strongly agree.

Table 4. Application usability percentage

Ítem	Answers (%)				
	1	2	3	4	5
The use of AR has allowed me to better understand the model	2,70	5,41	21,62	52,70	17,57
It has been easier for me to represent orthographics views from the AR model, than if this information is provided through an axonometry in a paper	1,35	6,76	18,92	48,65	24,32
I think that its use during exams can be very useful	1,35	8,11	16,22	44,59	29,73
The class is much more enjoyable if you use this type of tools	0	4,05	9,46	52,70	33,78
I have paid more attention in this class than in others of this subject	1,35	9,46	28,38	37,84	22,97
I consider that my skills in interpreting views and viewing ability improve with the use of AR	2,70	5,41	22,97	51,35	17,57
I think that AR is a tool that allows you to interact with complex information easily	1,35	0	22,97	54,05	21,62

In general, it is observed that the highest percentage in each item corresponds to answer 4 (agree), thus confirming a good level of utility of the application. In order to obtain a global response from users to the usefulness of the application, it was asked whether the use of AR motivated them to complete the task (Table 1). A response scale from 1 to 5 was used, being: 1, Strongly disagree; 2, Disagree; 3, Neither agree / nor disagree; 4, Agree; 5, Strongly agree. Figure 5 shows the response percentage according to the level of motivation in its use.

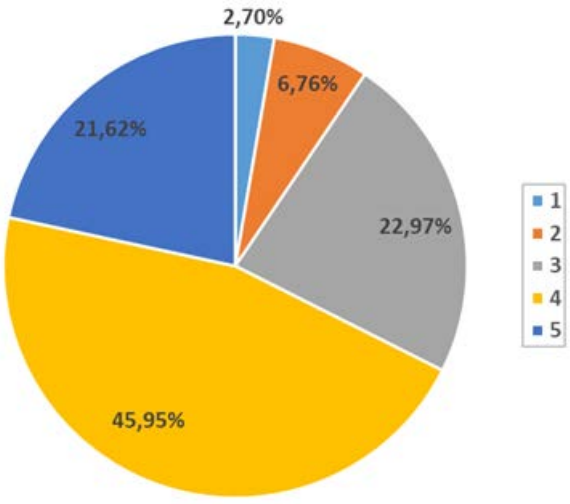

Figure 5. Percentage of motivation caused by AR to complete the task.

To take into account whether the level of motivation for the use of AR affects differently those users who already had prior knowledge of TD, two main groups of subjects were defined for the analysis: on the one hand, subjects who never have studied TD or have basic concepts learned in school, (32.43% of the total respondents); and, on the other hand, those who do have knowledge of TD or CAD, (67.57%). According to the results, for the 32.43% of students who did not have knowledge of TD, o 79.17% agreed that the application is motivating for learning, 12.50% neither agreed nor disagree and

only 8.33% of these subjects disagreed. Regarding the subjects with previous knowledge of TD, which (67.57% of the respondents) 64% agree that the use of AR is motivating for learning, 28% neither agree nor disagree, 6% disagree, and only 2% strongly disagree. The results reflect that the use of AR is more motivating for those subjects without prior knowledge of TD

Finally, students were asked about characteristics that would define AR as a learning resource. The characteristics evaluated are detailed in Table 5. A response scale from 1 to 5 was used, being: 1, Strongly disagree; 2, Disagree; 3, Neither agree / nor disagree; 4, Agree; 5, Strongly agree.

Table 5. Percentage of characteristics that define AR as a learning resource

Ítem	Answers (%)				
	1	2	3	4	5
Versatile	0	4,05	18,92	56,76	20,27
Adequate	1,35	0	5,41	72,97	20,27
Interactive	0	1,35	5,41	62,16	31,08
Funny	0	1,35	25,68	50,00	22,97
Economic	1,35	2,70	21,62	40,54	33,78
Easy to use	0	5,41	22,97	54,05	17,57
Flexible	0	6,76	29,73	50,00	13,51
Innovative	1,35	0	17,57	51,35	29,73

In general, it is observed that the highest percentage in each item corresponds to response 4 (agree), thus confirming that the established characteristics define AR as a good learning resource.

4 CONCLUSIONS

Augmented Reality has been recently incorporated in the educational field, including university education. Within the limitations of this study, considering that students participating in the experience are unfamiliar with the tools for using AR, the results show a good level of utility of the application, being as well positively valued as a good learning resource. Finally, the responses of the students suggest that also it is a motivating tool, especially for subjects which have never been studied before.

Given the results, the authors consider AR as a tool that can help to overcome deficiencies and demotivation of students from first year when studying Technical Graphics Subjects. As a next step to this first study, and given the difficulty of the students in interpreting the orthographical views, the authors consider as a second step, the creation of a collection of exercises so that the students could draw those models from those views. After this, the solution can be reviewed using augmented reality. This comparison can be evaluated both by teachers and other colleagues to complement the learning.

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