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TRAINING WITH AUGMENTED REALITY ON ENGINEERING DEGREES

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KEYWORDS

Spatial Ability, Augmented Reality, Engineering Education

ABSTRACT

This paper reports about the research based on the comparison of tests about the spatial skill of engineering students from two Spanish universities before and after the performance of specific training for improving several abilities based on tasks with 3D objects visualized through augmented reality technology. The training was completed at home with 66 students as participants, considering a control group composed of 25 students from both universities. The AR system technical aspects are also described as well as the application developed. The study's results show that students from both universities improve their spatial ability and there is no significant statistical significance between students from both universities, neither before nor after training so we may conclude that training's effect on both universities is analogue.

INTRODUCTION

Several studies pointed out that good level of spatial skills are a key aspect for success in engineering degrees as well as professional careers [1, 2].

An engineer should be capable of creating a mental image of an object and see mentally the different perspectives of it for finding out the relations between this object and another one or any other person in space. These skills are very important in the whole process design since the starting phase until the final prototype so improvement of spatial abilities and their successful application is an important research theme on engineering education. In this field, an investigation subject is the link between spatial skills and gender as women usually have lower levels of these skills which have an influence on their access to engineering degrees such as civil, electrical, mechanical or computer engineering.

Several reports point out that actually barely 10% of all engineers on duty and less than 20% engineering students are women [3, 4]. In Gibbon's study showed that only 8.5% of women got a university degree in any engineering [5].

Another research line is targeting factors influencing resources and improvement of spatial skills. Some conclusions point out that use of activities for improvement of spatial skills, such as sports requiring hand-eye co-ordination prove the trainability of these skills. "Trainability," as opposed to "inherent ability," is an important message to pass on [6].

Acquiring this ability can be done through an indirect process by means of Engineering Graphics subjects where

students perform sketching tasks to create and read orthographic and axonometric projections [7]. However, there is another approach based on the development of specific training for the development of spatial skills.

From our perspective as teachers, we realize what difficulties that first year's engineering students experience while learning Technical Drawing caused by the low level of spatial ability in engineering and that's why we feel the need of creating tools and methodologies for improving that ability.

In this paper, we expose the results of both research and comparison about the effectiveness of specific training for improvement of spatial skills on engineering students in two Spanish universities. The training proposed is voluntary for students from mechanical engineering of both universities. Although it's important pointing out that all students have the chance to improve their spatial skills as this is an autonomous training which students can perform anytime as material is available for everybody. Our specific aim is checking out that training is efficient and enough in both universities for stating differences between levels reached. Our broad aim is incorporating this training in engineering degrees curriculum to provide reinforcement of skills during a student's undergraduate career.

This paper is organized as follows: a brief overview of the literature on spatial skills is provided. The training system description based on augmented reality is followed by description of experimental tests and finally, the results and conclusions.

SPATIAL ABILITY: AN OVERVIEW

Cognitive psychology researchers have published their theories about spatial skills concept and it's usual to find terms from different authors referring to the same concept or the same term referring to different concepts. According to different authors, intelligence is composed by several factors, components, skills or abilities: verbal, numeric, spatial, memory, reasoning, etc. Their number varies according to each author, but all of them agree that one factor of intelligence is the spatial skill which is composed by several sub-components: spatial relations, spatial visualization, mental rotation, perception, etc.

Sánchez Carlessi and Reyes Romero [8] define the term 'skill' as the ability owned by the individual allowing him to act and perceive going beyond natural laws. They consider that someone is ready to do something because he owns a certain attitude, skill and ability to develop it. Going into specifics (which may extend to the rest of skills), it's pointed out that attitude is an inborn aptitude or natural strength owned by the individual meanwhile dexterity is the ability developed by a person with a high efficient level and skill comprises solving mental spatial tasks thanks to training, exercises and experience (figure 1). Starting from an initial potential we can train and develop this skill.

Sorby [9] discusses the difference between "spatial abilities" and "spatial skills." Technically, the former refers to

innate abilities and the latter to learnt abilities; however, both terms are often used alike.

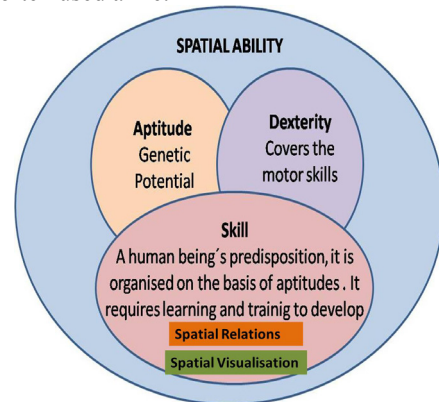


Figure 1. STRUCTURE SPATIAL ABILITY.

"Spatial skills" refers to a collection of cognitive, perceptual, and visualization skills. While lists may differ, there is substantial agreement that the core spatial skills are [10]:

- the ability to visualize mental rotation of objects
- the ability to understand how objects appear in different positions
- the ability to conceptualize how objects relate to each other in space
- three-dimensional (3D) understanding

Some of the most accepted theories come from researchers [11, 12] who have proposed three major sub-factors for categorizing spatial skills: spatial relations, spatial visualization, and spatial orientation, although some researchers don't recognize spatial orientation as a separate factor. The following classification proposed by researchers on both psychology [13] and engineering fields [14], are now reduced to just two sub-factors:

- *Spatial relations*, defined as the ability for imagining rotations in both two and three dimensions. Authors indicate that this skill includes mental rotation and spatial perception factors.
- *Spatial visualization* which is the ability to recognize 3D objects through the folding and unfolding of their faces. Visualization is defined as the ability of mental management of complex shapes.

To measure these components we use both the Mental Rotation Test (MRT) [15] and the Differential Aptitude test (DAT-5: SR) [16], as they are highly valuable tools for performing measurements of spatial skills (Figure 2).

The spatial ability is something that cannot be taught directly so the only way to improve this skill is trying to develop it through specific training.

Research on factors that affect the development and exercise of spatial skills has traditionally focused on gender differences in performance. Recent research efforts, however, indicates that other factors, such as socioeconomic status and working memory capacity, may be involved. Research identifying these other factors affecting skill levels further

indicates that an underlying factor may be the level of access to and use of objects and activities shown to improve spatial abilities such as video games [17, 18]: activities which males are more likely to use than females.

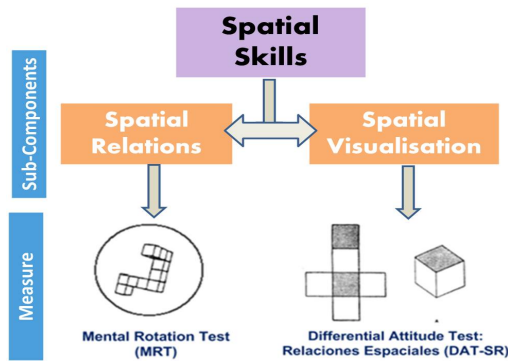


Figure 2. FACTORS AND MEASUREMENT TEST FOR SPATIAL SKILLS

Sorby [19] mentions that pre-college participation in activities relying on hand-eye coordination tends to be high among postsecondary students with good to excellent spatial skills, including certain sports and technical education/industrial arts classes.

Some studies in the engineering field demonstrate that spatial abilities can be improved by means of specific training with multimedia exercises, video games, 3D software and other technologies used in graphic engineering [9, 20, 21]. According to Mohler [22], spatial ability is the most important out of all the other abilities an individual can possess, which will enable them to carry out all kinds of tasks related to the engineering profession.

In the area of engineering, specifically in technical design and representation of views, there is an obvious connection with spatial reasoning and geometric transformations; both are excellent catalysts for developing perceptive abilities of students [23]. The integration of various orthographic views from the perspective of a student produces a training of spatial visualization, and obtains new orthographic views from the given view. This is a way which helps to understand the spatial relationship. Training of spatial visualization is achieved (among other exercises), proposing the student the choice of the appropriate model, which is reached through a process of mental manipulation from input data. In general, the procedures are the folding and unfolding of object surfaces. The spatial relationship is developed by recognizing a three dimensional object from different angles, which requires the student to recognize spatial position and relation to other objects.

Sorby, et al. [2] is one of many reports about how instruction in 3D CAD modeling leads to increased scores on tests of spatial reasoning skills. However, interventions do not necessarily need to be computer-based to be effective; technical drawing, 3D modeling with craft materials, and drafting activities have been shown to help develop and improve spatial skills; see, for example, [14, 20, 24]. These studies serve as a reminder that effective interventions can also be low-cost and accessible, an

important point to practitioners operating in resource challenged environments.

DESCRIPTION OF THE AR SYSTEM

A software library called HumanAR have been developed in order to ensure the integration of Augmented Reality into our applications and to overcome some drawbacks present in some public libraries.

The version of HumanAR shown here has been specially tuned to ensure a reliable implementation of the augmented book used in this experiment. This library uses computer vision techniques to calculate the real camera viewpoint relative to a real world marker, that it calculates the integration of three-dimensional objects codified by the camera and captured by the camera in real time. When the marker enters the scene picked up by the camera, the fusion of the real world with the virtual object is shown on the screen. This requires the application to relate the two worlds (real and virtual) in a single system of coordinates.

The key technical issues for the development of the AR system have been: marker detection, camera calibration, calculation of the marker position and orientation and finally, augmentation of the virtual object.

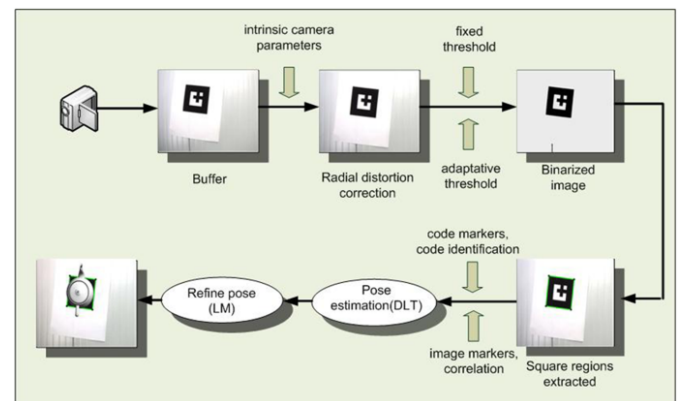


Figure 3. HUMANAR BLOCK DIAGRAM

Markers design

An ID-based marker must be designed in such a way that can be easily detected and be unique enough to be easily identified from others markers. Each marker must also provide some kind of hexadecimal code that fixes the marker orientation. We have an easy application for creating the fiducial marks that can also be interpreted by the augmented reality software. It's a Word document where there is an image we can manipulate. The image is a black frame containing a white surface divided in 4 rows and 4 columns meaning that we have 16 squares where colours can be changed. If we convert these squares to black we may design our own marks (see figure 4).

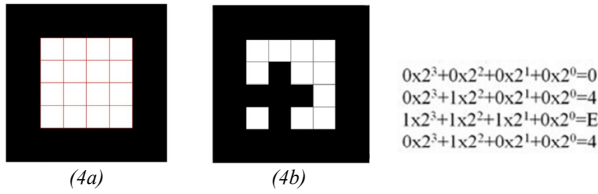


Figure. 4a and 4b. FIDUCIAL MARKERS DESIGN

Each one of the 16 cells is a 1-bit binary number so each form in one of the 4 rows belongs to a 4-bit binary number. Besides, every column has a different value (three for the column far left and zero for the column on the far right). Having in mind we are dealing with a binary code and its base being 2, the columns will have the values 2^3 , 2^2 , 2^1 , and 2^0 (column values from left to right).

According to the colour, and having in mind the binary base of each cell, it's considered sketching with value 1 the black colour on cell and with value 0 the white colour on cell. If we take the previous image (Fig 4a) the 16 squares are white so for each one of the four rows, the combination would be $0x2^3 + 0x2^2 + 0x2^1 + 0x2^0$. The result of each row is equivalent to a hexadecimal base digit (combinations of ones and zeroes in a 4-bit group are $2^4=16$). So, for each one of these marks, four hexadecimal digits are obtained, that will be read by the software from the upper row until the lowest one in the mark.

Our augmented reality software identifies the marker through a decimal association and that's why this hexadecimal code of 4 digits should be transferred to decimal notation. For personalizing the application that we are going to create, we modify a file from the program's source code. In this file, we associate the decimal code belonging to a mark with a 3D model file in any of these formats: FBX, MDL, OBJ.

The figure 4b shows a marker with a value equal to 04E4, which is associated to the augmented reality code as marker 1252 which is the equivalent value in decimal base to the hexadecimal value 04E4 value. A parameter file configuration is interpreted by the source code which contains information about the marker, the virtual object which codifies and the location parameters of the virtual information respecting the marker.

Marker detection

The recognition of the marks by the program is done in several steps:

In the first step, the camera picks up the image of the fiduciary marker and the program turns the image of the marker into binary code, that is, it converts the image into pixels that have certain characteristics that make it recognizable; this can done in different ways:

- Using a fixed threshold.
- Using an adaptive threshold.

Using a fixed threshold is recommended under ideal circumstances, where the lighting and camera parameters are

constant. In this case this technique performs properly. However, if the light conditions are different in each frame, using an adaptive threshold can be a better choice. HumanAR threshold determination is based on Pintaric's technique [25]. Basically this algorithm operates on an individual marker basis evaluating the mean pixel luminance over a threshold region of interest.

The second step is the marker's contour detection where the connected components must be extracted. Afterwards, the perimeter of each contiguous region of black pixels is traced for producing a chain representing an object border.

In the next step, the pattern is normalized by using a perspective transformation to square landmarks thus getting square landmarks. The transformation is applied to a square region of interest and the interior part of the marker is extracted. Finally it is necessary to identify the interior of the pattern. The Figure 3 shows the block diagram of HumanAR library.

Camera calibration

To calculate the real camera viewpoint relative to a real world marker is determining the intrinsic camera matrix K and a vector γ with the distortion parameters (intrinsic parameters).

$$K = \begin{bmatrix} f_x & \sigma & c_x \\ 0 & f_y & c_y \\ 0 & 0 & 1 \end{bmatrix} \quad \gamma = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \beta_1 \\ \beta_2 \end{bmatrix}$$

Where f_x , f_y are respective the focal length in the x and y direction, (c_x, c_y) is the camera's optical centre, α_1 , α_2 the radial distortion parameters, β_1 , β_2 the tangential distortion parameters and finally σ is the camera's skew between X and Y axes.

For the calibration step, the Zhang's method is the one of choice [26]. The input of this algorithm is the correspondence between 2D image points and 3D scene points over a number of images. The outputs are the intrinsic camera matrix as well as the radial distortion coefficients.

Computation of marker position and orientation

The camera pose can be estimated if the internal parameters of the camera are known. The relation between a 3D plane and its image projection can be represented by a homogenous 3×3 matrix, we usually called it a homography matrix. Let's assume that $Z = 0$, because the marker is in a plane. If we know several points on a plane that we call the reference plane, we look for its corresponding image on the image plane (homographic plane). This is known as projective transformation on the plane (fig. 5). The homographic matrix is used to determine the transformation of the points in space to points on the image plane.

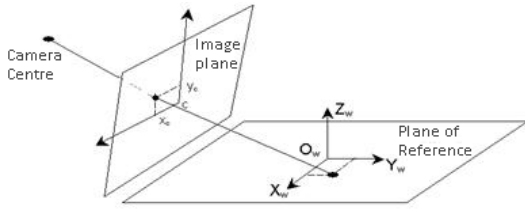


Figure 5. IMAGE PLANE AND PLANE OF REFERENCE.

The expression of the homographic matrix H assigns its corresponding point on the image plane to a point on the reference plane. The homographic matrix H is defined as:

$$\begin{bmatrix} x_c \\ y_c \\ w \end{bmatrix} = \mathbf{H} \begin{bmatrix} X_w \\ Y_w \\ W \end{bmatrix} \Rightarrow \begin{bmatrix} W X_w \\ W Y_w \\ W \end{bmatrix} = \begin{bmatrix} a & b & c \\ d & e & f \\ g & h & 1 \end{bmatrix} \begin{bmatrix} x_c \\ y_c \\ 1 \end{bmatrix} \quad (1)$$

Where:

- H is a matrix that describes the homography.
- The system of co-ordinates of scene $X = (X_w, Y_w, W)^T$, where $Z_w = 0$.
- The system of co-ordinates of image $x = (x_c, y_c, w)^T$

A point P in the real world will have its corresponding point 2D (p) in the image under the perspective $Q = K[R/T]$:

$$\hat{p} = Q\hat{P} = K(R^1 R^2 R^3 t) \begin{bmatrix} X \\ Y \\ 0 \\ 1 \end{bmatrix} = K(R^1 R^2 t) \begin{bmatrix} X \\ Y \\ 1 \end{bmatrix} = H \begin{bmatrix} X \\ Y \\ 1 \end{bmatrix} \quad (2)$$

R^1 , R^2 and R^3 are the first, second and third columns of the rotation matrix R respectively. Once H and K are known, the camera's pose can be recovered. The matrix H can be estimated from four correspondences $P_i \leftrightarrow p_i$ using a Direct Linear Transformation (DLT) algorithm.

The matrix H can be determined for four points:

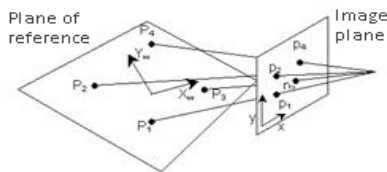


Figure 6. POINTS IN REAL WORLD AND ITS CORRESPONDING POINTS 2D.

$$\begin{bmatrix} x_1 & y_1 & 1 & 0 & 0 & 0 & -X_1x_1 & -X_1y_1 \\ 0 & 0 & 0 & x_1 & y_1 & 1 & -Y_1x_1 & -Y_1y_1 \\ x_2 & y_2 & 1 & 0 & 0 & 0 & -X_2x_2 & -X_2y_2 \\ 0 & 0 & 0 & x_2 & y_2 & 1 & -Y_2x_2 & -Y_2y_2 \\ x_3 & y_3 & 1 & 0 & 0 & 0 & -X_3x_3 & -X_3y_3 \\ 0 & 0 & 0 & x_3 & y_3 & 1 & -Y_3x_3 & -Y_3y_3 \\ x_4 & y_4 & 1 & 0 & 0 & 0 & -X_4x_4 & -X_4y_4 \\ 0 & 0 & 0 & x_4 & y_4 & 1 & -Y_4x_4 & -Y_4y_4 \end{bmatrix} \begin{bmatrix} a \\ b \\ c \\ d \\ e \\ f \\ g \\ h \end{bmatrix} = \begin{bmatrix} X_1 \\ Y_1 \\ X_2 \\ Y_2 \\ X_3 \\ Y_3 \\ X_4 \\ Y_4 \end{bmatrix}$$

Since $H_w^t = K(R^1 R^2 t)$, the translation vector t and the first two columns of the rotation matrix R of the camera pose can be retrieved from the product $K^{-1}H_w^t$. The last column R^3 is given by the cross-product $R^1 \times R^2$ since the columns of R must be orthonormal.

Augmentation of virtual objects

The graphical engine used for the augmentation of virtual object at the scene is Game Studio [27]. This is an advanced, multiplatform, real time 3D graphics presentation tool. In order to include Augmented Reality functionality in Game Studio, a plug-in has been developed in C++. This plug-in incorporates detection and tracking options from the HumanAR library.

AUGMENTED REALITY APPLICATION FOR TRAINING SPATIAL ABILITY

We have created a toolkit that promotes active learning, and encourages discovery through interactivity and object manipulation controlled by the learner. This tool comprises a book with activities which student must solve (augmented book). Each page of the book contains an activity and a pair of fiducial markers identifying the exercise and the 3D model linked. Besides, there is a general marker used for visualizing the piece belonging to each exercise (see figure 7).

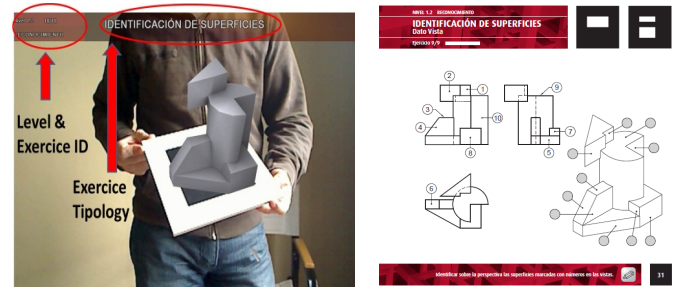


Figure 7. USING AR APP AND AUGMENTED BOOK

The way of interacting with the augmented book is showing to the screen the fiducial markers from the book so the exercise's number appears on screen. The user will be able to visualize the 3D object from any point of view.

The first exercise of each level is a solving example, so they have a linked interactive gesture for visualizing the solution. Like in the rest of the exercise, the user may visualize the 3D object through the general marker, although if he performs the gesture of bringing the object nearer to the camera, the exercise's solution will be shown on screen.

Several researchers [28] report that learners who have active control over novel objects perform better on later tests of object recognition and mental rotation. Further evidence suggests that active exploration and control of novel objects assists the learning of 3D structures, better object recognition and improved spatial ability. The content proposed in the

augmented book is an effective way of improving spatial abilities due to mental visual operations students have to carry out. This set of activities contributes to the development of the spatial factor of the intelligence. The didactic material was created using Bloom taxonomy [29] being structured on levels (*knowledge, comprehension, application, analysis-synthesis, and evaluation*), each one containing several kinds of exercises.

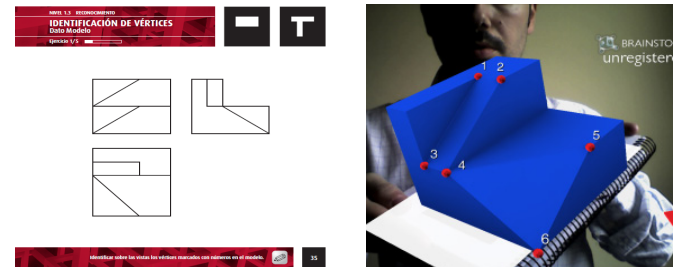
Purpose training is structured into five levels with duration of two hours for each one, excepting level 5 (evaluation) where six exercises must be completed in just one hour without any model help.

The training is organized into five sessions with a total duration of nine hours (four sessions of two hours and a final session that lasted one hour). Students can visualize the three-dimensional model in augmented reality (augmented book) and they can check if their freehand sketches correspond to the three-dimensional virtual models which they are viewing.

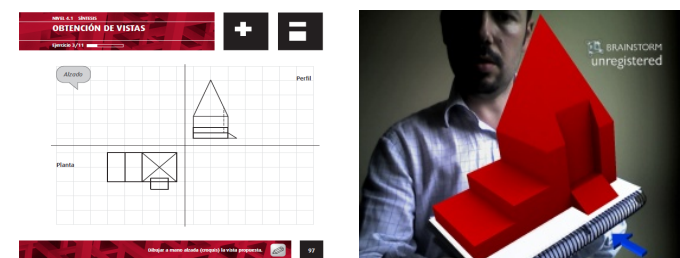
- *Level 1 (Knowledge)*. The students have to identify surfaces and vertices on both orthographic and axonometric views of a three-dimensional virtual object, which is created on the augmented book (contain three kinds of tasks).
- *Level 2 (Comprehension)*. The students have to identify orthographic views of the virtual three dimensional models from the exercise book (contain two kinds of tasks).
- *Level 3 (Application – Analysis)*. It is devoted to the identification of the spatial relationship between objects. This is carried out by means of “recount” exercises, where students are asked to identify how many objects are in touch with one selected. Also there are exercises about the selection of the minimum number of views to completely define an object (contain two kinds of tasks).
- *Level 4 (Synthesis)* Its difficulty is greater than previous levels. There are exercises where the students have to sketch a missing orthographic view, knowing two orthographic views of a model, using the virtual model as the only input, they have to sketch all the orthographic views (contain two kinds of tasks).
- *Level 5 (Evaluation)*. The exercises are the most difficult ones for students, because they require a greater level of spatial ability. Students are provided with three orthographic views of each object, and they have to build in their minds the corresponding three-dimensional model and then draw a freehand perspective of it. Students have one hour to complete six exercises, without any virtual model help. This level of the course is used for evaluating the advance of students.

When they have carried out the proposed isometric drawings, they can be verified.

This training is available for everybody through the www.ar-books.com website where the augmented book can be obtained and the AR application is available for download.



Level 1. Task 1.3. Identification of vertices.



Level 4. Task 4.1. “Missing view” exercises.

Figure 8. EXAMPLES OF SEVERAL KINDS TASKS

METHOD

Study’s description

The participants from this study were engineering students from both universities at the Canary Islands (Spain). Those first’s year mechanical engineering students performed the training for improving their spatial skill through AR. Therefore, 41 students from the Las Palmas de Gran Canaria University and 25 from La Laguna University took part on it. Besides, we chose a control group of 25 students who were randomly selected from the same degree and course than those performing this training. The participants belonging to the control group belong to both universities (12 from La Laguna and 13 from Las Palmas) didn’t perform any kind of previous training.

Training was done at home on their own. The specific aim is obtaining the results about the improvement of spatial abilities in the groups of students from both universities so they can be compared afterwards.

The study was performed during the first week of the academic year 2011/12 around October so, at the time of taking part in the experience, these students had not attended any Engineering Graphics classes in their degree courses. Spatial abilities of engineering students were measured before and after training through both Mental Rotation Test (MRT) and Differential Aptitude Test (DAT-5:SR).

For undertaking the training, only a standard PC and webcam are required. Students will visualize virtual elements on the monitor. It’s intended that students carry out training five

times in sessions on their own at home as no teacher assistance is needed. In the first briefing with the students, they were updated on the purpose and need for undertaking the training as well as obligation of submitting back to the teacher the training's notebook with all solved exercises when it's finished as guarantee that they have completed it. Later tests will be run to measure spatial skills and supplying the toolkit (augmented book and website where AR app is available for download). Afterwards instructions are explained on how to carry out training: "five levels, which will be completed in five consecutive days". It is considered that two hours work is required for each level with the exception of the fifth which requires just one hour. Once training is finished, students hand the completed exercise book to the teacher whilst spatial ability levels are measured once again for comparison with pre-training levels.

Measures and results

In Table 1, MRT (spatial relations) and DAT-5:SR (spatial visualization) values can be found before and after training for the three groups: general, experimental and control group. Mean values prior to training are quite similar in all three groups.

The analysis of variance (ANOVA) for MRT and DAT-5:SR measured in the three groups (general group, experimental group and control group), showed there were no significant differences between groups prior to spatial training ($F_{2,90}=1.817$, $p=0.169$ on MRT and $F_{2,90}=0.264$, $p=0.769$ on DAT-5:SR). So, all groups were statistically equivalent in spatial visualization and spatial relation at the outset of this study.

Table 1. VALUES PRE/POST TEST AND GAIN SCORES

	Pre- test		Post- Test		Gain	
	MRT	DAT 5:SR	MRT	DAT 5:SR	MRT	DAT 5:SR
Las Palmas	15.88	27.54	25.07	37.41	8.04	9.29
Group n=41	(6.05)	(8.85)	(7.54)	(8.10)	(5.31)	(4.08)
La Laguna	19.67	29.17	27.70	38.46	9.19	9.87
Group n = 25	(7.90)	(7.28)	(7.82)	(7.04)	(6.69)	(5.03)
Control	17.44	28.40	22.08	33.52	4.64	5.12
Group n=25	(9.82)	(10.17)	(9.94)	(11.77)	(4.36)	(7.13)

We compared the mean values obtained in pre and post tests using the *t-Student paired series test*: the training Las Palmas group scores show $t=8.80$ for the MRT; p -value=0.0 and DAT-5:SR $t=12.57$; p -value=0.00; the La Laguna group scores $t=7.42$ for the MRT, p -value=0.00 and DAT-5:SR $t=11.15$; p -value=0.00. In the MRT test, the control group obtained $t=5.32$; p -value=0.00 and in the DAT-5:SR $t=3.59$; p -value=0.001.

The groups that underwent training showed a statistical improvement in spatial ability levels. P-values are around 5% of statistical significance, which indicates that the students have a probability of over 95% of improving their levels of spatial ability by training as proposed by Augmented Reality. Besides this, results show there is no improvement in control group levels. To compare and check if there is any difference between

spatial ability levels obtained by groups that underwent training, a contrast analysis post-hoc LSD Fisher is performed. This allows multiple comparisons between the three groups with a different number of individuals in each group as seen on results Table 2 and Table 3.

Table 2. COMPARISON BETWEEN GROUPS FOR GAIN MRT

(I) group	(J) group	Difference between averages (I-J)		Typical error	Sig.	Confidence interval at 95%	
		Lower limit	Upper limit			Lower limit	Upper limit
1	2	1.15346	1.4826	.439	-1.7935	4.1004	
	3	4.55512(*)	1.4638	.003	1.6456	7.4646	
2	1	-1.15346	1.4826	.439	-4.1004	1.7935	
	3	3.40167(*)	1.6485	.042	.1250	6.6783	
3	1	-4.55512(*)	1.4638	.003	-7.4646	-1.6456	
	2	-3.40167(*)	1.6485	.042	-6.6783	-.1250	

1 (La Laguna Group), 2 (Las Palmas Group), 3 (Control Group)

* Difference between averages is significant at .05 level.

Table 3. COMPARISON BETWEEN GROUPS FOR GAIN DAT5:SR.

(I) group	(J) group	Difference between averages (I-J)		Typical error	Sig.	Confidence interval at 95%	
		Lower limit	Upper limit			Lower limit	Upper limit
1	2	.58638	1.4093	.678	-2.2148	3.3876	
	3	4.75805(*)	1.3914	.001	1.9924	7.5237	
2	1	-.58638	1.4093	.678	-3.3876	2.2148	
	3	4.17167(*)	1.5670	.009	1.0570	7.2863	
3	1	-4.75805(*)	1.3914	.001	-7.5237	-1.9924	
	2	-4.17167(*)	1.5670	.009	-7.2863	-1.0570	

1 (La Laguna Group), 2 (Las Palmas Group), 3 (Control Group)

* Difference between averages is significant at .05 level.

The results confirm that there is a significant difference between each one of the training and control groups but there is no difference between the training groups which underlines that improvement gained by the students has been similar on both universities.

CONCLUSION

Augmented reality is a cost-effective technology to provide students with attractive contents with respect to paper books, giving new life to classical paper and pencil exercises. In educational applications, it is of utmost importance to focus students' attention on the actual task and to reduce the cognitive overhead needed to use the application. This motivated us to design a user-friendly system and a friendly and agreeable environment. This AR application has proven to be an efficient and effective material for developing spatial abilities and for learning engineering graphics contents. The software has proven to be robust as no errors have shown up during its use.

According to results, the students accessing both mechanical engineering at canary universities don't show significant difference respecting spatial skills levels. Students from both universities improve their spatial skills in the same way obtaining better results than the average value belonging to the

whole country.

For engineering students, having a good level of spatial skill helps them getting a better performance in academic tasks, and training like the one proposed on this paper may provide them with the proper level of spatial skill

Following the trend pointed by The New Media Consortium's 2011 in Horizon Report [30], I regard augmented technology as useful university didactic material in the short-term because students frequently use several electronic gadgets (smartphone, iPads, laptops, etc.) while gathering information and studying.

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