Proposal of Methodology for Learning of Standard Mechanical Elements Using Augmented Reality

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Abstract – **Learning and teaching procedures need to evolve, considering the high technological profile most students have. Today's university students are steeped in a culture of technology and new devices such as smartphones, PDAs and laptops. These have found a place in students' lives as an important tool for studying. The use of these devices is widely used and seen when entering a first-year class, and most students work or take notes with them. This paper describes a physical interface (augmented book) based on augmented reality technology for learning standard mechanical elements. This book was included in the curriculum of an engineering graphics subject in a Mechanical Engineering Degree of a Spanish University. A validation study of didactic material was carried out by Twenty-five students that used this augmented book for studying the representation and designation of standard mechanical elements. A control group consisting of twenty-two students used traditional class notes with static images to study the same contents. We have analyzed the results through an evaluation test and a usability survey. The results show that the experimental group students enjoyed studying through the use of AR technology and even obtained better results in a contents evaluation test.**

Index Terms – Academic Performance, Augmented Reality, Engineering Education, Standard Mechanical Elements.

INTRODUCTION

Learning with technology involves learning situations in which the instructional experience is created with the aid of a physical device, such as a computer or the Internet. At some level almost all learning involves technology. For example, in a traditional lecture, an instructor may use chalk and a chalkboard, thereby employing an old but reliable technology. Similarly, a textbook constitutes a form of technology albeit one with a 500-year old history [1].

Over last decade the leisure and entertainment world have developed very attractive devices for the younger population reaching the point of becoming essential for study. It's a fact that when most students reach college they are used to new technologies and computer use.

Teachers notice that new generations of students in graphic engineering subjects show far more interest and pay more attention when they use CAD tools, multimedia material, web resources, virtual platforms and social networks but show apathy and less motivation however when using traditional drawing tools.

This paper focuses mainly on learning with augmented reality technology. An important feature of computer-based technology, and possible advantage if used appropriately is that, it allows the presentation of multimedia instructional messages [2] that is, instructional messages consisting of words (spoken or printed) and pictures (such as animation, video or 3D illustrations). Computer-based technology also allows levels of interactivity and graphic rendering [1].

One of main advantages of using this technology is the student's adhesion which allows the establishment of contact while studying tasks. Learning processes used to be long, involving a lot of boring didactic material leading to students dropping out of subjects. AR technology allows interaction, motivation and it can even be used at home. It's true that adhesion to any technology disappears overtime if used frequently. This kind of technology will focus on the specific content of the subject avoiding the study becoming a routine when students are no longer interested in it.

In this paper the benefits of teaching and learning are analyzed as well as the use of didactic material with additional information supplied by augmented reality against the use of traditional class notes. Both AR based didactic material and traditional note seek require that students learn sketching, designation and normalization of mechanical elements following ISO standardization international rules, ASME-ANSI, DIN regional regulations and UNE Spanish standardization rules [3-13]. These contents are common in subjects such as Graphical Engineering, Machine design and Mechanical technology among others. Students should master these fundamental subjects for successful professional performance.

AUGMENTED REALITY ENVIRONMENTS

Virtual reality (VR) is the use of computer graphics system combined with various displays and interface devices for providing the effect of immersion in the interactive 3D computer-generated environment. From VR technology onwards arise augmented reality (AR) where technology merges virtual images with real ones, maintaining contact with the real world while interacting with virtual objects.

Azuma [14] defines AR as a variation of virtual environments (VR). VR technology completely immerses the user in a synthetic environment which can be interacted with obtaining answers while not seeing the outer real world.

However, an augmented reality environment allows the user to see the real world with virtual computer-generated objects superimposed or merged with real surrounding.

A basic scheme of an augmented reality system consists of a camera which captures snapshots of the real world connecting to a computer that makes necessary calculations for merging virtual objects into the real scene. The result is an image shown to the user through a graphic interface (figure 1).

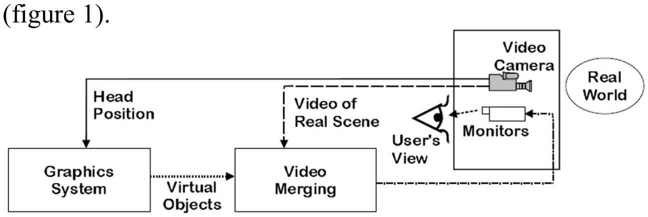


FIGURE 1
BASIC SCHEME OF AN AUGMENTED REALITY SYSTEM [15]

One of the most important characteristics is the way to create an interactive environment between computer system and user. Today's AR environments create interactive systems that aren't simply face-to-screen exchange any longer, but an interaction within the whole environment as well (see figure 2).

FIGURE 2
AUGMENTED REALITY ENVIRONMENTS [16, 17].

Short characteristics of an AR environment:

- Combines real and virtual environments
- Is real-time interactive
- Is registered in four dimensions (three dimensional space and time)
- Virtual objects can be stationary or animated
- There is interactivity between the object and the real world
- Abstract concepts can be made visible, enhancing understanding

AUGMENTED REALITY IN HIGHER EDUCATION

According to The New Media Consortium's 2011 Horizon Report [16] augmented reality is becoming a technical trend in higher education and is just two to three years away from making technology blend virtual and real and is expected to reach mainstream use in education through augmented reality textbooks (augmented book).

It's nearly impossible to forecast what technology will bring next year but is possible to predict the outlook in ten years. I believe that one of most relevant changes in our society will be augmented reality which is a technology that is actually being developed in several fields[1],[2] and applied to medicine, architecture, marketing, advertising, military, archeology, leisure, etc.

The versatility offered by AR technology has allowed the development of applications on several knowledge areas of education like mathematics, mechanic, physics, and town planning among many others. In higher education there are very few applied teaching applications but here are the only ones known to date:

- *Interactive Media System Group*[3], researchers from the Institute of Software Technology and Interactive System (Vienna University of Technology), is a pioneer of the development of augmented reality applications for education. Construct3D app, as described in [17, 18], is an application designed for teaching mathematics and geometry in higher education. Apps allow creation of geometric scenes so both teacher and student can interact while explaining. It can be used in three different ways:
    - Autonomous mode where students can see and interact with objects built by themselves
    - Collaborative mode visible for every user.
    - Teacher mode allowing him to choose visibility between some students or all of them.

  The author proposes giving an augmented class where students are provided with HMD and can interact with virtual objects and do exercises following the teacher's advice. Using this tool the student can learn how to manipulate 3 dimensional geometric objects in the space provided and also carry out geometric and mathematical operations.

  The Same authors developed an educational tool for explaining physical experiments [19]. The concepts are explained by way of animations and the student has the possibility to interact with virtual objects, which, with practice allow them to be learnt.
- In engineering education, Martin-Gutierrez has developed training that improves the spatial skills of students [20]. The Application is based on performing graphic engineering exercises using augmented reality, and through this obtain an improvement in the spatial capacity of the students, which in turn will help them to understand the contents of geometric graphics.
- In medical education, those seeking training for the future such as anesthetists, an AR simulation is proposed using operating theater material [21].

In higher education, some AR experiences have been performed already but haven't generated any didactic material for continued use, we can just mention a collaborative learning study in Land and town planning fields [22]. The experience concluded by showing that AR technology may improve the design of tasks performed by

[1] http://www.wikitude.org/en
[2] http://studerstube.icg.tu-graz.ac.at/handheld_ar
[3] http://www.ims.tuwien.ac.at

students. Another interesting basic app on the AR field is developed by Gillet, Sanner, Stoffler, Goodsell, & Olson [23].

AUGMENTED TEXTBOOK

Augmented textbook has been named SMELAR – ***S**tandard **M**echanical **E**lements **L**earning through **A**ugmented **R**eality.* The objective of this book is to provide the student with a study manual which contains the normalized industrial elements which can be seen in 3D, together with the paper which defines the technical characteristics. The availability of three dimensional objects for visualization allows the student to relate the real object with the technical information. (Graphic representation, uses and designation)

SMELAR – Augmented book consists of two volumes containing eight chapters:

1- Simple thread elements: bolts, nut, stud…
2- Non thread simple elements: Pins, cotter pins, washer…
3- Security device
4- Bearings
5- Gears
6- Spring
7- Motionless Machines
8- Machines in motion

Each chapter has an introduction with theoretical contents and the following technical card for each standard element. The card has literal information about use, rule number and element standard designation. Besides this, it also contains graphic information about standard representation, photorealistic image and a marker which allows visualization of the 3D standard element from any point of view through augmented reality using BuildAR[4].

FIGURE 3
TECHNICAL CARD SAMPLE

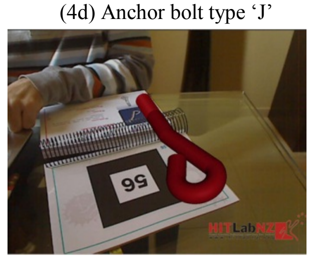
The augmented book experience only requires the addition of a webcam to a typical PC configuration and the proper software whilst using the computer screen to visualize the augmented scene. In an educational context, It is a cost-effective and eye-catching alternative. In the following images we may see a student manipulating SMELAR cards.

(4a) Augmented Book SMELAR

(4b) Hex-head screw

(4c) Hex-nut perforated

(4d) Anchor bolt type 'J'



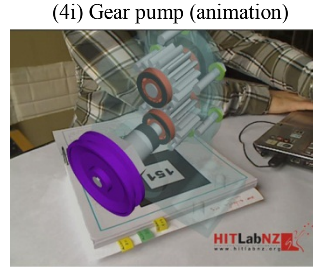
(4e) Cylinder bearing

(4f) Cylindrical gear - helical teeth

(4g) Worm gear

(4h) Cylindrical helical spring

(4i) Gear pump (animation)



(4m) Wind turbine parts (animation)

(4n) Pencil sharpener exploded (animation)

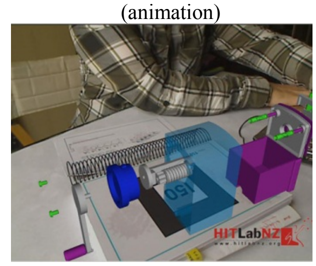


FIGURE 4
AUGMENTED INFORMATION ON SMELAR

[4] Human Interface Technology Laboratory New Zealand (HIT Lab NZ), http://www.hitlabnz.org/BuildAR

EMPIRICAL STUDY

A study was performed with first year students from The Mechanic Engineering Degree of La Laguna University (Spain). Graphic Engineering subject contents are structured in several blocks so when each one is finished an exam is sat. Students taking part in the experimental study have all passed the evaluation tests on a graphic engineering subject. The Last block of the subject requires understanding, sketching, designation and normalization of standard mechanical elements.

I. Participants, Design and Procedure

A total of 47 students from the first-year of mechanical engineering ranging in age 17 to 21 (M=18.7, SD=1.1) took part in the study. Twenty five of them belong to the experimental group because they will use the augmented book for studying and following the teacher's explanations. The other 22 students belong to the control group which will use traditional class note taking. The experimental procedures took part in the last 6 weeks of the academic course 2009/10 (April-May 2010).

The teacher explains each of the standard mechanical elements like in previous years. At the end of experimental procedure students belonging to the study will perform an exam to evaluate their knowledge on mechanical standardization. They already know that by making a final effort they will pass the subject completely, so they will have a responsible attitude while studying it. Meanwhile, the experimental group will complete a survey designed for data collection and AR material effectiveness levels, which are a measurement of technological efficiency. Besides this, student satisfaction will also be measured with respect to AR technology use.

Bevan's points out that, effectiveness value measured is the average score of participants' answers (using a numeric scale) and respecting efficiency and satisfaction, we may obtain a qualitative or quantity value depending on how questions are formulated [24].

Both, the experimental and control group, will carry out a survey to evaluate motivation levels when studying this content. The questions formulated by Biggs evaluates the motivation they feel from the questionnaire R-SPQ-2F [25].

We believe that the material used influences the result as it's the only controlled variable which is different for both groups. Questions asked are shown on TABLE II. Students answer using Likert's scale with a range of values between 1 and 5 (Totally disagree, Disagree, neither agree nor disagree, Agree, Totally agree).

FIGURE 5
SCENARIO: FIRST YEAR STUDENT STUDYING AT THE LIBRARY

MEASURES AND RESULTS OF EFFECTIVENESS, EFFICACY AND SATISFACTION

To check if the material used for studying has had an influence on learning, we check scores obtained by students from each group (control and experimental). TABLE I contains average score and standard deviation for each group. It is interesting to point out that in the experimental group, 20 students passed out of a total of 25 meanwhile in control group only 11 of 22 were successful (see figure 6).

TABLE I
AVERAGE VALUES AND STANDARD ERROR IN ACADEMIC PERFORMANCE

	Mark (Std. Desv.)	Std. Error
Experimental Group (SMELAR) n = 25	5.84 (1.54)	0.31
Control Group n=22	4.5 (1.84)	0.39

For statistical analysis *t-student* contrast is used to compare statistical difference between the average value from both groups scores. We consider null hypothesis H_0, the fact that there is no statistical difference between average values of both groups. The result of the comparison between both average values using "*t-student in independent series"* shows that both scores are different from the statistical point of view so null hypothesis H_0 is rejected (t =2.708, p-value=0.009). P-values below 1% indicate that students have a probability of over 99% of obtaining better results using the augmented book. Kolmogorov-Smirnov Test compares the distributions of two samples. This test is performed by computing the maximum distance between the cumulative distributions of the two samples. In this case, the maximum distance is 0,458 (K-S=1.567, p-values=0.014). Since the P-value is less than 0.05, there is a statistically significant difference between the two distributions at a 95% confidence level.

We can conclude that academic results are statistically significant when comparing results from experimental group with the control group.

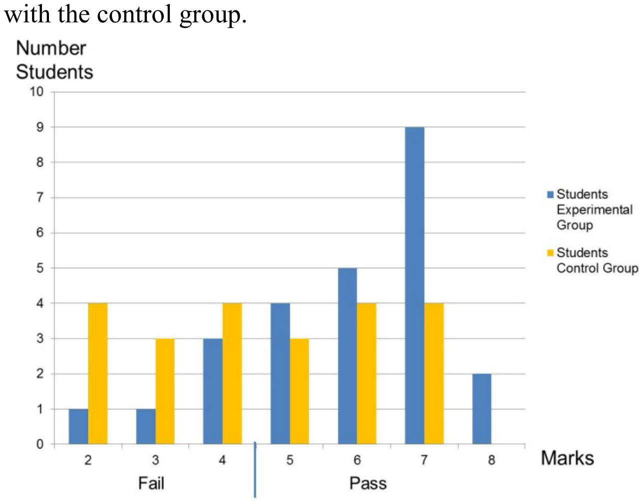


FIGURE 6
MARKS OBTAINED BY STUDENTS

In usability there are different quantitative measures established which allow understanding of the product's acceptance level; in our case, we will find didactic material and used technology's success rate. In TABLE II, values are shown for effectiveness, efficiency, satisfaction and motivation.

Augmented textbook has been positively appreciated with an effectiveness value of 4.47 points, almost reaching the 5 points top score. Among other valuations, students think that the book is visually attractive and that the contents are appropriate and nicely structured. Book size is suitable for correct performance of necessary gestures when visualizing augmented information. Augmented textbook is regarded as quite complete on information supplied as they consider there is no need to check out any other documents while studying.

Concerning efficiency and satisfaction all aspects are positively valued. Every student (100%) believes that the technology used is interesting and most of them think it will help them perform better in a final exam. The overall valuation is that, AR technology and augmented textbook base allows easy learning and becomes a frustration-free tool for the user (as shown on figure 7).

TABLE II
EFFECTIVENESS, EFFICIENCY AND SATISFACTION SURVEY

A	**Effectiveness material. (error free)**	**Mean Value (Std. error)**
A1	Augmented textbook is nicely presented	4.80 (0.08)
A2	Proper chapter contents structure	4.76 (0.77)
A3	A5 textbook size adequate for virtual contents manipulation.	3.88 (0.1)
A4	No image leaps when manipulating virtual objects	4.72 (0.2)
A5	AR application stability (doesn't freeze)	4.84 (0.1)
A6	No additional content needed while studying	4.84 (0.1)
A7	Allows following teacher's explanations	3.44 (0.3)
	Mean Value Effectiveness	*4.47 (0.2)*

B	**Efficacy and technology satisfaction (speed)**	
B1	Augmented textbook is easy to learn	4.84 (0.04)
B2	I would rather choose traditional class notes over new augmented textbook	1.00 (0.0)
B3	Proper 3D figures visualization with no definition problems	4.88 (0.1)
B4	I think this augmented textbook will help me performing a better exam	3.72 (0.2)
B5	I liked using this augmented textbook at home by myself	3.88 (0.2)
B6	Augmented Reality technology has been interesting to use with this didactic contents,	5.00 (0)
B7	Augmented Reality is useful for studying this didactic contents	4.12 (0.3)
B8	How do you value the Augmented Reality technology working with three-dimensional models? (1 bad – 5 excellent)	3.96 (0.5)
B9	Technology Augmented Reality technology seems useful	4.40 (0.2)
B10	Objects' use and manipulation with AR technology is frustrating	1.36 (0.2)
B11	Overall experience rating	4.32 (0.3)

C	**Motivation**	**Exp.G**	**Ctr.G**
C1	Sometimes studying gives me a feeling of deep personal satisfaction.	3.86 (0.03)	1.86 (0.03)
C2	I feel that virtually any topic can be highly interesting once I get into it.	4.64 (0.02)	2.22 (0.04)
C3	I find that studying academic topics could sometimes be as exciting as a good novel or movie.	4.92 (0.01)	1.04 (0.01)
C4	I work hard while studying because material is interesting.	4.96 (0.008)	1.59 (0.04)
C5	I attend most classes with questions in mind that I want to answer.	1.2 (0.02)	1.23 (0.05)
	Mean Value Motivation [StdDev]	3.94 [1.50]	1.76 [0.97]

For motivation measurement five questions have been formulated. Average score obtained by the experimental group is higher than control group. We compare and see if there is any statistically significant difference between both groups over the weeks in which the study took place.

Applying t-student on each question we may obtain p-values equal to zero. Considering the average value of 5 questions as overall motivation score we find that p-value is null as well (Table III). We may conclude that there is over a 99% chance that students feel higher motivation using augmented textbook compared to traditional class notes.

TABLE III
STATISTICAL RESULT. P-VALUE ON MOTIVATION QUESTIONS.

Question	P-Value
C1	P-value=0.000
C2	P-value=0.000
C3	P-value=0.000
C4	P-value=0.000
C5	P-value=0.001
ALL	P-value=0.000

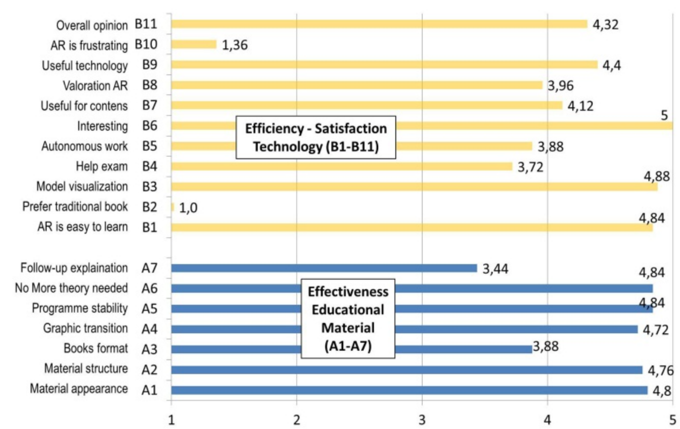


FIGURE 7
EFFECTIVENESS, EFFICIENCY AND SATISFACTION RESULTS.

CONCLUSION

Results obtained show benefits from augmented textbook use. Students may get better results than by using just traditional textbooks. They also show higher motivation while performing tasks and studying. Besides this, satisfaction level over augmented textbook use is quite high.

Textbook's information increment requires less need for consulting any other documents to obtain information. Following the same trend pointed out by The New Media Consortium's 2011 in Horizon Report, I consider augmented technology will be used in university didactic material in the short-term where students use electronic gadgets frequently (smartphone, iPads, laptops, etc.) while studying and looking for information.

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