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The acceptance of learning augmented reality environments: A case study

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***Abstract*— The aim of this study was to investigate the attitude of learners toward an augmented reality learning activity designed to help engineering students to solve an electromagnetic problem. The sample was 122 students. Students were asked to complete a survey questionnaire based on the Technology Acceptance Model (TAM) enhanced with perceived enjoyment items. The results of the evaluation show that intention of use the system is dependent of perceived enjoyment but not from perceived usefulness of the learning tool.**

Keywords- Augmented reality; assessment; interactive learning environments; technology acceptance model

I. INTRODUCTION

Learning is nowadays shifting from merely transmitting knowledge as stated by objectivist theories; to an active, learner-based approach supported by constructivist principles [1]. The central assumption of constructivism is that humans create meaning as opposed to acquiring it [1]. According to Jonassen (1992, p.137), "constructivism proposes that learning environments should support multiple perspectives or interpretations of reality, knowledge construction, and context-rich, experience-based activities". A challenge in education is to deploy learning experiences following these principles.

Information processing technologies have come to the aid of instructional designers willing to translate constructivism into practical learning experiences. Initially, this task has been done through the use of the flat web, then its natural evolution: Web 2.0 with collaborative tools such as wikis and blogs. Nowadays, emergent technologies such as 3d virtual worlds (3DVWs) and augmented reality (AR) are beginning to be explored as learning environments following the learning-by-doing paradigm [3].

Augmented Reality supplements the user's perception of the real world by the addition of computer-generated content registered to real-world locations [4]. The real world and virtual content can co-exist and interact in real time. AR environments offer opportunities of learning-by-doing through physical interactions in spatial contexts [5]. Although AR is considered as having potential for educational applications [6], educational research regarding AR-aided learning is in its infancy [7]. Since, a key determinant of the effectiveness of learning strategies implementing the learning-by-doing approach in AR learning environments is interactivity [8], this study might contribute to a better understanding of the impact of the AR on learners' attitude toward an assessment activity highly interactive.

This paper begins by presenting basic concepts related to augmented reality environments, as well as an overview of applications of AR in education (Section II). In Section III, an overview of the AR-based application designed for this study is presented. In Section IV is described the research study. In Section V, the results of the system evaluation is presented. Finally, Section VI concludes the paper.

II. AUGMENTED REALITY IN EDUCATION

Augmented reality is the technology that enables the integration of digital information with the user's environment in real time. The definition implies three AR properties: (1) AR systems combine real and digital objects in real environments; (2) align real and virtual objects with each other; and, (3) run interactively in real time [4]. AR systems require of enabling technologies such as computing hardware (e.g. wearable device, tablet, or smart phone), software architectures (e.g. wireless and 3D networking), and tracking and registration (e.g. GPS) [9]. The AR applications can be categorized as (1) marker-based, and (2) location-based [10]. The former, requires specific labels or track natural features of physical objects for appropriate location of the virtual contents related to objects. In contrast to image-based AR, location-based AR systems use the data about the position of mobile devices to identify the user's location, and superimposes digital information. Thus, AR technology offers different ways of interactions that makes this technology potentially useful to design different types of learning experiences.

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Maker-based educational applications have been used to help students to improve their spatial abilities. Indeed, J. Martín-Gutiérrez and colleagues [7] developed an AR-library and a didactic toolkit to improve engineering students' spatial abilities by means of an augmented book. Whereas, S. Cuendet and colleagues [11] presents TapaCarp a collaborative learning environments based on AR technology to help carpenter apprentices to understand the link between the 2D representations of an objects (its orthographic projections) and the real object. TapaCarp uses a camera-projector tabletop system to project in real time the orthographic projections of the blocks equipped with fiducial markers. Maker-based educational applications, have also been used as means to deploy virtual laboratories where students might experiment with basic principles of chemistry [12] or physics. For instance, in [13] is presented an AR-based simulation tool for experimenting with basic principles of electricity. In the experimental activities, students manipulate 3D shapes enhanced with fiducial markers that mimic the elements of a basic electrical circuit. The application includes an instructional design which superposes diagrams to guide students in building and experimenting with electrical circuits, it also displays animations that show the behavior of the circuits.

Locational-based educational applications have been generally used in blended environments to promote inquiry-based learning. For instance, W. Tarng and K.L. Ou [14] used augmented reality and mobile learning technologies to design a virtual butterfly ecological environment for learning butterfly ecology. An open area was enhanced with different kinds of virtual caterpillars and digital butterflies that the students were able to see and bred using smart phones. A similar intervention which promoted students collaboration was presented in [5], where a narrative-driven, inquiry-based AR simulation played on handheld computers that uses GPS technology to correlate the student's real world location to their virtual location in the simulation's digital world. Students navigated the AR environment and solved various puzzles according to the role assigned and share information with their teammates.

Finally, some initial attempts to allow learners to generate content have been made in both types of augmented reality applications. For instance, L. Simeone and S. Iaconesi [15] present an AR pre-trained system to recognize parts of a sculpture called the Minkisi. Users can visualize and annotate virtual information on the real parts of the sculpture. Thus, content is developed through a process of communication among the different author-consumer who use the physical object as the central part of conversation.

A common feature in the applications mentioned above is that they are mainly driven by the learning-by-doing paradigm. Therefore, its effectiveness is determined by the quality of interactivity offered [8]. High-quality user experiences are difficult to achieve and interaction with the learning environment should help, not hinder the teaching-learning process [5]. However, once high-quality interactions with the learning environment is achieved, learners' emotional states contribute to improve students' cognitive processes and learning outcomes [16].

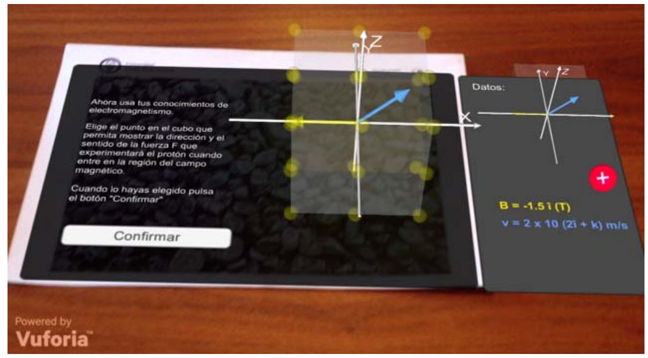

Figure 1. A snapshot of the AR application

III. AR-BASED ASSESSMENT APPLICATION

The aim of the application is to help students of a Physics undergraduate degree course to understand, visualize in 3D and solve an electromagnetic problem. The problem statement is divided in two parts:

A. Relevant Information to the Problem

This part provides the data of the problem's statement which includes:

- A uniform magnetic field: its magnitude and direction.
- A particle: its charge, magnitude and direction.

The tool provides a digital 3D cube where students must determine the direction of the magnetic field and the particle's velocity. The tool also allows students to select and place the charged particle that will go into the magnetic field.

If the student fails to answer correctly after three attempts, s/he will be provided with the right answer ant s/he will be allowed to continue.

B. Questions to Solve

Students are asked to determine the force exerted on the particle, indicating its magnitude and direction. To this end, the tool provides a digital 3D cube where students must determine the direction of the force along with a spatial view of the magnetic field and the velocity vector. There is also input window to include the magnitude of the force. Fig.1 shows the AR interface.

The learning activity includes two single choice questions with four options to inquire about the trajectory that the particle describes in the magnetic field. Before answering these questions, students might observe a 3D simulation of the particle's trajectory.

Finally, students have to answer two fill in the blanks questions to indicate:

- The time the charged particle spends into the magnetic field.
- The output cartesian coordinates of the charged particle when it leaves the magnetic field.

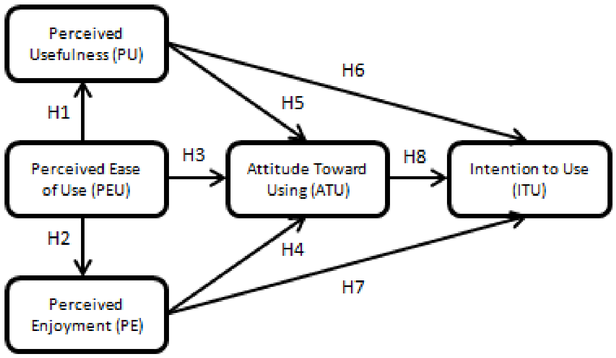

Figure 2. Research model based on TAM

IV. Description of Experiment

A. Research Model

The aim of the experiment was to evaluate the learner's attitude toward assessment in an AR-based environment. Technology Acceptance Model (TAM) [1] [17] was adopted aiming at studying how learners perceptions affect the acceptance of the technology for evaluation purposes. TAM has become one of the most widely used technology acceptance model. TAM is also the most commonly used theory in e-learning acceptance studies [18], [19].

In the TAM model, acceptance of a system is understood as the intention to use the system, which is determined by the user's attitude toward using the system and perceived ease of use. Where perceived ease of use is defined as "the degree to which a person believes that using a particular system would be free of effort" [20]. In our case, this factor represents a challenge due to the lack of knowledge about how to use effectively AR technology in learning environments. Attitude toward using the system is determined by users' perception of the usefulness and ease of use. Perceived usefulness refers to "the degree to which a person believes that using a particular system would enhance his/her performance" [20]. In our learning context this might be understood as the degree to which learner believes that using such a AR system would enhance his/her performance solving electromagnetism problems.

On the other hand, motivation is considered to be relevant in the process of learning because motivated learners are more likely to engage, persist, and expend effort for task completion than those who are unmotivated [17], [18]. Psychologists distinguish between different types of motivation based on the different reasons or goals that give rise to an action. "The most basic distinction is between intrinsic motivation, which refers to doing something because it is inherently interesting or enjoyable, and extrinsic motivation, which refers to doing something because it leads to a separable outcome" [21]. Original TAM model takes into consideration extrinsic motivation in the form of perceived usefulness, whereas perceived enjoyment is considered as intrinsic motivation [12]. Davis and colleagues extended the TAM model including perceived enjoyment as intrinsic motivation factor and defined it as "the extent to which the activity of using the computer is perceived to be enjoyable in its own right, apart from any performance consequences that may be anticipated" [17].

In this work, we explore the impact of four factors: (1) perceived ease of use, (2) perceived usefulness, (3) perceived enjoyment and (4) attitude toward activity in the intention of use of the AR learning environment developed. The first and third and forth factors are considered as usability factors by TAM model [17] whereas the second and third factors can be considered as extrinsic and intrinsic motivation factors respectively [12]. The following research hypotheses were formulated based on the TAM model and motivational theories (see Fig.2):

H1: Perceived ease of use (PEU) will positively affect perceived usefulness (PU).

H2: Perceived ease of use (PEU) will positively affect perceived enjoyment (PE).

H3: Perceived ease of use (PEU) will positively affect attitude through activity (ATU).

H4: Perceived enjoyment (PE) will positively attitude through activity (ATU).

H5: Perceived usefulness (PU) will positively affect attitude through activity (ATU).

H6: Perceived usefulness (PU) will positively affect intention to use (ITU).

H7: Perceived enjoyment (PE) will positively affect intention to use (ITU).

H8: Attitude through activity (ATU) will positively affect intention to use (ITU).

B. Participants

In this study participated 122 students enrolled in the first Physics undergraduate degree course at Universidad Carlos III de Madrid (Spain). 54 students did not complete the test and thus were not considered for the purposes of this study. Among the 68 respondents, 9 were female and 59 were male.

Students had basic computer skills but they never had used an augmented reality application before.

C. Procedure

The study was set in three sections from Computer Engineering at Universidad Carlos III de Madrid (Spain). The sections were taught the basic principles of electromagnetism by two teachers who followed the same Physics curriculum.

The week before the intervention, participants practiced with an AR tutorial application how to determine the position of points in 3D space. Students were invited to download and install in their mobile phone the AR-problem to solve during the week before the intervention. The AR-problem required a password to unblock the application.

Before starting the intervention, those students who had obsolete mobile phones were provided with tablets. Then, all students received the password required to unblock the AR-application. Students had 25 minutes to solve the proposed problem. Upon completion of students' intervention, those students who accepted to participate in the study completed

TABLE I. MEAN SCORES AND STANDARD DEVIATIONS OF THE QUESTIONNAIRE STATEMENTS OF THE RESEARCH MODEL CONSTRUCTORS

Questionnaire statements	M	SD
Perceived usefulness (PU)		
PU1. The use of such a system helped me the 3D visualization of magnetic fields.	3.75	0.90
PU2. Using the system would facilitate understanding of basic notions associated to magnetic fields.	3.19	1.11
PU3. I believe that the system is helpful when learning electromagnetism.	3.63	0.91
Perceived ease of use (PEU)		
PEU1. The system is easy to use.	4.06	0.77
PEU2. It is easy to learn how to use the learning tool.	4.10	0.87
PEU3. Operation with the system is clear and understandable.	3.71	0.92
Attitude toward AR activity		
ATU1. The use of such a system makes learning more interesting.	4.15	0.70
ATU2. I believe that using such a system in the classroom is a good idea.	4.22	0.79
ATU3. Learning in such a way is engaging.	4.34	0.80
Perceived enjoyment (PE)		
PE1. It was nice to learn by interacting with physical phenomena.	4.01	0.80
PE2. I enjoyed using the system.	4.22	0.84
PE3. Learning with such a system is entertainment.	3.91	0.89
Intention to use (IU)		
IU1. I would like to use similar systems in the future if I had the opportunity.	4.35	0.71
IU2. I would like to use similar systems to learn Physics and other topics.	4.25	0.89
IU3. I would recommend my friends to use the learning tool.	4.03	0.86

the usability survey. The time given to complete the survey was 10 minutes.

V. DATA ANALYSIS AND RESULTS

The statements of the questionnaire and the descriptive statistics for each statement are presented in Table 1. All mean values are within a range of 3.19 and 4.35. The standard deviation range from 0.701 to 1.11.

TABLE II. THE CRONBACH ALPHA VALUES

Variable	Cronbach alpha
Perceived usefulness	0.77
Perceived ease of use	0.65
Attitude toward AR activity	0.70
Perceived enjoyment	0.78
Intention to use	0.75

To measure the internal consistency of statements a coefficient Cronbach alpha was calculated for the statements belonging to each construct specified in the research model. To consider the internal reliability of statements concerning the same construct as satisfactory Cronbach alpha should be greater than 0.7. The obtained Cronbach alpha values for each constructor except perceived ease of use are at a satisfactory level, as shown in Table 2. In the case of ease of use, the value is slightly lower, which may indicate minor differences between the statements formulated regarding this TAM factor.

Following the empirical study, intention to use was the most significant factor of the study followed by perceived enjoyment. Perceived usefulness was the factor with the less mean score items. Furthermore, PEU2 (the item with the less mean value and the highest standard deviation of the study) suggests that the AR tool was perceived as moderately useful to learn the basic principles of electromagnetism.

TABLE III. THE REGRESSION ANALYSIS

Dependent variable	Independent variable	Coef	R^2	p-value
Perceived usefulness	Perceived ease of use	0.34	0.08	< .02
Perceived enjoyment	Perceived ease of use	0.58	0.29	< .001

To verify hypotheses H1 and H2, regression analysis was used to examine the relationship between pairs of the appropriate constructors defined in the research model. All tests were conducted using a two-sided alpha level of 0.05. The results of the regression analysis are presented in Table 3.

For the H1 and H2, we reject the lack of dependence since the p-values were less than the assumed significance level of 0.05. Although the R^2 is low, low p-values still indicate a real relationship between the significant predictor and the dependent variable. From the regression analysis, it was found that perceived ease of use positively affect users' perceived usefulness and also users' perceived enjoyment.

TABLE IV. THE STEPSISE REGRESSION ANALYSIS

Dependent variable	Independent variable	Coef	R^2	p-value
Intention to use	Attitude toward activity	0.54	0.55	< .001
	Perceived enjoyment	0.31		< .01
Attitude toward activity	Perceived enjoyment	0.54	0.44	< .001

In order to investigate factors that affect attitude toward the activity and intention to use, we used stepwise multiple regression analysis to obtain the best models. The results of the analysis are presented in Table 4.

Following the empirical study, we found that perceived enjoyment and attitude toward the activity had a positive effect on intention to use the AR environments (R^2= 0.55). Therefore the results supported the hypotheses H7 and H8. From the models, intention to use is expected to increase by approximately 0.54 when the attitude factor increases by one.

The results also suggest that intention to use is expected to increase by 0.31 when the perceived enjoyment increases by one. It was also found that perceived enjoyment had a positive effect on attitude toward activity (R^2=0.44). Indeed, attitude through activity is expected to increase by 0.54 when the perceived enjoyment increases by one. Thus, H4 was supported.

VI. CONCLUSIONS

This study used the technology acceptance model to explore the undergraduate students' perceptions of an AR learning tool, their attitude toward it and their intention to use this technology to solve electromagnetism problems.

The findings suggest that perceived ease of use had a positive effect on perceived enjoyment but not on perceived usefulness. In this sense, it is worth noting that the problem proposed to students had a strong visualization component but it required to know how to apply different Physics formulae. The tool was designed to help students only in the visualization arena.

The study also found that perceived enjoyment has a positive effect on attitude toward the activity and intention to use the AR technology.

Therefore, the use of AR learning environments to solve electromagnetism problems could motivate students to perform learning activities.

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