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ARCHITECTURAL EDUCATION IN THE ERA OF MOBILE AUGMENTED REALITY TECHNOLOGY
التعليم المعماري في عصر تكنولوجيا الواقع المعزز المتنقل

Hala Adeeb Fahmy Hanna

Lecturer, Department of Architecture, Faculty of Engineering, Mattaria
Helwan University, Egypt

ABSTRACT

Humanity has witnessed a series of revolutions that transformed history. Today, the world lives in the era of technological revolution seen in scientific knowledge and the optimal utilization of the information influx. Technological development has swept across all societies into the everyday life, especially that of youths who are fascinated by anything new. Technology has become a fundamental aspect, it is difficult to disregard it due to the facilities and benefits that offers in all areas of life; especially education. As much as it has affected education, it did similarly to architectural education.

Although technology has revolutionized education in many countries of the world, in local practice to the present, there are ways of architectural education and teaching used traditional methods that no longer fitting the digital age or modern learner/ teacher thinking in that era, it is an obstacle to the development of education. In addition, architectural education lacks the on-the-job training that helps students understand the environment and practice the profession effectively after graduation. In fact, many different technologies have been integrated in the global educational arena that provide opportunities to design an attractive learning environment. One of these technologies is the use of Augmented Reality (AR) on mobile devices on a large scale. It is one of the latest technologies that provide a new educational method due to the popularity of mobile devices. It is also a new educational model to generate greater self-learning capacity on the student's part.

This study focuses on assessing the integration of mobile augmented reality (MAR) technology in architectural education by presenting some global applications. First, to explore their potential in architectural education. Second, study the impact of their application in some architectural courses on both ends of the educational process: the student and the university educators. Finally, to complete the vision, the difficulties of use are examined. Then study their applicability in the local reality. The study concludes with the most important research findings and proposed recommendations.

الملخص:

شهدت البشرية سلسلة من الثورات التي كانت بمثابة نقط تحول. اليوم يعيش العالم عصر الثورة التكنولوجية، وتتمثل مقوماتها في المعرفة العلمية، والاستغلال الأمثل للمعلومات المتدفقة. لقد غزا التّطور التكنولوجي كافة المجتمعات، وتسرّب إلى الحياة اليومية، وخاصّة إلى فئة الشباب الذين يفتنون بأيّ جديد. حتى أصبحت التكنولوجيّا من الجوانب الأساسية، وبات من الصعب التخلي عنها نظراً لما تقدّمه من تسهيلاتٍ وفوائد في كافة مجالات الحياة، وخاصةً التّعليم. وكما أثرت على التعليم كان لها أثر مماثل على التعليم المعماري.

بالرغم من أن التكنولوجيا أحدثت ثورة التعليم في العديد من دول العالم، إلا إنه في الممارسة المحلية حتى وقتنا الحاضر هناك طرق للتعليم والتدريس المعماري عالقة في الماضي وتستخدم الطريقة التقليدية التي لم تعد تناسب العصر الرقمي أو تفكير المتعلم والمعلم في ذلك عصر، كما تعد عائقاً أمام تطور التعليم. بالإضافة لذلك، يفتقر التعليم المعماري إلى التدريب العملي الذي يساعد الطالب على فهم البيئة وممارسة المهنة بفاعلية بعد التخرج. في الواقع، تم دمج العديد من التقنيات المختلفة في الساحة التعليمية العالمية وتوفر فرصاً لتصميم بيئات تعلم جذابة. إحدى هذه التقنيات هو استخدام الواقع المعزز على الأجهزة المحمولة على نطاق واسع. وهي واحدة من أحدث التقنيات التي توفر وسيلة جديدة للتعليم نظراً للشعبية العالمية للأجهزة المحمولة. وهي نموذج تعليمي جديد لتوليد قدرة أكبر للتعلم الذاتي من جانب الطالب.

تركز هذه الدراسة على تقييم دمج تكنولوجيا الواقع المعزز المتنقل (MAR) في مجال التعليم المعماري من خلال عرض لبعض التطبيقات العالمية. لاستكشاف أولا إمكانياتها في التعليم المعماري. وثانياً دراسة تأثير تطبيقها في بعض المقررات المعمارية على طرفي العملية التعليمية: الطالب والمعلم الجامعي. ولاكتمال الرؤية يتم أخيراً التعرف على صعوبات الاستخدام. ثم دراسة قابلية تطبيقها في الواقع المحلي. وتختتم الدراسة بأهم النتائج البحثية وعرض التوصيات المقترحة.

***Keywords*:** reality-virtuality continuum, augmented reality, mobile augmented reality, context-aware learning, mobile augmented reality techniques, architectural education.

1. INTRODUCTION

Architectural education aims to prepare the students by providing them with knowledge areas that suit the needs of the society and the environment and provide a database that is used in professional practice efficiently and effectively. Given the scientific and technological revolution worldwide, architectural education has become required to search for new educational methods to face many challenges. Therefore, there is an increasing interest of university professors and researchers in introducing new useful methods to improve the architectural teaching and learning process where they look forward to adopt new technologies to enhance the learning experience. Mobile Augmented Reality technology is one the growing technologies that has been integrated into the global educational arena and is changing the way students' vision and interact with their environment.

1.1. PROBLEM

Two major themes constitute the study problem:

First: architectural education is an issue affecting professional practice must assist the student to transform knowledge into practical concepts that enable him to understand the environment. However, today, many architectural generations practice so-called theoretical practice, which led to apparent lack in the professional performance of the architect after graduation, where faces many situations and makes decisions not exposed during the educational process. Prof. Kamal Riad in the article "Egyptian architecture between present and future" explains that there is a mismatch between the educational curriculum in architecture schools and what the graduate collides with, for several reasons including lack of educational programs into practical training [1].

Second: architectural education is a guided process based on the transfer of architectural knowledge and foundations from university educator to the student with a view to develop his architectural trends and ideas. There are multiple effective ways to transfer knowledge. However, the majority of local practice follows in teaching many architectural courses using methods, which rely on the educator's effort to provide information, in which the student receives an education negatively from a specific source of information without effective methods contribute to his interaction with it, as well as the weak participation in the learning process. In addition, using this method is due to that the educational techniques that appeared in previous periods and may play a role in the advancement of architectural education is high cost. Prof. Ahmed Rashed, al-Mansoura university confirms that: "in architectural education, some still insist on teaching from one or two main references (limited sources of information) and through a method based on memorization, conservation and restoration of a single information" [2].

1.2. HYPOTHESIS

The main hypothesis of the study is based on that integrating mobile augmented reality technology as a new technique in the architectural education process (many architectural courses) contributes to:

A. Offering empirical and exploratory education in real-world environments;
B. Providing architectural student with a great capacity for contextual self-learning;
C. Raising the efficiency of architectural education; thus improving academic results; and
D. Creating an attractive and entertaining educational environment at low cost.

1.3. OBJECTIVES

This study aims to answer the questions as follows:

- Major question: What is the added educational value of this technology to architectural education?
- Does MAR technology change the roles of both architectural educators and students entirely?
- Does this type of technology change the current phase of architectural education?

In this context, the appropriateness of integrating Mobile Augmented Reality in architectural education is assessed by:

A. Exploring the possibilities of MAR technologies in architectural Educational contexts (teaching + learning);
B. Examining the impact of applying MAR technologies in some architectural courses on:
   - Architectural Student's abilities (as the main target of the educational process) and his role; and
   - The role of the architectural university educator.
C. Discussing the difficulties of using MAR tech.

The different results are reached by reviewing some of the recent educational applications implemented using MAR techniques in architectural education. To assist the university architectural educator in formulating innovative educational methods using this technology works on the development of the architectural educational environment.

1.4. METHODOLOGY

To achieve the research objective, the study addresses following points:

- **Theoretical framework**: identifying the basic concepts of the study and its technical hardware.
- **Analytical framework**: consists of two main factors
  - Studying and analyzing MAR technology affordances in education.
  - Studying and analyzing MAR techniques and applications in architectural education.
- **Applied framework**: conducting a simplified application study to determine the applicability of

MAR technology in the architectural education in the local reality.

2. AUGMENTED REALITY

Augmented Reality (AR) is one of the new 'realities' and novel concepts emerging nowadays, has attracted much research attention in recent years. Before understand its definition, need to take a brief look at where AR is located concerning other realities.

2.1. AR in relation to other realities

In 1994, Paul Milgram et al. coined the term "Mixed Reality" (MR) and defined it as "... anywhere between the extrema of the Reality-Virtuality continuum", i.e. extending from the completely real to the completely virtual environment and involving the integration of real and virtual worlds. Between these two extremes, there is an augmented reality (AR) (closer to the real environment) and augmented virtuality (AV) (closer to the virtual environment) [3, 4] as in Fig.1.

In addition, AR is related to the concept of mediated reality, an older than MR. Mann described it as the devices that deliberately modify reality in various ways; in other words, it is a general framework for artificial modification of human perception by way of devices for augmenting, diminishing for altering sensory input [5]. In this sense, mediated reality is a proper superset of mixed, augmented, and virtual reality, as it also includes diminished reality. So, AR is a special case of mediated reality [6] as in Fig.1.

Milgram's Continuum, [7] Mann's Diagram [5]

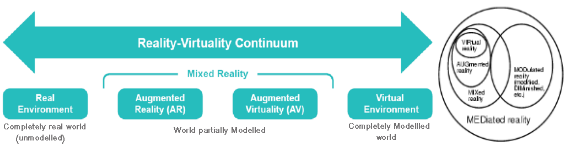

Fig.1. AR as part of Milgram's continuum & special case of Mediated reality.

2.2. Understanding AR

The term "augmented reality" was coined by Prof. Tom Caudell in the early 1990 [5]. In an attempt to discover its definition, many complementary definitions to each other with a common feature were found. AR according to the dictionary is defined as "a system or technology used to produce such an enhanced environment as viewed on a screen or other display, produced by overlaying computer-generated images, sounds, or other data on a real-world environment." [8]. From the point of view of technology devices, AR can be defined as a set of techniques and tools that allow adding digital information to the physical reality [9]. A more precise definition presented by Azuma in 1997 and has become the most used academic definitions: "a system involving three criteria: (a) the combination of virtual and real-world elements, (b) which are interactive in real-time, and which (c) are registered in 3D" [10].

Based on the previous review, AR is one of the forms of artificial modulation of human perception by devices (as a case of mediated reality), applied to situations which including the merging of the real and virtual worlds (as part of mixed reality). In addition, it involves the real-time immersion of digital augmentations in a physical space, as in Fig.2.

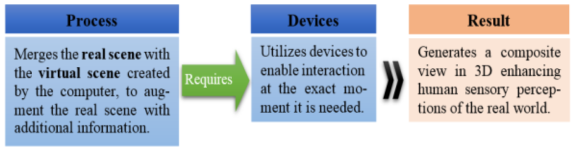

Fig.2. The concept of AR technology. Source: researcher.

From the previous definitions, the process of enhancing the reality is done through some hardware, overviewed briefly in the following section.

2.3 Overview of AR hardware technologies

AR hardware comes in many shapes; hence, a diverse, and complicated field. Types of AR devices, according to Azuma's taxonomy, the most used by researchers and depending on the position between the viewer and the real environment, are [11]:

A- **Head-Mounted-Displays (HMD)**: a display device worn on the head, and having a small display optic. HMDs include headset glasses, a helmet, a visor and contact lenses [12]; Fig.3-1.

B- **Handheld displays (HHD)**: a small display held in a user's hand. HHD includes mobile devices such as smartphones, tablets, notebooks, etc. [11]; Fig.3-2. In previous devices, a camera captures the real world image, then the virtual content is superimposed on it, and the integrated image is shown on the screen.

C- **Spatial Displays (SD)** /Projection displays: project virtual component onto the surface of physical objects either a single object (virtual table, wall) or cover the entire room. SDs use projectors, or holograms. SDs offer both 2D and 3D images [13]; Fig.3-3.

1-Head-mounted display [14, 15] 2-Handheld displays [16, 17] 3-Spatial displays [18, 19]

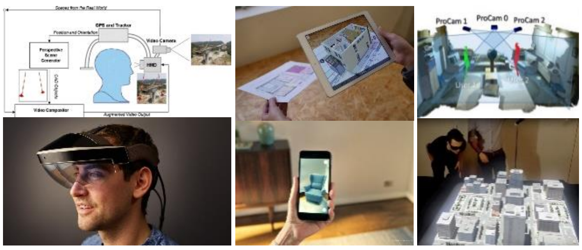

Fig.3. Different types of displays and hardware technologies used for augmented reality.

According to the previous review, the next stage will be concerned with the study of one type of devices used to enhance the reality, handheld displays or Mobile Augmented Reality in architectural education. This choice is based on several motives, firstly, that with the ongoing improvement of mobile devices, they have become low-cost, easy to use and lightweight. As a result, they become an indispensable part of life. Secondly, in education these days, almost each student has a mobile device, carrying it all the time anywhere. They are also regular users of it. So, they are not required to carry anything to experience AR more than their devices. Accordingly, MAR is examined to determine its impact on architectural education.

3. MOBILE AUGMENTED REALITY (MAR)

When the AR experience is conducted on handheld displays or mobile devices, it is termed as Mobile Augmented Reality (MAR), is state-of-the-art technology that has revolutionized the way of accessing and interacting with information, thus invoking new expertise for users [20].

3.1 Definition of MAR

The simple definition for Dr. Alan B. Craig is that MAR "is AR that you can take with you wherever you go. This means that the hardware required to implement an AR application is something that you take with you wherever you go."[21]. In addition, Hollerer & Feiner defined MAR as "Mobile AR applies (the concept of AR) in truly mobile settings; that is, away from the carefully conditioned environments of research laboratories and special-purpose work areas."[22].

3.2 MAR in architectural education

Mentioned by the Emerging Technology Initiatives of New Media Consortium (NMC) in the most recent Horizon Reports (NMC 2010, 2011 and 2012), AR is one of the emerging technologies in teaching and learning. Now, AR are growing rapidly on mobile devices as a result of an increase in handheld computing usage in recent years across the world [23].

Hence, several important questions arise: Does this type of technology change architectural education in the current phase? What is the added educational value of this technology to architectural education? Does MAR technology change the roles of both architectural educators and students entirely? Thus, this part of the study aims at identifying changes that take place in architectural education in light of using MAR technology, exploring their potential in it, as well as studying its impact on the two poles of the educational process: the student and the university educators. In the context of evaluating the appropriateness of integrating MAR technology in architectural education. These objectives are achieved through reviewing and studying several modern empirical research papers that have been implemented by integrating MAR techniques in some architectural courses at the university level.

3.2.1 Affordance of MAR in education

In education, using MAR technology supports mobile learning (ML), a subfield of distance education that includes e-learning strategies, but it is enabling learning via wireless technologies and mobile devices. Also, ML incorporates ubiquitous learning (UL) [24]. Hwang and Chen indicate that UL happens without the restrictions of time and space. Thus, ML offers a new way to infuse learning into daily life. In addition, the idea of context awareness has received attention in the field of ML. Dey defined context as contextual information about an entity, which may be a person, a place or a physical object. It aims at providing learners with the information they need with the aid of sensing elements and wireless networking according to their physical locations. The most important context-aware technologies are Global Positioning System (GPS), Quick Response (QR) codes, and others [25- 26].

Recent research in ML explores the importance of context-aware u-learning which offers to the learner through combining different technologies many characteristics are Accessibility and Immediacy, Permanency, Interactivity, and Situated Learning [10]. Besides, it enables learners to step outdoors to real-life learning contexts, as H.-C. Chu, et al, indicated, also it can take any situation, location, environment, or experience to a completely new level of meaning and understanding, as J. Haag indicated [27].

In addition to the above, Mobile technology and AR applications represent one form of Information technology (IT) constituting a set of tools and applications that allow the incorporation and strengthening of new educational strategies. In accordance with Massy & Zemsky (1995), any methodology that promotes the inclusion of IT in teaching must have the following objectives:

- Personal production help: applications that allow both the professors and students to carry out tasks faster and more efficiently.
- Content improvement: the use of tools that allow for the notification and modification of content rapidly and efficiently (e.g., digital content, multimedia) without changing the basic teaching method.
- Paradigm change: the teacher reconfigures the teaching activity and learning activities to utilize the new incorporated technologies [28].

To incorporate a new IT based methodology such as MAR into a teaching environment, some recommendations for avoiding student rejection must be considered (so-called "good educational practices") From the characteristics that shape these practices, three points can be extrapolated, as follows [29]:

- Promotion of professor-student relationships, allowing for a more effective feedback process;
- Contribution to better task realization by heterogeneous learning methods that meet high expectations; and
- Applying teaching/learning methods based on teaching innovation and new IT technologies.

The interest of educators in using this technology in the teaching process presupposes greater engagement and an increase in student motivation in understanding the content, leading to improved academic results. Researchers believe that these new concepts could help generate a new type of student, much more dynamic and capable of participating more extensively in the educational process [28, 29].

3.2.2 MAR techniques

With context-aware ubiquitous learning, MAR allows to create and design innovative learning scenarios in real learning environments. Where, technically, MAR is divided into two primary types: marker-based and markerless MAR. Each type differs in its concept, objectives and implementation [30].

3.2.2.1 Marker-based MAR technology

The easy access to mobile devices with a camera and multimedia features, has generated a global explosion of the use of 2D markers, which have gone from industrial use to general use in any field [31].

General concept: Known as the object/image recognition, it utilizes different forms of images as markers, to provide a fixed point of reference to be an interface between the physical world and the AR content. These markers such as simple patterns (Quick Response-QR/2D code) or an actual real world image as building plans or real object, as in Fig.4, [30, 32].

Method of implementation: The marker system is composed of two major sub-systems: an AR materials remote server and an AR-based mobile system. The AR materials remote server enables educators or students to create AR-based learning environments by selecting the marker and the multimedia materials associated with course content, then loading it in the cloud database, in preparation for its presentation.

In an AR-based mobile system (AR application), students scan a marker using a mobile device camera to distinguish the marker from the other real objects. AR software recognizes this marker by matching with the saved content. Then the application is able to retrieve and overlay the stored AR materials on top of the marker. AR materials that replace the marker on the screen may be playing a short video, 3D models, images, location in Google Maps, web page or any kind of educational multimedia[33, 34], as in Fig.4.

This system allows the learner to investigate the virtual information in more detail and from various angles [30] Gayathri D., et al indicate that the use of markers by tutors for teaching or by the students themselves to learn, improves self-learning [35].

2D code [36] real image (paper plans)[37, 38]real object [39]

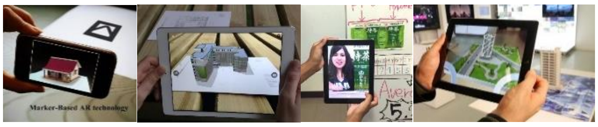

Fig.4. Different examples of use of marker-based AR technology in architecture education.

3.2.2.2 Markerless MAR technology

New advancements in mobile hardware and software technologies have led to the recent introduction of markerless AR, also known as Location-based or Position-based AR.

General concept: is a term used to denote those AR systems and/or applications that do not require any pre-knowledge of the user's environment to overlay 3D content into a scene. It is a technique maps unknown surroundings and identifies its own localization at the same time based on different types of triggers, such as GPS, digital compass, velocity meter, or accelerometer, which are embedded in the device to provide location-based data [30, 40].

Method of implementation: The markerless MAR system is also composed of the same two major sub-systems of marker system. After creation of the 3D content, and through the AR material remote server, this content is uploaded in any storage method mentioned above without association with any marker. When visiting the site, after recognizing and displaying it on the screen of the device, and through MAR application, the stored material is downloaded and superimposed on the real environments to visualize the 3D content in the real context [24].

3.2.3 Applications of MAR techniques in architectural courses

Several modern empirical research papers have been carried out about architectural education, which incorporated MAR techniques in some educational courses, tested their effects, and evaluated their usefulness. Some of these studies will be reviewed in the context of answering the previous research questions and assessing the integration of MAR technology in architectural education.

3.2.3.1 Application 1 [28]:

Study objective: David Fonseca and his colleagues proposed the implementation and evaluation of an experiment MAR technology in the presentation of architectural projects and the visualization of a group of layouts & 3D models by students of architecture and building engineering. The proposal was based on the premise that the use of MAR in the classroom highly correlated with motivation and academic achievement. The objective was to assess the feasibility of using MAR in educational environments and to investigate the relationship between the usability of the tool, student participation, and the improvement in academic performance after using MAR. Results were obtained from pre- and post-tests.

Course and participants: The project was modeled by the CAD/BIM Group of the Architecture Department of La Salle Barcelona, Ramon Llull University. The study was performed during the 2011-2012 academic year with students in their third year for the "Representation Systems II" course. To conduct the experiment the students were divided into two groups: those who took the course for the first time, and those who were repeating the course, but at the first time used a traditional system through printed layouts for information.

Educational activity & implementation procedures: The experiment consisted of making an innovative gallery to represent a group of the layouts, information, and graphic content for the some selected projects. Graphic information and project documents were collected, classified and organized in a public internet site. The final work consisted of a set of six colors-printed images 20 × 20 cm, each having the QR code, which allowed any visitor to the gallery having a mobile device with the required applications to access the virtual content: videos, 3d models, websites, etc. The final presentations were made in a public exposition at the university, as shown in Fig.5. Study details are described in Fonseca et al. (2014).

Experimental results of the students' pre- and post-tests showed several aspects:
Students evaluated AR as a technology easier to use than was expected, which improved their motivation and participation, and led to an improved academic performance. The overall assessment was approximately 3.5 points out of 5, confirming the feasibility of using MAR in educational settings. As the results indicated that MAR technology was a good system to visualize simple models, it was less able to display more complex models, either in detail or in volume. This problem is directly related to the screen size and the scaling method within the application. The results also showed some problems, such as the 3D model shocks when displayed on screens. Some colors and materials that were used in AutoCAD, 3DMax, Sketchup were not imported correctly into used AR application.

With regard to course activity, the capacity to generate physical and digital galleries by MAR has led to active students, with significant improvements in research and interaction skills, particularly with virtual content; thus, maximizing the learning process.

Fig.5. Different presentation strategies of architectural projects using QR codes, Source: [41].

3.2.3.2 Application 2 [24]:

Study objective: Ernest Redondo and his colleagues presented an educational experience using AR on mobile devices as a tool for learning urban design concepts for architecture students. The main objective was to evaluate the usability of technology as well as the learning and academic performance improvement of students using this technology. The working hypothesis was that using advanced visualization methods for architectural and urban proposals, the students would improve their spatial skills, which are one of the most important competencies to develop. To validate the hypothesis, the participants were asked to answer pre- & post-experiment questionnaires.

Course and participants: The experiment was conducted by students in the Computer Applications, and Architectural Representation III courses. For this purpose, the class was divided into two groups: a control group (CG), who followed the conventional course in the laboratory, and a test group (TG), who used MAR technology. The case study was on Flassaders Square, Barcelona. Details of the study are described in Redondo et al. (2017).

Educational activity & implementation procedures: The experience focused on designing outdoor spaces & architectural interventions in urban environments with marker-based MAR technology, i.e. based on optical image recognition of elements in the environment that act as markers. In the experiment, the students designed, analyzed, developed and presented scenarios for an urban sculpture by generating its virtual models. Then through MAR technology, 3D models were visualized in their real space, and suitability checked in terms of form, scale, location, materials, etc., taking the surroundings into account. Students were also able to examine the proposals of their fellow students and discuss the proposals made by each member to adjust the scale of their model to fit the environment.

Experimental results: The CG students made disproportionate proposals in comparison to the TG students who were able to visualize, discuss the proposals of each member in site in addition to adjust its sizes. Using MAR applications resulted in a significant improvement in the students' academic performance, as shown in Fig.6. Besides, experimental results of a comparison between TGs and CGs showed that despite the initial similarities of grades at the beginning of the course, there was a significant improvement in TG grades. The overall assessment was rated 4.18 points out of 5. This gives an idea of the degree of satisfaction achieved. As the results suggested, the combination of an attractive technology and the user-machine interaction that AR entailed making students feel more motivated as well as contributed to a better understanding of basic concepts, such as the scale and position of sculptural elements in the urban space. It supported the hypothesis that AR technology was a valuable educational tool in architecture and urban planning and design.

However, experimental results showed some problems; for example, used markers had to be placed within 10-15m of the users due to technical limitations imposed by the resolution of phone cameras. This created problems because it was not possible to move away from the marker to get a wider perspective of the environment. As such, the most obvious result was that the size of the sculptures using AR visualization should not exceed 2.5 meters in the height to be adjusted.

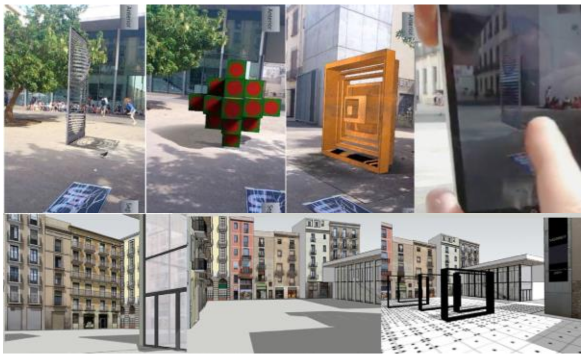

Fig.6. Viewing generated models on location (top row); urban with early intervention proposals (bottom row); Source: [24].

3.2.3.3 Application 3 [29]:

Study objective: Albert Sánchez and his colleagues addressed the implementation of the MAR tool in architectural education that aimed at evaluating the feasibility and effectiveness of this new and non-traditional technology in educational settings through an assessment of motivation. In order to prove these aims, on-site questionnaires were designed about the use of MAR technology and software, which were conducted after the experiment was completed.

Course and participants: The experiment was carried out with students of Architecture and Planning during the academic year 2011-2012 in an elective course called ''ICT applied to Spatial Analysis'' taught in the Research Master in Land Management and Valuation at UPC, Barcelona-Tech. The researchers worked at Barcelona Knowledge Campus.

Educational activity & implementation procedures: The experiment focused on the use of MAR technology in urban design. The proposed approach was based on visualization of virtual new buildings proposals, and visual impact assessment on the planned site through mobile devices in the architectural design phase, as in Fig.7. This work used a geo-location-based AR application (based on a GPS) to register virtual information on real space. This was done by linking the 3D models to virtual information channels through a database that contained their geolocation in real positions. In the experiment, all groups evaluated the models of the other groups on-site. The questionnaire was accessible through a descriptive label on the display or by pressing on virtual models to respond and make comments about appearance, impact and scale of the building.

Experimental results: the global opinion was rated very positively, despite having no prior knowledge of it. The overall assessment was rated at 4.27 points out of 5, which confirmed the feasibility of using MAR in educational environments. In relation to MAR technology and software, responses confirmed that performance improvement of handheld devices has made them useful tools for using AR technology in architecture. In relation to usability, the results showed that despite the limited interaction with the small size of their screens, it seemed to be enough to guarantee the feasibility of these experiences. However, the researchers believe that greater computational capabilities are needed (complex model rendering, or simultaneous analysis of several options). The results concluded that geo-location, AR, and mobile technologies are becoming accessible and easy to use, and increasing student satisfaction and interest in the course content, as they feel very motivated.

Fig.7. Visualization sequence of geo-referenced models (top row); 3D model visualization and questionnaire responses on the site (bottom row); Source: [29].

3.2.3.4 Application 4 [33]:

4. DISCUSSION AND RESULTS ANALYSIS

Based on the detailed review explained in the previous section, the research in this section aims at assessing the appropriateness integrating MAR technology in architectural education. This is achieved first through an analytical study to explore the possibilities of applying different MAR techniques on architectural educational contexts (teaching + learning); as illustrated in the following Table 1:

Table 1: an analytical study of the instructional potentials of applying different MAR techniques on architectural education. Source: researcher.

<table>
<tr><th colspan="3">MAR Techniques</th><th>Marker-Based MAR technology</th><th>Markerless MAR technology</th></tr>
<tr><td rowspan="3">The potentials of MAR technology</td><td rowspan="2">potentials for architectural education contexts</td><td>Teaching</td><td>- Improves teaching by enhancing the architectural scientific materials with digital multimedia information (3D models, videos, or any content related to architectural concepts).
- Helps to explain technical concepts related to architecture.</td><td></td></tr>
<tr><td>Learning (through learning activities)</td><td>- Improves architectural presentations.
- Gives a deeper understanding of educational content & basic concepts related to architecture and perceiving more information by interacting with educational multimedia content.
- Improves the visualization of the architectural project designs and engages with the design by enhancing 2D blueprints with 3D models.
- Overlays the 3D model on the project site.</td><td>- Conducts architectural studies outdoor.
- Increases awareness and understanding of the real-world environment.
- Visualizes and checks the architectural design proposal in its natural environment.
- Allows for the comparison of different scenarios of virtual architectural proposals.
- Helps to adapt architectural proposals with the environment, avoiding problems of scaling, lighting, and texturing.
- Helps to evaluate the impact of urban proposals on their planned site.
- Improves workflow of urban planning and design, where helps the evaluation of the outcomes of decisions before they are materialized.</td></tr>
<tr><td colspan="2">General potential</td><td colspan="2">- Offering context-aware ubiquitous mobile learning that enveloping the learners anywhere at anytime
- Allows for the creation and showing of images impossible to exist in reality.
- Providing interaction between the learner and the real-world contexts (places, multimedia content, …..)
- Providing self-learning opportunities.
- Stimulates involvement more extensively in the educational process through learning activities.
- Stores learning processes in the cloud or otherwise and consumes them anytime and anywhere.</td></tr>
</table>

Based on the previous table, many results can be derived, the most importantly:

- Applying MAR in architectural education provides valuable educational potentials for teaching and learning.
- MAR offers new potentials for architectural education, more specifically in learning, where it provides real time and contextual learning experiences both inside and outside the classroom.
- Marker-based MAR technique uses and provides a new way for both teaching and learning.
- MAR technology liberates education from space and time limitations.

As for the research questions, it is clear that:

- The most important added educational values for applying MAR in architectural education is:
  - Providing realistic exploratory education by integrating architectural knowledge with the empirical dimension in real environments, which transforms the educational environment to a more lively and interactive experience.
  - Improving teaching by enhancing the scientific content with digital multimedia materials
  - Generating new paradigm for contextual self-learning.
- We are facing a new stage of technological development moving towards changing the current stage of architectural education and perhaps the future, because it has the power to push the contextual learning anywhere and anytime.

In the framework assessing the integration of MAR technology in architectural education, the impact of its application on the two poles of the educational process is studied. First, explore the result of its application on the architectural student's capabilities, whether architectural or educational. Then, on his role in the educational process by comparing it with his role in traditional education. The following tables (2, 3) illustrate these:

Table 2: an exploratory study of the impact of MAR technology application on the different abilities of the architectural student. Source: researcher.

Impact of applying MAR techniques on architectural student's abilities	
Effects on educational capabilities	**Effects on architectural capabilities**
- Strengthens the motivation for learning. - Enhances self-learning. - Achieves a deeper level of understanding the educational content through interaction with it. - Increases awareness. - Improves academic performance. - Improves academic outcomes resulting from understanding content.	- Enhances sensory perception of reality. - Improves visualization. - Gives the ability to interact with, understand and interpret real world contexts. - Improves spatial skills. - Encourages experimentation.

Table 3: a comparative analysis of the behavior and role of architectural student in both MAR-based education and traditional education, which illustrates the extent of change in their role. Source: researcher.

Aspect of comparison	**MAR- based education**	**Traditional education**
Role & behavior of architectural student	- Partner in the learning process through conducting educational activities. - Self-learning learner. - Interacting positively. - Sharing ideas, discussing alternatives. - More active and dynamic learner. - High level of reflection.	- Recipients of scientific contents. - Listen and take notes. - Largely passive absorptive. - Passive attendees. - Low level of reflection.

Based on the previous tables, the following results can be drawn:

- Using MAR technology in architectural education:
  - An architectural student can experience a different form of learning based on "learning by doing" with the ability to visualize, which helps him practice architecture in the real environment by conducting educational experiments that enable him to understand the environment, make decisions, and evaluate their results during the design process before they are realized.
  - Encourage the architectural student to explore learning materials through interaction with them.
  - The student role has changed completely from a passive behavior to an active and more dynamic role:
    - Capable of participating more extensively in the educational process through conducting contextual learning activities that improve his academic performance and skills.
    - Capable of self-learning and building of knowledge and understanding through interaction with educational content, which leads to improving his academic outcomes.

Completion to study the impact of MAR technology application on the two poles of the educational process. Second, the role of architectural university educator and the extent of change it in the educational process is explored during applying this technology, by comparing it with his role in traditional education. The following table (4) illustrates this:

Table 4: a comparative analysis of the role of university educator of architecture in both traditional vs. MAR-based education, which illustrates the extent of change in his role. Source: researcher.

Aspect of comparison	MAR- based education	Traditional education
Main role of university educators of architecture	- **Educational Designer**: designs educational activities and experiments whether indoor or outdoor consistent with the course objectives. - Helps students become self-educated learners, and develop their abilities. - **Technologies**: provides a climate of learning consistent with the technology used. - Solves technological obstacles students face during the practice of educational experiments. - **Adviser**: gives advice and guidance to students during educational activities. - Provides effective feedback process.	- **Expert**: Provides and transfers knowledge and scientific content. - A source and guide for knowledge. - **Educational facilitator**: facilitates content understanding for student. - Sets procedural goals for education. - Manages completely educational process.

Based on the previous table, the following results can be drawn:

- The use of MAR technology, adds to the role of university educator of architecture in providing of scientific content and defining educational goals, many roles that are:
  - Employing modern technologies as MAR in the educational process.
  - Designing exciting educational experiences that connect students to the real-world environment and achieve the objective of the course.
- The role of architectural educator departs significantly (with respect to student) from its traditional role in the transfer of knowledge only to the role of mentor, advisor and counselor to his students at all stages of the educational activities, as well as facilitating the learning process to them.
- MAR technology changes education by changing the role of architectural educators from a teacher-controlled education to a student-oriented learning.

To complete the evaluation of the appropriateness of integrating MAR technology in architectural education, the problems of applying this technology, which emerged during the various experiments and applications described in the previous part of the study, are explored and identified. The following table (5) illustrates them:

Table 5: an analytical study of the problems of applying MAR technology in architectural education. Source: researcher.

MAR implementation problems in architectural education.	Problems related to Mobile devices	- AR technology was not an optimal fit to visualize complex architectural models either in structure or in volume because of its direct association with the screen size and the method of scaling within the application. - Low degree of immersion provided by devices as well as limited interaction with the small size of screens. - Limited computational capabilities. - Inability to get a wider perspective of the urban environment during the experiment because the user could not be 10: 15m away from the marker due to technical limitations imposed by the resolution of the phone camera.
	Problems related to AR	- Some colors and materials used in 3D programs were not imported correctly into the AR application. - 3D models shook when displayed on mobile device screens.

Based on the previous table, the following results can be drawn:

- Most of the problems related to the technical aspect, according to the rapid growth in the technological sector globally and its achievements so far, these problems require more technical development, flexibility and stability in its applications to improve performance and increase adaptation with architectural content.
- In relation to the size of mobile screens and the usability in various architectural learning activities, the experiments proved to be enough to guarantee the feasibility of these kinds of experiments, but they were not an optimal fit to visualize complex architectural models.
- It was noted that all the problems that emerged during the various applications, did not obstacle the use of this technology in the process of architectural education.

5. APPLICABILITY OF MAR TECHNOLOGY IN LOCAL REALITY

MAR technology has emerged in the field of architectural education on the global stage, as presented in previous sections, as one of the options that offer a realistic, empirical and exploratory educational experience, as well as a new paradigm for contextual self-learning. Therefore, this phase of the study seeks to identify the applicability of MAR technology to activate it in the local arena.

As university architectural educators are responsible for applying this technology and motivating students to use it. A simple survey was conducted through personal interviews to get the views of some teaching staff and their collaborators who are teaching different architectural courses in the Department of architecture, faculties of Engineering, different Universities, in order to determine the applicability of this technology in university architectural education in the local reality.

The interviews were based on two main pillars: the first was characterized by the presentation of MAR's techniques and their various possibilities in architectural education and its impact on the role of both the architectural university educator and student in the educational process. While the second examined the applicability of MAR's techniques in various architectural courses and Are there reasons for non- acceptance?

Based on the compilation and analysis of the views of some of those who teach the university architectural courses, for the purpose of this applied study, the following conclusions can be drawn:

- The new possibilities for teaching and learning, and the various positive effects of MAR's techniques has admired by most of architectural educators.
- Despite this admiration, but views varied about welcome and willingness to incorporate this technology into their architectural courses, where faced integrating MAR techniques resistance from most of the faculty members.
- The reasons for their resistance to integrate this technology are due to there are many local challenges that may impede its application in architectural education at the local reality. The researcher classified these challenges, which are summarized as follows:

A-Challenges facing the architectural university educators:

- The large number of tasks and burdens required from the architectural university educators such as teaching and scientific research tasks and the burden of examinations, control and quality of education works, where educational activities add additional burdens require a lot of time and effort to train and provide full support for students permanently.
- Lack of sufficient conviction with this type of education, which might infect the educational process failure. This is due to the skepticism about the effectiveness of the MAR technology compared to traditional methods, especially the experimental local studies that measure its effectiveness in architectural education is nonexistent.
- Many architectural educators lack the skills and abilities of computer professionals in general and MAR technology mechanisms in particular.
- Lack of specialized and professional human resources in MAR technology to assist the architectural educator in solving technical problems that facing him or facing students during the practice of learning experiments.

B- Technical and Financial Challenges:

- The financial difficulties of implementing such a modern technology in the local reality, which is the financial burden required from the governmental university institution to provide the necessary infrastructure for wireless networks.
- The heavy reliance of MAR technology in education on wireless networks, which requires the efficiency of these networks permanently and high speed so as not to cause many crashes during implementation.
- The rapid and progressive development of technologies makes it difficult for many architectural educators to keep pace with him.
- Smartphones for most students in the department may have a small screen which reduces the interaction with various educational contents.

It is clear from the applied study, that despite the prominent role of MAR technology in architectural education, which appeared in a discussion of the results mentioned above, there are many difficulties and challenges facing the application of this technology in local reality.

6. CONCLUSION

From the above discussion demonstrates the feasibility of using MAR technology, its appropriateness and its effectiveness in architectural educational environments, where it contributes to:

1- Add many of the valuable potentials in both architectural education contexts, teaching and learning, the most important of which is the provision of exploratory education in real environments, as well as to improve teaching by enhancing the scientific content with digital multimedia materials and generate new paradigms for contextual self-learning, through real-time and contextual learning experiences.

2- Improve performance and skills of architectural student, and transform him into an active and more dynamic student. By enabling him learning based on "learning by doing" with improving his ability of visualization in real environments that enhances his understanding and interaction with the environment, and how to evaluate the results during the design phase to take the necessary decisions. Besides providing him with the ability to participate in the educational process by enhancing motivation for self-learning and building knowledge and understanding.

3- Add several roles to the architectural university educator, which is the design of contextual learning experiments both inside and outside the classroom, in addition to facilitating the learning process for students and provide instruction, guidance and feedback to them in all stages of learning activities.

4- Create an attractive and entertaining learning environment at low cost, where each student uses his personal mobile device.

5- There are no difficulties obstructing the use of this technology in the architectural education process, most of the problems that emerged during the various applications related to the technical aspect.

Despite the prominent role of MAR technology in architectural education there are many difficulties and challenges facing the application of this technology in local reality.

The presented results enable to assist architectural faculty members, especially those interested in MAR technology in formulating innovative educational methods that develop the architectural learning environments, which lead to raise the efficiency of architectural education and improve performance and skills of architectural student that qualify him to practice after graduation.

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