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A CONCEPTUAL FRAMEWORK FOR ENRICHING ARCHITECTURAL CLASSROOM WITH MOBILE AUGMENTED REALITY

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ABSTRACT
Due to the emergence of digital technology and its necessity in their lives, students of architecture are facing many challenges in this digital era. Unfortunately, it did not succeed the same way in their education as in architectural practice. By away or another, traditional architectural classrooms still depend on obsolete visualization methods and traditional approaches. On the other hand, many architectural students are complaining of lack of interaction and real engagement with the learning environment. Many studies have revealed that architects are "digital natives "and "visual learners", for that; they are in need of an innovative visualization tool to support their style of learning. This study utilizes Mobile Augmented Reality (MAR), technology as an innovative tool for enriching architectural education. Although, engaging MAR technology in architectural classroom is not a new idea, yet it is still not widely applied due to many different reasons. Educators still insist on using the same traditional methods, they still do not know how MAR should be integrated in their teaching strategies. For this purpose, this study is presenting, a conceptual model for integrating the basic concepts of MAR technology in architectural education based on one of the Instructional Design (ID) models and Student-Centered Learning, (SCL) approach. The mod el works as a key guide for architectural educators to design a successful instructional environment that is planned with ID models. This paper presents the key concepts of the framework and the related learning theories, its potential applications, current challenges and future directions. Experiences and lessons learned and presented in this paper could help architectural educators to plan, design and develop their MAR educational experiences.
Keywords : Architectural Education, Student-Centered Learning (SCL), Visual Learning, Edutainment, Mobile Augmented Reality (MAR), Instructional Design (ID.)

ملخص البحث
يواجه معماريو المستقبل العديد من التحديات في عصر التكنولوجيا ؛ وأهمها تدخل التكنولوجيا الرقمية والمنافع العديدة التي تقدمها لهم في حياتهم العلمية والعملية.الا انها لم تحرز نجاحا في مجال التعليم المعماري كما أحرزته في الممارسة المهنية حيث انه لاتزال الفصول المعمارية في الوقت الحالي تتبنى أساليب التعليم التقليدية .ومن ناحية أخرى ؛ يُشكو العديد من طلاب العمارة من قصور التفاعل والمشاركة الحقيقية مع بيئة التعلم الحقيقية .فلقد أثبتت الدراسات أن المعماري هو مفكر مرئي يحتاج الى أدوات تعزز أسلوب التعلم التصوري وتقترن باساليب التعلم الذاتي و نتيجة لذلك؛ اقترحت هذه الدراسة أداة تعليمية مبتكرة وهي تكنولوجيا الواقع المعزز النقال . حيث تعمل على نقل مسار العملية التعليمية من المعلم الى الطالب بالتكامل و الدمج لعدة مفاهيم تربوية حديثة أهمها التعلم الذاتي والتعلم النقال بهدف زيادة دافعية التعلم والادراك. وعلى الرغم من الأثر الايجابي لتقنيات الواقع المعزز على طلاب العمارة وانجذابهم لها كاداة مبتكرة لتعزيز التعلم المرئي ,الا أن عدم انتشار أساليب

واستراتيجيات تعليمية واضحة لدمجها في سياق التعليم المعماري وتجنب المعلمين والمؤسسة التعليمية لهذه التقنيات؛ أدى الى تقليص فرص استخدامها في الفصل المعماري. وحتى مع تقبل هذه الفكرة، فانه لا توجد خبرات كافية للتعامل تقنيا وتربويا مع هذه الادوات.لهذا هدفت الدراسة الى تقديم تصورمقترح يعمل كدليل ومرشد رئيسي للمعلم والمصمم التعليمي في تصميم بيئة تعليمية ناجحة للتعليم المعماري تقوم على أساس استراتجية التعلم الذاتي ومدعمة باحد تطبيقات الواقع المعزز النقال والمتوفرة في التطبيقات المتاحة حاليا في الهواتف الذكية.وقد بني هذا التصور على أساس أحد نماذج التصميم التعليمي بهدف ان يمثل اطار نظري ليدعم كلا من احتياجات طالب العمارة المعاصر و امكانيات تكنولوجيا الواقع المعزز النقال .

1. Utilizing Mobile Augmented Reality in Architectural Education

Some researchers consider future architects as "digital natives" and "visual learners", (Shirazi, et al. 2014). They need a powerful digital visualization tool to develop their architectural learning process to go beyond the traditional Teacher-Centered Learning (TCL) and the conventional learning tools. Nowadays, free digital applications, web and mobile computing technologies combined with "Mobile Learning", (M-learning) concept has widely spread. Broadly speaking, M-learning is the next innovative level of E-learning (Anshari, et al. 2017). According to (Parhizkar, et al. 2012), it is the delivery of learning content to learners utilizing mobile computing devices.

This study assume that with the success obtained in various educational areas as military, art, urban planning and different architectural fields in using mobile augmented reality as an educational tool for teaching architecture based a " Student Centered" teaching approach. Research reveals that MAR has a positive potential for architectural students in experiences with regard to different evaluation criteria such as (increasing motivation, social skills, feasibility and overall improvement their academic performance), (Redondo, et al. 2013), (Abdullah, et al. 2017), (Kassim, et al. 2016) and (Domínguez, et al. 2014).

Recently AR techniques begin to be applied in our Egyptian universities, in a study by experiment, in Shebin El-kom University three different architectural case studies was performed for examining MAR's approach on architectural students regarding different case studies in different architectural disciplines such: the building construction, architectural design and landscape design courses .The study showed that students was satisfied regarding using MAR techniques, they had a positive impact on their academic performance based a self learning experience, their learning motivation, spatial skills and perception was improved. (El-Sayed, M., 2016). In Addition, in a study by (El-Sayed, N., 2011) performed in Banha University, MAR had a great acceptance among students, they were satisfied by the efficiency of this tool for learning history, art, science and biology.

Multiple innovative learning opportunities may be generated in the field of architectural education due to the integration of mobile devices with AR as MAR can potentially be used in photographing buildings, construction elements, serve as a means for sharing interests with friends and promoting direct interaction among students anywhere and anytime (Wolpers, et al. 2011). Although, earlier researches have proven the benefits of MAR in education and architectural education fields, they are still not implemented on a large scale due to the educators' limited programming skills that are essential for 3D modeling and multimedia development (Abdullah, et al. 2017). In addition, when educators accepted the idea of integrating these technologies in their teaching strategies, "they really do not know how it should be embedded" (Redondo, et al. 2012). *Consequently, this study is not aiming to prove the effect of MAR on architectural students; rather the study is emphasizing the lack of clear instruction strategies regarding this tool in architectural education from the educator's perspective. For that purpose, a conceptual model is presented to answer the main question posed by the architectural educators: What steps should I follow while designing a MAR learning experience?*

1.1. Architectural Education towards a Shift in Pedagogy Directions

MAR techniques have an innovative impact upon student learning and potential in transforming learning environments from a physical to virtual environment. These techniques allow for the SCL experience with regard to all students at their own personal mobile devices.

Each student has his own rhythm of thinking so he should have his own learning environment. Hence, this study proposes a pedagogical vision shift via MAR capabilities. There are three shifting axis connect to "Constructivism", "Mobility" and "Virtual Learning Environment" concepts as illustrated in Figure. (1)

From TCL to SCL: MAR will allow for more potential for "*Student-Centered Learning" SCL* or "*Constructivism*" concept in a broader way. Students construct their knowledge through direct interaction with the 3D learning content and supportive online information, by building on MAR's ability of linking with GPS and internet. This new approach is giving an opportunity for transferring from the "*Teacher-Centered Learning"* (TCL) strategies,
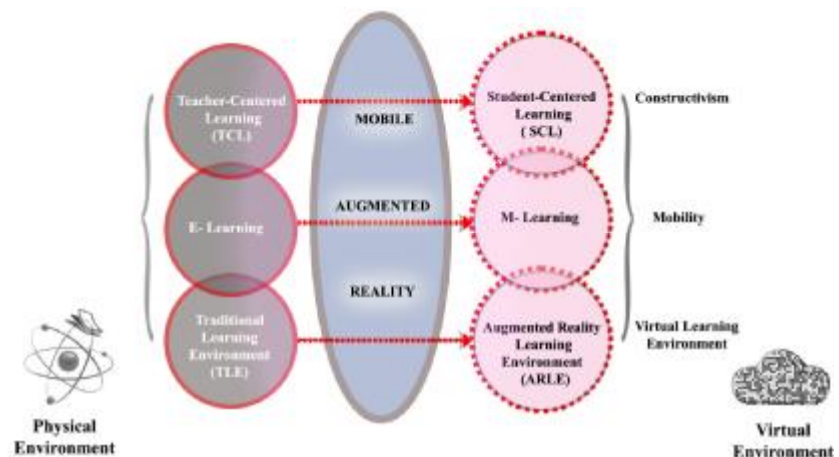

Fig.(1) : The Pedagogic Three Shifting Axis Enhanced by Mobile Augmented Reality (as interpreted by the authors)

which provide a verbal knowledge, to a facilitator through mobile platforms' capabilities, such: messaging, annotations, online sharing, cloud storage and various supportive multimedia and feedback strategies

From E-Learning to M-Learning: with M-learning, the MAR's environments can facilitate the learning process. According to, (Stanton, et al. 2013) mobile learning is different from face to face and "*E-learning"* with the "*Mobility*" concept. Being able to move around is a unique feature that differentiates mobile learning from other learning environments; it is seen as freeing the learner from the classroom disk, As students are given the opportunity to explore projects, buildings and masses physically on site through the use of handheld devices with user friendly Graphical User Interfaces (GUI). Thus, shifting from Human-Computer-Interaction (HCI), to Human-Mobile-Interaction (HMI), allowing for further pedagogic flexibility (Redondo, et al. 2013).

From TLE to ARLE: with MAR integration, architectural educators can develop their new pedagogic approaches enhanced by MAR applications via innovative Augmented Reality Learning Environments ARLE characteristics' potentials among students. Broadly, according to (Cubillo, et al. 2015), ARLE as a part of " Virtual Environments" gives a room for educators to test with low cost their teaching materials and without real consequences which is a privilege when compared with traditional learning environments or the "Physical Environment" in a broad way.

2. Paper's Intent and Methodology

This study aims at testing a theoretical model for integrating MAR application in architectural education adapting a SCL approach since both ARLE and M-learning are considered constructive environments, (Berking, et al. 2012). This framework is meant to inject concepts, considerations, and specific guidelines to M-learning, and AR into appropriate points based on one of the generic ID models, the ADDIE model. While ADDIE is an acronym, referring to the five major phases of the generic Instructional System Design (ISD): **A**nalysis, **D**esign, **D**evelopment, **I**mplementation and **E**valuation phases (Schlegel, et al. 1995,p.10).

The paper adopts the ADDIE model adding to it an additional layer of M-learning ID considerations with respect to ARLE characteristics that was conducted by (Cubillo, et al. 2015), such as: ensuring immersion, enabling exploration, incorporating description of virtual resources and designing non-linear content for improving motivation. We have integrated our idea with collected ID mobile learning considerations from the literature and mostly adopted from "Mobile Learning Handbook" 1 to inject these considerations into each of the ADDIE phases. Regarding the final stage of ADDIE; the "Evaluation" phase, it is generally interpreted. However, not assessed since the application was not tested in a real environment with students. A validation assessment has been conducted by gathering some architectural educators on an open questionnaire. In the conclusion, they presented ideas for developing and improving our framework. Moreover, lessons learned are presented and guidelines are given in order to help educators plan, design and develop their learning contents with existing free MAR applications while saving time in the overall development process. The study ends with a vision for generic design characteristics to implement an "Architectural Mobile Augmented Classroom" (AMAC) that was coined by the authors.

3. Augmenting the ADDIE Model with MAR in Architectural Education Context: "Parquet Wooden Floor" Building Construction Details, Case Study

This section of the study proposes a theoretical framework by implementing the ADDIE instruction design (ID) model on MAR application (AR-media™). A Sub User Interface (UI) was adapted from (AR-Media™ plug-in) on desktop was designed for juniors' level one to facilitate the SCL teaching approach of one of the basics building construction courses for "Parquet Wooden Floor" architectural details. In addition, we have added some developed features for AR-media™ application, in order to enhance our SCL approach to provide a deeper understanding of the architectural content. For the aim of this study, the ADDIE model is utilized as a guide and a "Basic model" to combine the ARLE and the instructional design for m-learning considerations within the architectural education context. According to (Saidin, et al. 2016), ADDIE is widely used in system development for teaching methods, particularly in E-learning systems, educational games and M-learning. The study is not trying to create a new ID model rather it has suggested an augmentation for ADDIE with an additional layer by ID for m-learning considerations in each phase. The following are examples of a few questions that are

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(1) https://sites.google.com/a1/adlnet.gov/mobile-learning-guide/best-practices . Accessed in 12/7/2017

addressed during each phase, and adopted from Mobile Learning Handbook to incorporate in
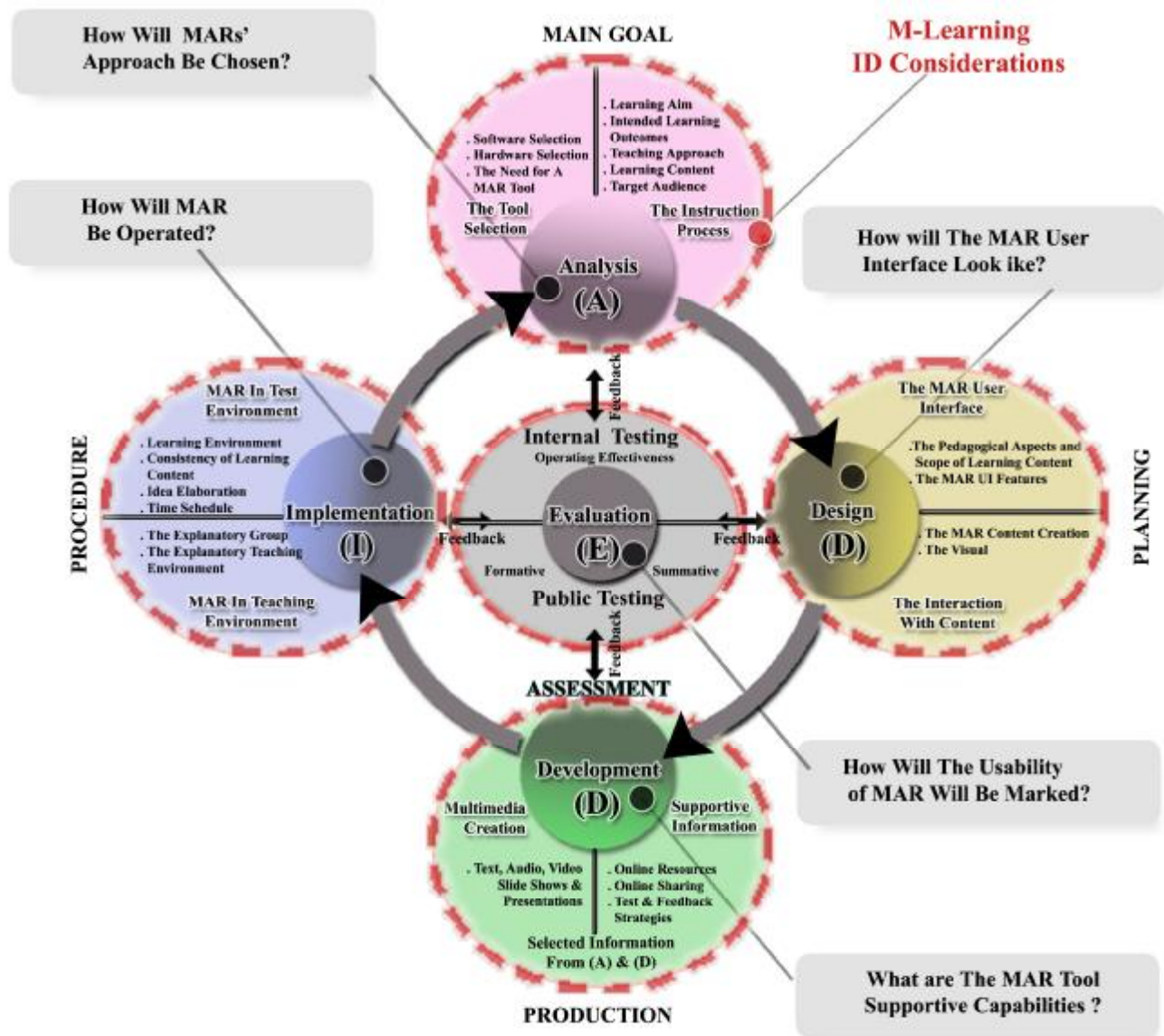

**Fig. (2): Augmenting the Main ADDIE Phases After (Gustafson, et.al. 2002)
With Instructional Design for M-Learning Considerations**

every step of ADDIE, as illustrated in Figure.(2)

3.1. Focus on Analysis

The analysis phase is mainly about "Goal setting stage" (Kurt, 2018), that planning for gathering information and decisions about instructional strategies (Norashikin, 2007). The focus of the architectural educator is on learning goals and objectives, characteristics of target audience and the circumstances of the instruction process. For this purpose, the study has broken-down the analysis phase into two main tasks, "The Tool Selection" and "The Instruction Process ":

1. The Tool Selection: the analysis phase starts with selection of MAR tool that would allow the educator to create the AR educational content. For that, the choice of the tool depends on three factors:

- *Software selection*: an evaluation survey was conducted for three known successful MAR applications in architectural education been used, were evaluated and studied for developing the proposed building construction content, which they are "AR-media™ ", "Aurasma" and "Augment". AR-media™ was chosen based on the selection criteria proposed by (Yilmaz, et al. 2015), such: usability, system features, cost and multimedia creation. In addition, according to a study conducted by (Broschart, et al. 2013), interaction with AR-media™ application is easy and do not require prior knowledge to complete the learning experience to use it only simple gestures and finger touches to complete a learning experience. The software used for modeling was 3Ds Max 2014 and AR-media™ V2.3 plug-in and AR Media Player from Google Play on mobile device.

- *Hardware selection*: it is important for the educator consider the mobile platform capabilities while creating and supporting the learning experience such camera, document viewer, touch screen interaction, cloud storage and other important capabilities, that been addressed in "Advanced Distributed Learning" (ADL) by (Pimmer, et al. 2014). Our device of choice was Samsung Galaxy S6 Edge cell phone as shown in figure 3 , equipped with 16MP camera and Android 5.0.2 Lollipop software. This device is suitable to use with applications on multiple platforms such PC, MAC, Android and IOS as it can accept exported models from renowned architectural modeling software such as 3D Max, Maya and Google Sketch up.
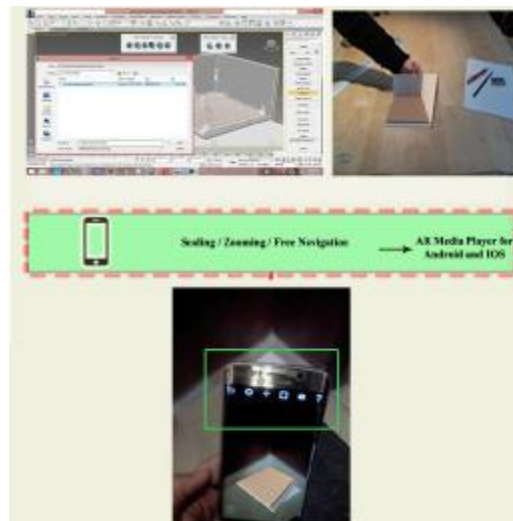

Fig. (3): Displaying the Model on Galaxy S6 Edge Android Platform After Exported From 3D Max

- *The need for a MAR Tool:* which represents the instructional problem. On other words, the need for MAR, which concerns issues, related to the difficulties of Building construction learning in a broad way. It is a subject, which students often complain about missing contact with reality, which lowers their motivation and academic performance (Shirazi, et al. 2015). Beside it is a subject that needs site visits and practical learning side. According to the case of study, the type of "interior flooring "(Parquet Wooden Floor) course, has caused some

confusion to students who were trying to imagine the relation between the parquet floor and the subfloor layers. It is a hard task for traditional approaches to illustrate these relations through white board and 2D sketches.

2. The Instruction Process: after the tool has been selected, an instruction process analysis is established to identify all pedagogic approaches and learning environment needs, the instructional goals, objectives, the learning environment, learner's existing knowledge and skills. The instruction process analysis depends on five factors:

- *Learning aim:* the main objective is to increase the students' motivation and enhance their levels of thinking. There are six levels by Bloom's in (Stanton, et al. 2013); knowledge, comprehension, application, analysis, synthesis and evaluation, in order to provide an important framework for educators to use to focus on higher order thinking in a broad way. The main aim here is to learn the basic "Parquet Wooden Floor "contents, basic scales and integration of different materials in a self-edutainment (Education+ Entrainment) experience. For that purpose, we have pointed out a set of objectives regarding our topic as represented in three main points:

  - Ü To introduce the "Parquet Wooden Floor".
  - Ü To analyze the basic "Parquet Wooden Parquet Floor "components.
  - Ü To explore the main execution stages of" Parquet Wooden Floor".

- *Intended learning outcomes:* by allowing students to explore various interactions with the 3D model of Parquet wooden floor through different scenarios, at the end of this experience, the student is supposed to be able to define the wooden parquet execution stages, its standard dimensions and the wooden details of each layer. In addition, to explore construction details, such as: steel spring clips, spacing distribution regarding different wall directions, wooden blanks, Arashalli, timber and parquet board connection, parquet grove connection and parquet board connection. Moreover, to identify the execution stages of the concrete slab, wooden panels, (sub floor) perpendicular wooden panels on the wooden frame, ventilation void, sand immersion, wooden parquet floor and baseboard molding.

- *Educational approach:* a SCL approach was assumed as a foundation and pedagogic approach. Students gain knowledge through direct interaction with the 3D learning content and supportive online information and able to share their experiences online with their colleagues and receive their educators' feedback for guidance upon their request.

- *Learning content:* broadly, it is important for educators to study the nature of learning content and to study the diversity of introducing this content. The learning content represented as an online resource and a 3D model, that considers the learning objectives and AR-media features. In order to, facilitate the educational approach by showing the 3D "Wooden Parquet Floor" as built of three basic layers; layer one: Concrete Slab, layer two: wooden panels, Perpendicular Wooden Panels, Wooden Frame+ Sand Immersion (Sub Floor), layer three: the final finish of Parquet and Wooden Shoe mold.

- *Target audience:* according to (Pantelić, et.al. 2017) characteristic of target audience should be analyzed when designing a MAR experience. For our case the learning content was

designed to suite the characteristics of first year architecture junior student's academic level, in other words, to consider their level of skills, prior knowledge, their digital profiles, their goals and motivations to engage with instruction process and their style of learning.

3.2. Focus on Design

The Design phase is about "Planning". In this phase, the study determines all learning goals and identifies the learning tools used to gauge performance, feedback, tests, subject matter analysis, planning of resources (Kurt, 2018). However, according to studies conducted by (Saidin, et.al. 2016) and (Pantelić, et.al. 2017) some specific considerations should be taken into account regarding designing for MAR applications such the User Interface (UI) design, and the visual when pointing on the marker. In addition, the limitations and capabilities of the technologies involved to serve the pedagogic approach and the use of supportive tools to serve the scope of learning content. For that purpose, the design phase was broke-down into two main tasks, "The MAR User Interface" and "The Interaction with Content" as follows.

1. The MAR User Interface : the UI is about how and what are the enhancement tools for enabling the interaction with the learning content, it represent it two factors the pedagogical aspects scope of learning content and the developed MAR user interface features, as illustrated below.

- *The Pedagogical Aspects and Scope of Learning Content*: the considered UI design guides the students to gain further knowledge with clear, simple and non-linear content presentation for enriching their self-learning experience and increasing their motivation through different media .Students with AR Media UI features are free to begin their learning process anytime with any step they prefer. In addition, they may have the opportunity to complete their learning task on the fly as AR media storage enables downloading full 3D content. The AR Media UI has served the designed educational content to reproduce multiple learning scenarios such as (descriptive text, online information, specific level of details required, audio and 3D animation).

- *The MAR UI Features:* while designing for MAR, it is important to consider some technical aspects for the UI. The screen size and RAM capacity of the mobile device (Elias, 2011). UI features should be simple and concise. Hence, the study has divided the UI into "AR media original Tools" by "Inglobetechnologies", and "AR Media Player Sub UI". The Main page displays an upper tool bar of the "Parquet Wooden Floor"; The Original UI" with six main features. Moreover, a lower slider bar for the Sub UI comprised of ten proposed features. Seven of them are involved for interaction with the 3D model while, three of them represents an Additional Information options for producing a further support to the SCL approach as shown in Figure(4).
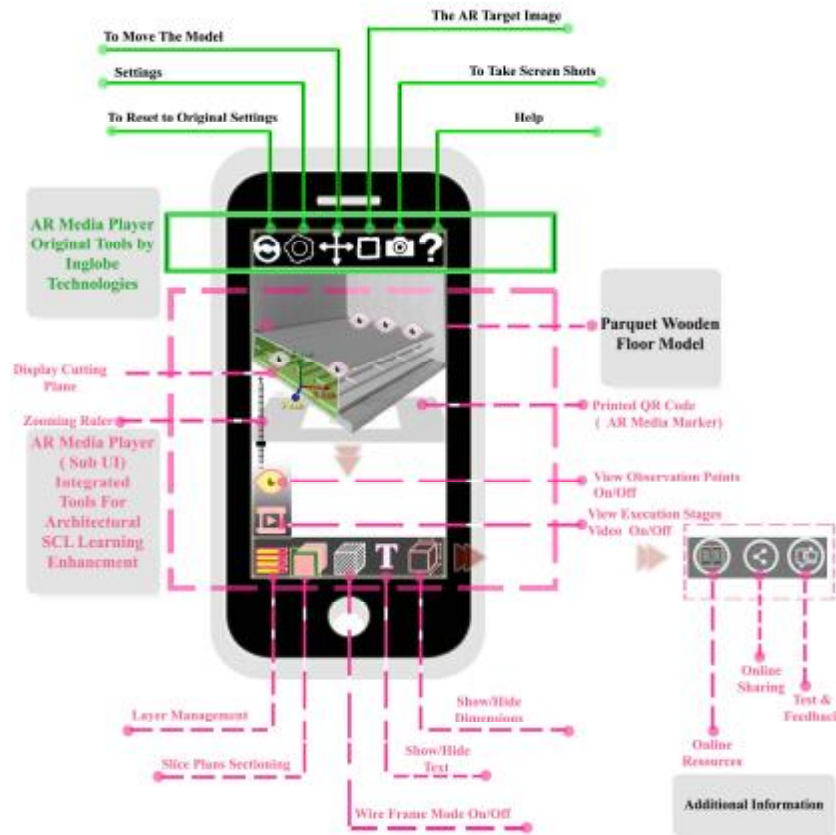
Fig. (4) Integrated SUB UI Based SCL Approach for Learning "Parquet Wooden Floor"
Details on Android Mobile by AR-media™ Application (as interpreted by the authors)

2. The Interaction with Content: the interaction with content design comprised of two main factors the " The MAR Content Creation" and "The Visual". MAR's content creation has sketched in four main steps, which describes the link between the modeling programs and the MAR's application. After the content being created, it is important to design the visual when student points on the marker, as follows.

- *The MAR Content Creation:* is represents by four main sequential and procedural steps. Begins with step1 (Modeling +Setup on the Selected Mobile Device), the process of designing the "Parquet Wooden Flooring" model on an hp laptop by Autodesk 3D Max modeling program. Then, "AR-media™ plug-in" is installed on 3DMax to create "woodenfloor.armediafile" .The next is step2 (Printing the Marker + Exporting for the Mobile Device), where the AR player is installed on the mobile device, the marker image is printed from the Inglobetechnologies website, then "woodenfloor.armediafile" is exported to the mobile device. In addition, step3 (Marker Recognition + Generating the Model as a Learning Content), which appears in tracking the marker QR Code and the loading the model. An additional feature is available that allows uploading other files on AR Media web library for

multiple markers experience which, requires a licensed version of AR Media. Finally, step4 (MAR Learning Experience at the Architectural Classroom) which clarify the student's navigating the model with mobile through body movements, start interacting with AR Media and ends with possibility to add another marker (which refers to another flooring model) by returning back to step2 and generating another ".armediafile".

- *The Visual:* is what the user will see, hear and experience when pointing on the marker. Various learning scenarios enhanced by the AR media UI such as: recorded video of the execution stages of wooden floor, free navigation, zoom in/out, scaling, moving, layer management, specific observation points beforehand created by the instructor, sectioning, wireframe views and additional information.

3.3. Focus on Development

Broadly speaking, if previous "Analysis" and "Design" phases are about "Goals and Planning" respectively, then the development stage is about "production", "that collects all these aspects and puts them into action (Kurt, 2018). In other words, the developing stage of MAR will be based on selected information as represented in the previous phases of analysis and design. According to a mobile learning ID study conducted by (Berking, et.al. 2012), this phase addresses how the application will look like and what are its (web or native application) capabilities. For that purpose, this phase was broken-down into two main sections, "Multimedia Creation" and "Supportive Information".

1. Multimedia Creation: while scanning the marker image using AR-Media application installed on mobile device, it is important to consider the multimedia creation in this phase. The study poses one of the different scenarios of how could the MAR application enhance the visualizing of "Parquet Wooden Floor "based on SCL approach by integrating multimedia as illustrated below.

- *Text, Audio, Video and Slideshows Presentations:* through the integration of different Multimedia is presented by the educator in $360^o Video / Audio$ model navigation that enables view of the wooden floor model execution phases. The learning process is enhanced with helpful text for layers descriptions and standard dimensions represents by *text and dimension tabs*. Students are free to begin their learning experiences and navigate the layers of their choice. The *layer management* feature (isolates and builds each layer respectively also is available. There are other additional developed features such as; *observation points,* that are previously designed by the teacher in order to be able to focus on a certain details of the educational topic. Students are free to focus on these points and visualize them moving from one point to another via different perspectives. The *wireframe rendering is also available* with retention to allow for zooming. Moreover, the students may *take cross sections* of the whole model (x, y & z) axis, which is accessible by *slice plans sectioning* tab.

2. Supportive Information: students may also tab for *additional information* for a deeper content delivery and social interaction, which represents by "Online Resources", "Online Sharing" and "Test and Feedback Strategies" that illustrates as follow:

- *Online Recourses:* additional learning scenarios are available when selecting *additional information* tab, online recourses such: eBooks, stored shared web data. These have benefits to serve the SCL approach, accessible anytime/anywhere and lower cost source of knowledge.
- *Online Sharing:* One of the important academic objectives enhanced by MAR is online sharing of information, allowing for further collaboration and interaction among students and their educators. We are suggesting a web-sharing site (to be accessed via Sub UI) that supports our topic and offline scenarios.

- *Test and Feedback Strategies:* according to ARLE characteristics, the role of feedback strategies has been emphasized. Feedback strategies as mini books (Saidin, et al. 2016), online chartrooms and web platforms enable the educators achieve quantifiable results in order to measure the level of achievement. The study suggested MCQs designed specifically for our topic as addressed in details in (Sharkway, 2018).

3.4. Focus on Implementation

This phase of the process describes the first use of the instruction or materials with learners and educators reflects the continuous modification and updates on the application to make sure of the new tools effectiveness in reaching the learning outcomes and to examine them from both educators' and students' perspectives. Since the analysis phase represents "Goal setting" while Design reflects "Planning", and Development reflects "Production" then the Implementation phase is all about "Procedure". In other words, implementation is the phase where the MAR application is initially tested and redesigned in teaching and learning environments to ensure the course is delivered effectively. The implementation phase represents the examination of the MAR tool from different perspectives that were broken-down to two main points, "MAR in Test Environment" and "MAR in Teaching Environment".

1. MAR in Test Environment: the application is tested among educators to discover the possible errors or bugs in order to ensure that the proposed navigation, interaction and communication tools, fulfill the learning objectives that depend on four factors as illustrated below.
- *The Learning Environment:* the circumstances of the educational environment whereas is (outdoor/indoor) which goes with their context, learning goals and learning content). In our case, we have adopted MAR based indoor use. As conducted by (Redondo, et al. 2012), the indoor use is more widely spread for educational purposes than the outdoor use as it requires specific technologies and essential cameras tracking capabilities
- *Consistency of learning content:* the degree of required details (must consider the device limitations; battery, platforms, capacity, screen size) (Elias, 2011).
- *Idea elaboration:* for non-programmer, it took us approximately seven working days to elaborate the whole idea and two days to create the 3D model.
- *Time schedule:* it is important to plan and keep track of issues such as: feedback tests, Number of lectures and their durations, the pre-test and the post lecture on MAR technology. Moreover, the time taken for building cumulative knowledge should be considered in order to minimize bugs and errors in order to fulfill students' need without distraction them too long or less than they deserve.

2. MAR in Teaching Environment: the application is tested by students to ensure its validation (refers to how well a test measures what it is purported to measure) and reliability (is the degree

to which an assessment tool produces stable and consistent results) test for the MAR application (Colin, et al. 2005). In addition, it is important to check if the students understand the different components of the model to ensure that MAR has provided them with the required knowledge.

- *The Explanatory Group:* first, the application is tested on the "Explanatory Group" of students who were chosen with the same characteristics of the actual "Test Group" in order to determine the problems and modifications in the same circumstances.

- *The Explanatory Teaching Environment:* begins by selecting the AR media player installed on the students' devices so that they can automatically choose the "woodenparquet.armediafile" as exported from AR media library, which was previously uploaded earlier via email. Once mobile devices' cameras tracked the marker image, the AR experiences will commence. When "Layer Management" is tapped, students will be able to view or hide the model layers one by one or randomly with available description text. Finally, via certain tabs, the whole model can undergo sectioning, zooming or changing its mode from solid to wire frame rendering. At any time, students may explore observation points in the model .In addition; educators may need to return to previous ADDIE phases in sequence to track the tools, system, feedback strategies and other criteria in order to eliminate errors and to ensure that the learning approach is effective.

3.5. Focus on Evaluation

This phase represents the final and actual test results of applying the application. The evaluation process is done via gathering educators and students' feedback. The application is subjected to final testing regarding the what, how, why and when of the things that were accomplished (or not accomplished) of the entire project. The study broken-down this phase into two main tasks **"Internal"** and "Public "testing

- *The Internal Testing*: represents the "Operating Effectiveness" that occurs inside the system on issues regarding the operation of the application: testing feedback strategies, UI efficiency, and devices 'compatibility.

- *The Public Testing*: comprises the "Formative" and "Summative" tasks (Kurt, 2018): the "Formative" determines the students' learning outcomes while the "Summative" occurs at the end of the program. The evaluation answers whether the students were more motivated to continue using MAR in their learning experience or thought that the MAR approach is effective while learning about "Wooden Parquet Floor" details more than the traditional approach, or if there were more modifications to be made regarding the MAR user interface. Broadly, evaluation is for the application and for students' performance. By one way or another, it assesses whether the main goals have been met to move forward towards a further efficient and successful learning experience.

The Framework Validation: at the end of the study, the researchers held interviews with 15 architectural educators who teach building construction courses. They were chosen with long educational experiences (more than 10 years teaching experience), and are familiar with digital technology in general. By the end of the interviews, *they recommended in order to design a successful mobile AR environment by architectural educators, to follow one of ID models and our augmented ADDIE framework in particular, also to submit it to implementation.* Where, the aim of these interviews was to check the validation of the suggested model and MAR application, through an open questionnaire in different aspects. Educators were asked about their opinion on the MAR application's selection criteria, the appropriate learning content, the proposed UI features, multimedia accuracy, number of objective questions, model's strengths and weaknesses,
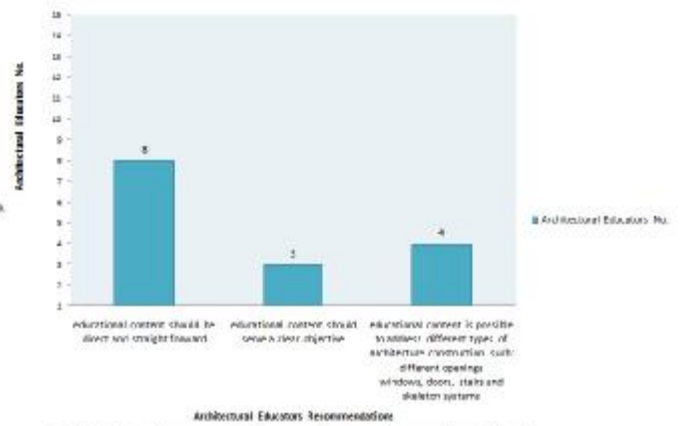
the MAR's learning environment constraints, and architectural educators' training in order to develop the proposed framework as shown is figure (5).
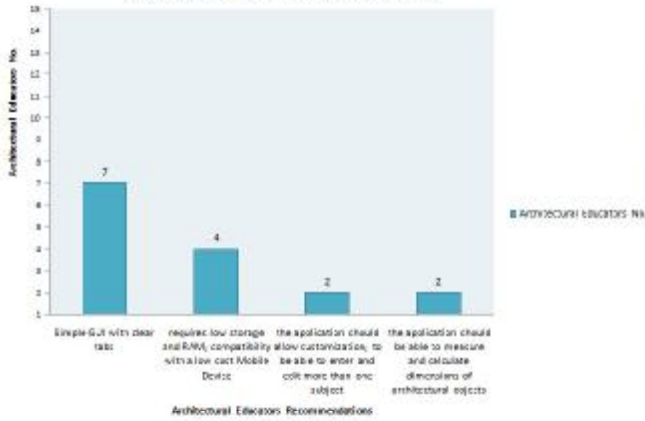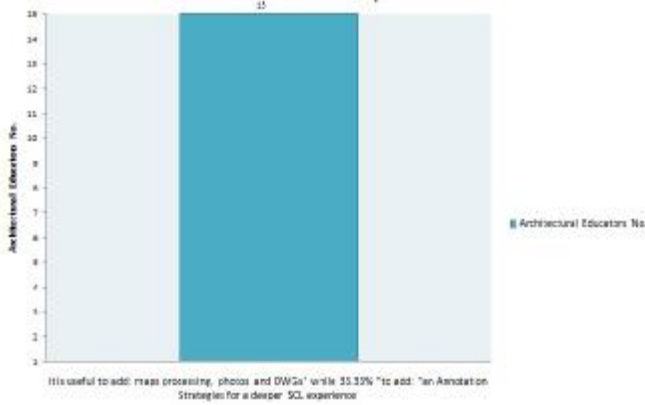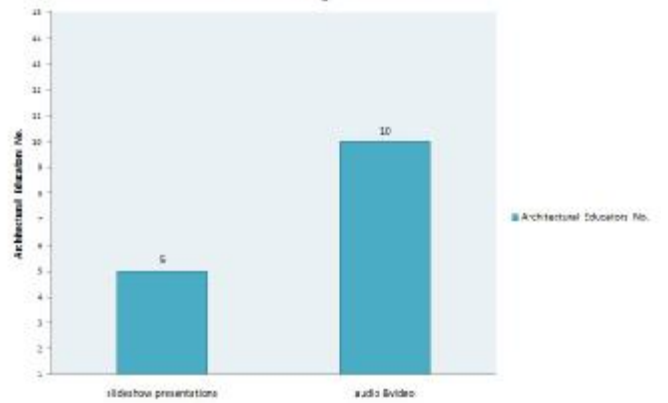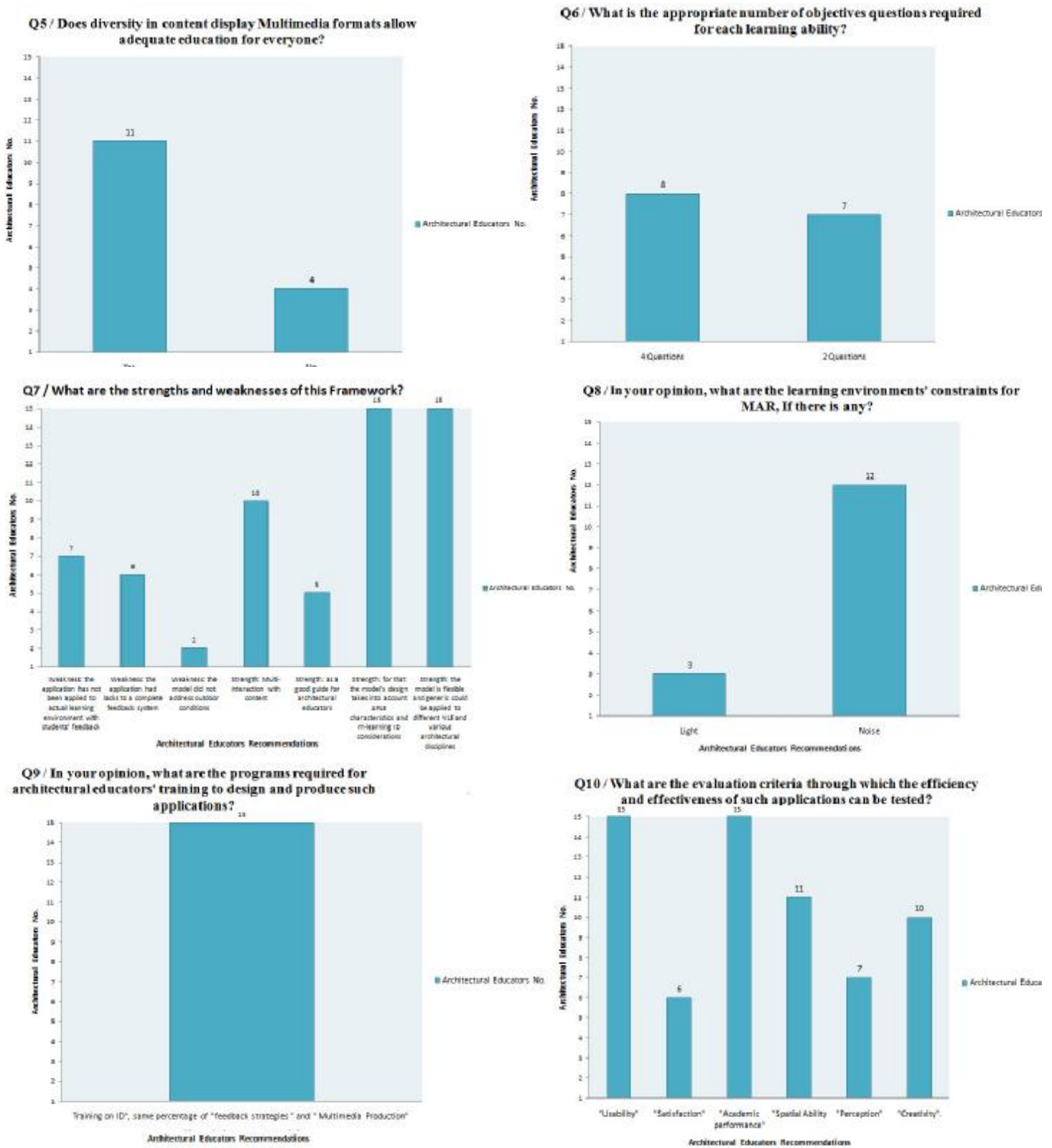
Fig. (5): Architectural Educators Questionnaires and Recommendations

4. Discussion and Conclusions

In this study, the ADDIE model was used as a foundation for a based SCL strategy for learning parquet wooden floor details by AR- Media™ application. This approach enables multiple paths for the students to interact with the educational topic through images, recorded videos, 3D model presentations and text. Functionalities of AR-Media™ have enabled the authors to develop the learning content and to integrate the prepared multimedia elements required to complete the vision, and the additional features that have been added to the mobile learning experience. The study found that it is essential to consider the problem and the requirements of the learning environment prior to the design. The study also found that it is useful during the analysis phase while choosing the AR-media™ tool to study the tools' configurations, description and to learn how to use AR-media™ features through useful tutorials[1].During the implementation, it was found that issues such as the clarity of the printed image could affect the camera tracking feature. Therefore, it is recommended to have a clear printed marker image. As for the software modeling compatibility with MAR application, we have found that Google sketch up 2013, was easier for designing learning content while 3D max design 2014 was more simple in exporting and installing the compatible AR-media™ Plug-in v2.3. Broadly speaking, while developing the MAR educational content, architectural educators should consider assessing the available resources (software, hardware, editing tools, additional equipment) and ensure that the educational content is appropriate for integration into AR context. In addition, it is recommended for architectural educators to evaluate the quality of designed educational content.

This is important for minimizing the probability of students' cognitive overload and misunderstanding. The best way to assess the quality of learning content is to have students use it, then collect their feedback in order to make improvements for MAR application. However, these feedback strategies should not be considered as a substitute to the feedback of the human tutor, nevertheless, they are considered a good and an interesting method to guide the learning process. Moreover, the students might find these strategies helpful, flexible and able to interact with as many times as they want. Educators and instruction designers need to work closely to incorporate better technology for possible transformation from traditional curriculums to MAR's curriculums. They should also pay more attention to consistency in the content creation, organization and interface since mobile screen limits the users' view to only few elements at a time. The multi-layered aspect of MAR's user interface reflects what the student sees and thus, it dictates that it should be more users friendly to navigate for a deeper level of information. *In this research*, we *believe classroom, as a space for learning in the digital era is nothing but a concept. In every space, we move in with the aid of the right tools and methods, learning could become a never-ending journey that could happen independently anywhere and anytime. Taking into consideration the technology presented in this current framework according to mobile learning ID relation with ARLE characteristics in an architectural education context, we have proposed the characteristics for designing an* **Architectural Mobile Augmented Classroom (AMAC)** that encompasses the following characteristics:

- ⋁ *Constructive Approaches***:** new innovative technologies such AR and mobile computing provide students with SCL learning opportunities. As it allows them to learn, build knowledge during their learning experiences, provide access to information (through search functions and carefully designed navigation, with opportunities for communication and collaboration with peers).
- ⋁ *Experiential Learning:* MAR learning experiences enhance SCL by adopting notions concerned with "learning by doing" techniques and methods.
- ⋁ *Adaptive to Social and personal modes***:** this technology based human-mobile interaction, support diverse modes of communication and collaboration.

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(2) The AR media "Quick Start Guide" at www.armedia.it/showcase.php?sid=3dsmax_tutorials. Accessed at 21/7/2018

- ⌄ *Flexibility:* learning should always take place even if students did not have enough time during their academic schedule. Students have the opportunity to take offline moments or on the fly data and review it anytime / anywhere. Moreover, the flexible nature of AR also appears in the capability to integrate with many technologies such: Intelligent Augmented Reality systems (IARs), AR based BIM (Building Information Modeling), systems and Cloud computing.
- ⌄ *Motivation:* these tools attract the attention of the digital natives to explore and gain knowledge. Hence, one of the main advantages of ARLE is increasing the students' learning motivation.
- ⌄ *Edutainment:* provides potential for memorizing knowledge, as it provides enjoyment while learning through deep inquiry and social engagement with real problem situations.
- ⌄ *Immediacy*: mobile devices may contain supportive tools and capabilities that provide immediate feedback and information delivery.
- ⌄ *Accessibility*: learning environment should be easily accessed and learner's requirements should be fulfilled through; cloud storage, MAR libraries and similar means.
- ⌄ *User Friendly GUI:* offers visual context of environment and other prospects. It appears through a representation that illustrates the key elements of the educational context, which are necessary to create a sense of satisfaction, control and richness.

5. Challenges and Future Directions

- There are several MAR tools for non-programmers' authorization it is necessary for architectural educators to get informed with functionalities of these tools, as well as with the tools that will be used to create or modify the required multimedia elements.

- The applicability of linking AR to various technologies is one of the future directions in architectural education. Because of its special nature, AR is not limited to a specific type of technology as it could be reconsidered from broader views as Building Information Modeling (BIM) and Cloud. Besides, the distinguished advantage of mobility, when linked to cloud, it is possible that architectural classroom may go beyond M-Learning, to Ubiquities learning (U-Learning), "where the data are stored in the cloud and are consulted on any place by all kinds of educational programs and social networks" (Redondo, et.al.2013) .On the other hand, the effectiveness of BIM and AR system integration to enhance task efficiency through improving the information retrieval process enhanced by AR visualization technologies is a valuable combination. Thus, the capabilities of linking Mobile-BIM-AR systems (Chu, et al. 2018) and cloud-based storage could give new horizons of pedagogic potentials for educators and researchers to improve architectural learning not only as visualization but also as information tools.

- Despite potentials of the proposed MAR framework for using digital technology in architectural education, there is still a need to investigate physical, mental and psychological impacts.

- This study has focused on the positive impact of one of the AR techniques, which is MAR techniques on the development of architectural learning space from a pedagogic perspective. On the other hand, it is possible to study the impact of MAR on the design of the physical learning space and their impact on changing architectural classroom design.

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