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Theme 2: Towards New Pedagogy: Philosophy of Teaching Architecture

AUGMENTED REALITY
A CREATIVE TOOL TO TEACH ARCHITECTURE IN SITU

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Abstract:
Since the very early beginnings of human civilization, teaching architecture was done through philosophical approaches; because architecture was seen as the main tool for demonstrating the power and progress of nations. Architectural products were developing in accordance with the philosophical paradigms and concepts in every era; until we reached the 21^{st} century. Architecture started getting seen then as a kind of science that should adapt to the technological revolutions happening to the means of communication; which can be considered the paradigm of our current era.
To teach architecture through a technological philosophy, students need to receive knowledge interactively. This can be achieved through Augmented Reality; which can combine physical and virtual dimensions. For example, the place which had witnessed the story that needs to be told – featuring the design or construction of the building – could represent the physical dimension, while the augmentation could be the actual information added to the built environment during the process of introducing this site to the audience. The method of displaying the information depends on the users' visual experience, and the information they choose to see with relevance to the place where they are and the buildings they can already see in front of them. This combined dimension is based on a theoretical analysis of the kind of information to be presented like architectural techniques and details which are clearer when presented in situ. The audience is also considered in the combined dimension; that is to say, to whom the information is presented; so that the augmentation can be tailored to suit this audience.
In this research, the target audience was represented in architectural students, and the site that was augmented was the construction site of The National Museum of Egyptian Civilization (NMEC). The goal was to make the museum a source of augmented educational knowledge for architectural students; to elevate the user experience at the museum and to apply this new technology to disciplines of architectural education. The experiment featured a network of informative points to be augmented in situ through an application that is designed for smart android mobile phones, which are widely used by most of the students in Egypt.

Keywords: Augmented Reality, Construction, Architectural Philosophy

1. Research Methodology
An experimental research approach was applied through developing and testing an augmented reality application; while a case study approach featured The Museum of Egyptian Civilization. This museum is considered a successful example; due to its rich architectural and construction details which can be presented to the students in situ.

2. Research Hypothesis
Through augmented reality, construction sites can be used as interactive tools of architectural education.

3. Research Objective
An augmented site experiment was created to introduce architectural and construction details through a new creative teaching philosophy. The experiment targeted architectural students as part of their academic studies, and has proven to enhance their level of understanding.

4. Introduction
Methods of teaching architecture have massively changed as time passed, since some members of the current generation have received their primary education using smart technologies with new tools that make the old ways of teaching really absolute, especially when talking about architectural engineering. In Egypt, it's hard to introduce smart technologies in teaching architecture, since Egyptian governmental universities don't generally invest in technological methods of learning, such as virtual reality, augmented reality, and such. However, out of understanding its true value and even its inevitable necessity in the future, this research presents Augmented Reality as part of teaching architectural engineering.

Augmented Reality can be defined as a multi-technology combined to mix two dimensional and three dimensional computer-generated content with reality[i]. It is assumed to enhance student perception; where the student can see the built environment linked to construction details so he can actually see beyond the external architectural forms. Construction work stages can even be augmented in order, so that the student can see all stages until the project is finished; where he can see the final product in reality. To combine these construction details with the physical reality, a tracking software is required to connect the surrounding environment with the images that are being projected. The hardware, on the other hand, should include a computer that produces detailed construction drawings, which will be seen by the observer in relation to the points of tracking. A display device is also needed, where this could simply be a smart phone acting as a hand-held device. The software program, computer, and display device together formulate an interactive physical environment that is connected to the projected augmented details, where all the information needed is shown to the observer directly in situ.[ii]

To use this technique in construction sites, a problem might arise in case of mega-sized projects where much information would need to be saved. In this case, the approach must consider simplification by narrowing the level of details that can be observed. Another problem could be the means of presenting data through tight areas of circulation inside a building; where it would be hard to maneuver among a large number of visitors while trying to find tracking points on the smart devices. In all cases, the accuracy of the camera must be considered, as well as users' comfort while tracking the points in case of detailed spots. The tracking positions also need to be carefully chosen, as well as the place in which the data is projected.[iii]

5. Involving Augmented Reality in Education

Using AR technologies for educational purposes depends mainly on the ability of new generations to deal with smart devices. The higher the ability to use these devices, the more helpful it is to transform the information presented into actual knowledge. Students get to deal with their own familiar devices through a new type of educational experience where they explore the physical environment with data chosen in accordance with the educational category. Students thus interact through Augmented Reality while being motivated into the physical spaces[iv].

In order to create an educational AR experience from scratch, many aspects should be considered; such as tracking. Tracking involves determining the positions where we can display the virtual data, so that when we track certain coordinates, we can see certain virtual content. Then the operation of registration comes which involves introducing virtual data to the physical building. This can be done through saving the Auras (saved connection points between the physical building and the virtual components). In the process of registration, every point in the physical building has X,Y and Z coordinates linked to the virtual file, with virtual content that would appear when this point is tracked within the application. The output of mixed physical space and virtual content will appear through the smart hand-held device[v]. Mobile phone developers have indirectly supported the idea of using mobile phones in AR experiences with the current high development of built-in cameras, which in turn act as perfect tracking tools.

From one point of view, the AR technology depends on discovering the items through moving the hand-held devices to track the AR features, so students never know what they will see until they discover it, which is an attraction point. From another point of view, using this technology is usually done within groups of students, so it opens doors for teamwork brainstorming which results into better information perception, and thus the information easily transforms into knowledge.

As the applications of smart technology differ from one mobile phone to another, and the level of mastering the application varies from one student to another; from the usability point of view, it's recommended that the students work and interact in groups prior to interacting through an Augmented Reality application.[vi]

Using hand-held devices in education mostly gets supported by teachers or lecturers; being a tool to teach in situ, especially in the fields of art history, architecture, maintenance, and construction. The idea has developed much through time, where it began with overlaying 2D information and then transformed into 3D information and eventually; videos. Integrating the element of interaction with Building Information Modeling (BIM), the perception gets even better on students' side because they enjoy how the educational process gets rid of its traditional classroom style.

Most of the students use hand-held devices that operate with 3G and 4G networks. They use their mobile phones in everything through their everyday life, so why not in education as well? Instead of watching entertainment videos, they can use the phones more positively when these phones have become tools for better information perception. The people involved in the AR experiment, the scenario of teaching the “lecture”, the kind of information presented, and the device used as a hardware, as well as the software program; these are the elements that formulate the AR teaching environment.[vii]

6. Designing an educational AR experience

Utilizing the AR technology with hand-held devices depends on the presence of a built-in camera in order to capture either photos or videos. It also depends on the global positioning system (GPS) to put the tracking points in certain locations in the construction site. The accuracy of the linkage between the physical building and virtual data varies according to the quality of the smart device and that of the application. Another requirement for fulfilling the experience would be the wireless connection or mobile data which can operate through both android and IOS[viii] mobile phones.

The AR mobile application is the new version of the older computer web page which required head-mounted devices. In both cases, this web page represents the programming environment through which the data gets transferred. In our case here, the mobile application acts as an intermediate tool to let the students receive the data from the environment of programming via a gate which is the application itself. The experience is based on the programming language of AR; which involves the registration of data in relation to the physical building, the overlaid and projected data; and Java script as a definer of dynamic interactions.

7. AR Software Platform

Being a free to download application for android and IOS devices, the mobile application "Aurasma" was used in the experiment of this research. The app was originally established for educational purposes;[ix] helping in visualizing construction stages and details, as well as supporting the design process through visualizing the design components in a real environment and overlaying the virtual product in its place in reality. When the virtual object - which will be later used in reality - is primarily seen in situ via the AR technology, this helps in deciding to alter its size or material. We can consider this process a kind of clash detection and correction, if used in the phase of schematic design sketching.

8. Case Study

8.1. Experiment Scenario

In the experiment scenario, construction details were seen connected to their place in the physical building, so that the presented information could explain the lecture in an interactive way. This approach supports the belief that architectural education requires an understanding of the importance of integration between construction and architectural design and that both of them should be coordinated together[x].

There are generally two AR systems, one is marker-less while the other is marker-based. In the marker-less system, data is shown on certain points of 2D coordinates, while in the marker-based system, the tracker can see the overlaid information over actual components. This experiment was marker-based as it depended on the presence of the physical building, on which the augmented photo appeared to show the construction details as part of the lecture scenario.

The scenario of teaching construction in situ mostly depends on connecting architectural design with curriculums of construction-related subjects. These subjects are already part of the architectural disciplines taught at many architectural departments at different Egyptian faculties of engineering. Through this experiment, the scenario of teaching in situ integrated the courses "Architectural Design Studio 3" and "Building Construction"; which are part of the academic curriculums taught to students of the third year at The Architectural Department of The Faculty of Engineering, Zagazig University. The aim of the experiment was to fulfill the intended learning outcomes (ILO) of both courses, which are:

- Knowledge and understanding; achieving an understanding of the role of the architectural profession in relation to construction
- Intellectual skills; including the integration of structural studies and specifications of building materials within the design process
- Professional and practice skills; that is, teaching how to use appropriate construction techniques and building materials to implement different architectural designs

The previous three learning outcomes initially formulated the lecture target which was later measured through a questionnaire to act as an indicator of perceiving the AR lecture. The questionnaire was applied on two groups of students. The first group received this lecture partially at the university premises and partially in situ; using augmented reality. When they tracked any part of the building, construction details showed up through stages of actual implementation, in the order of construction and finishing as in the real construction process. As for the second group, they received the lecture solely in class through a Powerpoint presentation; which is the traditional way of teaching this kind of lectures.

The questionnaire was given to both groups at the end of the lecture. It included 3 questions covering the following aspects:

1- Usability of the application and the augmented reality technique (only for the first group)
2- To what extend the intended learning outcomes were achieved
3- A set of technical questions from the lecture content as a quiz to measure the level of lecture understanding

Usability of the application was assessed according to the terms of usability in The ISO 924 –11 [xi] featuring:

- The framework used through AR to perceive construction details in the lecture (usability of the product)
- User performance through the application and user satisfaction[xii]

8.2. Experiment Location

The experiment was held at the National Museum of Egyptian Civilization, a museum which gives visitors the opportunity to know the history of the Egyptian civilization; starting from the pre-historical age and pre-dynasties era to the ancient Egyptian, Greek, Roman, Coptic, Islamic and modern eras. The aim of the museum is to present the changes in Egyptian citizens' lives from all aspects; such as the level of general knowledge, science, art, beliefs, and all relevant human activities. The museum scenario is designed in a way to introduce either a fast track story for short duration visits, or a detailed civilization record preview for longer ones.

The idea of this museum was proposed in the year 1980 by the Egyptian government who invited UNESCO to hold an architectural competition for the purpose of designing the museum. The competition was held in 1983 and two years later, the Egyptian architect Prof. Dr. El-Ghazaly Kessieba was announced as the winner. Four years afterwards, tender documents were ready to be presented to contractors to start the construction of the museum. However, the construction process faced a problem with respect to the project location; which was supposed to be The Expo Land in El-Gezeera area of Zamalek, Cairo; which is a small space that could not fit the proposed idea. The project was suspended until the year 2000, in which The Cairo Governorate municipality approved the request previously presented by The Egyptian Ministry of Culture to make the project location Al-Fustat City in old Cairo, and so it was, (see fig. 1).

Fig. 1: A, old remains at NMEC site. B, museum buildings

A full update and revision process was done to the architectural drawings of the museum to let it suit the new location; a process which involved all contributing parties: the architectural consultant Prof. Dr. El-Ghazaly Kesseiba, The UNESCO, and different architecture and construction experts. Since the project location lied in a sacred area; it was considered a witness on the Egyptian civilization itself. When you explore the site, you find the Religious Complex on the west. The complex features monuments from three religions; including The Jewish Temple of Ben Azer, different historic churches such as Abo Serga Church, The Hanging Church, Mary Girgis Church and other gorgeous Coptic monuments. There's also the Mosque of Amr Ibn Al-A'as; which is considered the node of spreading Islam in Egypt. In fact, Al-Fustat City was the first Islamic city in the history of the Egyptian civilization.

At the background of all these monuments, lies the great Pyramid of Khufu. In the north, there's the huge Al-Fustat Park and Magra El-Oyoun fence which is a historic Islamic monument that reflects the genius irrigation system operating back then through seven waterwheels. In the eastern north, there's The Citadel of Salah El-Din Al-Ayouby, while in the East; there's the famous Al-Juyushi Mosque which lies next to the mausoleums of the famous religious Imams Al Shafi'e and Al Laith. All these monuments surround the National Museum of Egyptian Civilization (NMEC); while Ain Elsera lake is already inside the project land; along with the ancient dye shop from the era of the 'wise' Khalifas.

The NMEC project consisted of three phases. The first phase featured the building construction and the electro-mechanical infra-structure works. The second phase featured furnishing the spaces. This included the supply and installation of all project equipment that was required for the antiques mobilization, and the storage areas as well as the restoration laboratory. Finally, the landscaping was achieved, the temporary exhibition was set, and the exhibition show was established along with other landscaping elements.

8.3. Experiment Implementation Method

Hand-held devices were chosen to fulfill the experiment. A smart phone software was used to make the AR experience. First, tracking the needed construction details was done by the device camera, then the Auras were created by overlaying the images on the tracked physical features, which is the registration process. When we tracked a physical feature, the saved photo appeared, so by following the scenario of the details that were chosen to appear in different parts of the physical building, the data appeared on the same smart device. To use this scenario via multiple devices, an option of sharing this data was made available; where data was being sent via emails to be received by the students, so they could access it through the application and save it. While the students were at the site, the application was tracking the physical features and presenting the data that was connected with the tracked points.

8.4. Lecture Scenario

The lecture merged the courses of "Architectural Design Studio 3" and "Building Construction". The plan was to design a theatre hall, while at the same time discuss the finishing materials and their relation to each other. The goal was to merge those two scientific subjects through one lecture, where each was presented separately as well as together. The first part of the lecture was presented at the university premises through a presentation, while the second part was given at The NMEC using augmented reality in situ. The design aspects covered were hall interiors, height leveling, and wall treatment for better acoustics, in addition to choosing the locations for translation rooms inside the hall. Another aspect covered through this lecture was the stage itself with its components such as the curtains, the decorations; like material suitability to function, and the reasons for choosing a specific type of flooring. From one side, the lecture represented the "Architectural Design Studio 3" course, and from the other; the "Building Construction" scientific course. We covered how multi materials could be fixed together, what their fixing stages were and how to fix these materials together while appearing smoothly through the same surface with its many levels.

8.4.1. Design Studio Content

NMEC consists of two main buildings. From the main street, an axe leads to the reception building, (see fig. 2). This is a multi functional building; featuring a theater, a restaurant, and a box office located right before the suspended link structure which connects this building with the other; that is the museum itself. You enter the reception at the ground level, below which lie the lecture and conference halls, then further below, there's the cinema and commercial shops.

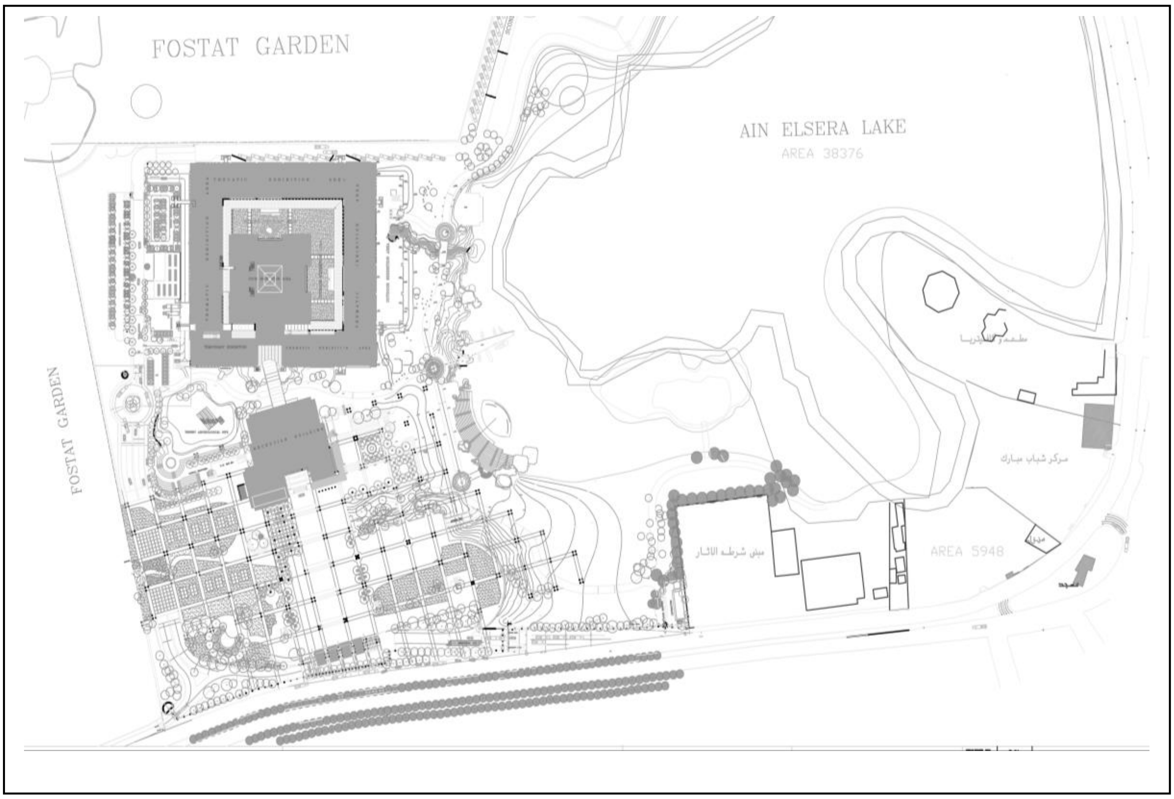


Fig. 2: Site plan of the museum

The reception building has a very strong connection with the landscape to ease emergency escape which is in the same level of the entrance. Inside, and at the entrance of the theater, a foyer introduces the audience to the theater hall, it lets the visitors enter the hall from the back through steps where each visitor can access his place, (see fig. 3). From the foyer mentioned earlier, a staircase can be taken to the balcony, where the hall has 333 chairs and the balcony has 180 ones, (see fig. 4).

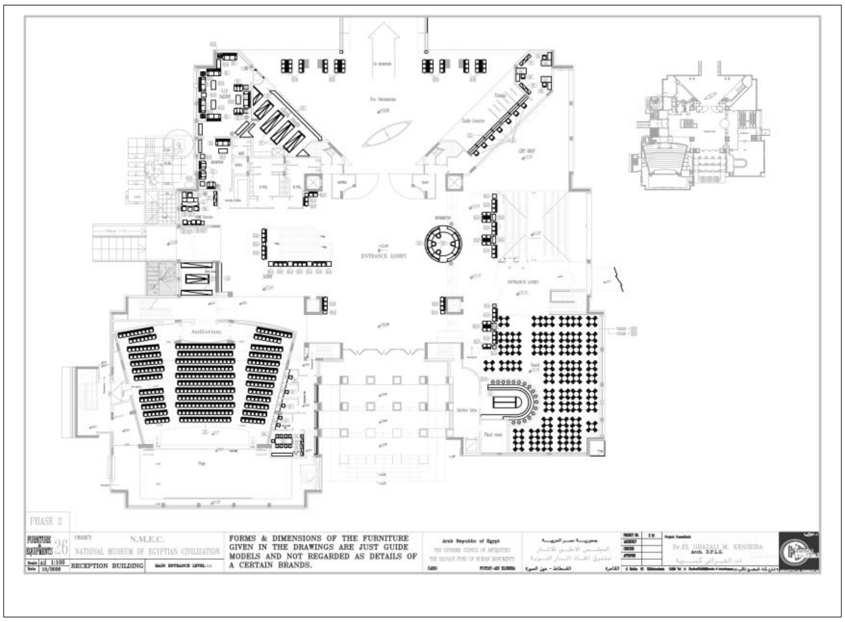


Fig. 3: Reception building plan showing the building entrance and the theatre hall (the auditorium)

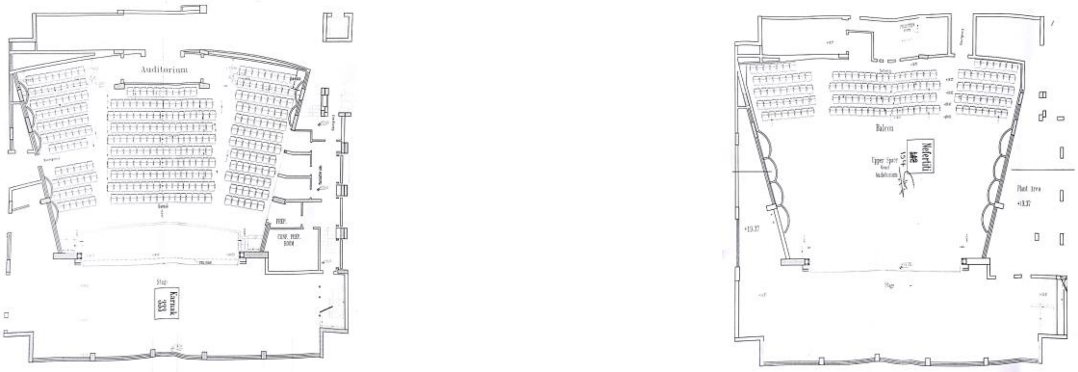


Fig 4: A, first level of the theatre auditorium. B, second level which is the theatre balcony

The building circulation is totally separated for three kinds of building users. The first circulation route is that of the audience from the entrance to the auditorium and vice versa, and the second is that of the actors or performers from their backrooms; such as makeup, changing, or rehearsal rooms, to the stage, and vice versa. As for the third circulation, it's the administrative one, and while it overlaps with the actors' circulation, it doesn't cross through the auditorium. These circulation routes were the main focus of the "Architectural Design Studio 3" lecture, added to the level of relation between the foyer and the entrance to the auditorium or stage which is a horizontal relation. There's also the vertical relation between the foyer and the stage decoration control unit upstairs; achieved through a steel staircase, (see fig. 5).

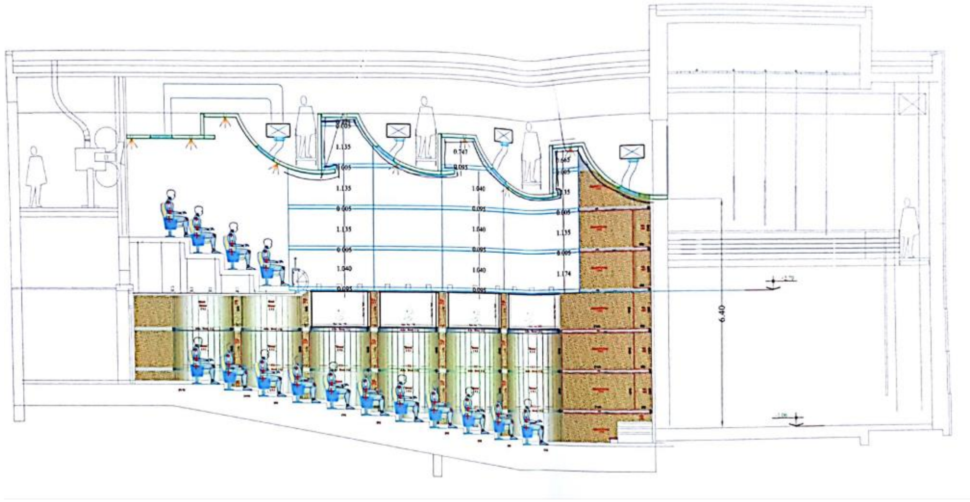


Fig. 5: A, theatre stage. B, theatre chairs at the main hall and balcony. C, section showing levels of the theatre and the relation between the audience seats and the projection in addition to the catwalks

Another aspect covered in the lecture was that of the exits, the emergency exit, the middle exit doors, and the employee exit; which is connected to the actors rooms at the ground floor of the entrance building.

8.4.2. Construction Content

All architectural elements were explained one by one along with construction details; including the flooring and steps which were illustrated through detailed section drawings, (see fig. 6). Every element was discussed from a form/composition point of view, and from a material choice point of view, as in why we applied vinyl layers to the flooring and how we installed the steps and audience passages, (see fig. 7). The ceiling design was discussed while revealing details of its inlaid layers. The walls and their folding were also discussed; thanks to acoustic studies on which we based the explanation of ceiling wall materials; such as the wooden cladding and the usage of Ecophon products. A spatial explanation was also given to translation rooms and their relation to the auditorium, as well as the maintenance catwalks and their design with relevance to locating spatial theatrical lighting.

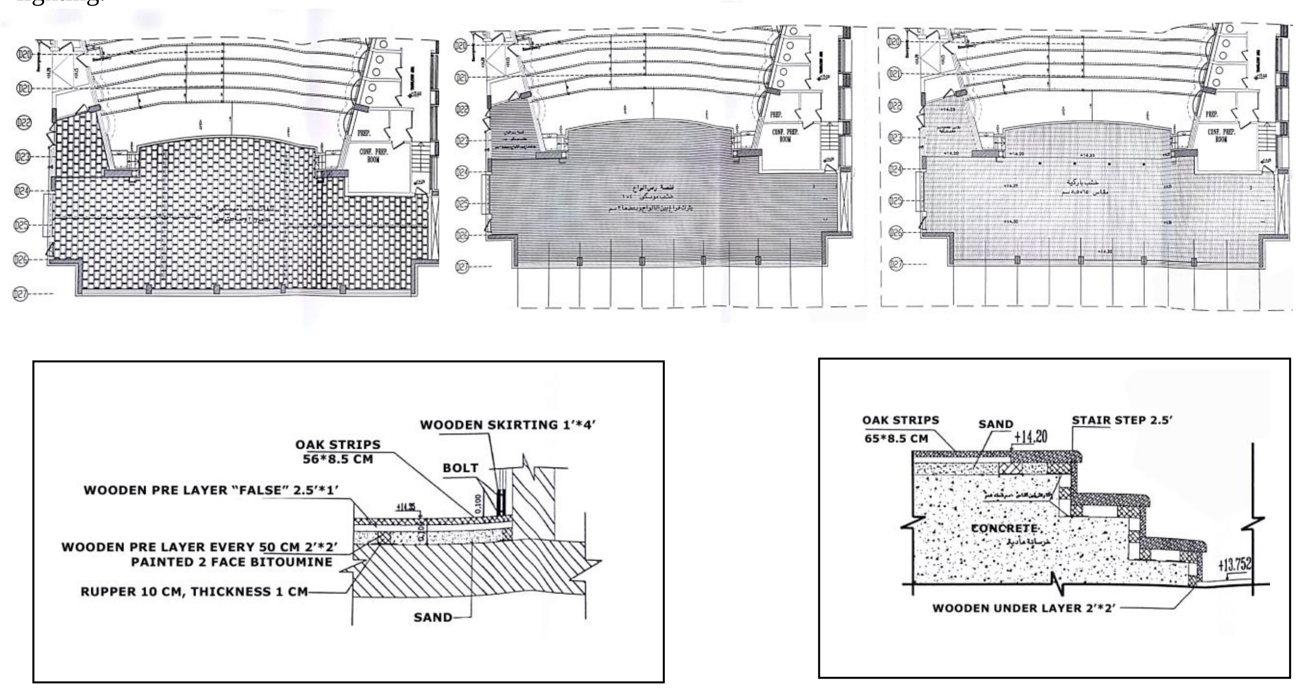


Fig 6: A, parquet phases of implementation. B, details of construction for wooden elements

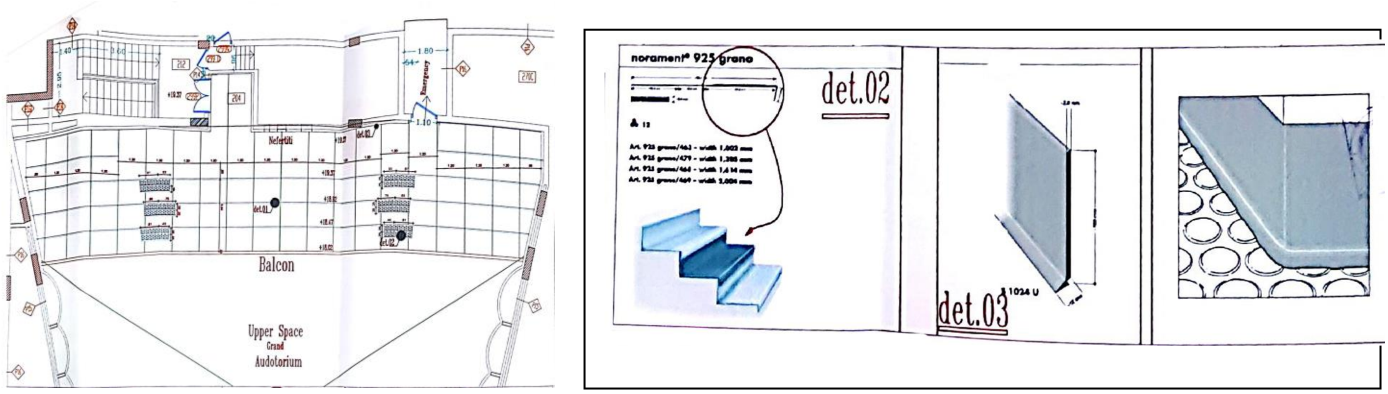


Fig. 7: Vinyl flooring and stairs details

8.4.3. AR record in situ

The design content was explained and the linkage between design and construction was demonstrated, then construction details were explained; so students eventually had full information about the museum design and structure. The design and construction linkage was dynamically demonstrated then through the AR experiment. The goal of this scenario was to distinguish between schematic architectural concepts and the actually seen physical appearance of the auditorium by seeing every little construction detail on the students' smart devices. The students tracked the data as the details were being explained. For each design element, many auras were taken to record the work stages. The installation phases of the theater stage were demonstrated, while explaining why certain materials were chosen; such as for preventing noise as in the case of using wood. Circulation was explained; as in how the user would move from the main hall of the auditorium to the stage; if needed. The idea of using Augmented Reality attracted the students very much. They were encouraged then to ask questions on construction details with much more depth than they did during the first lecture at the university premises. Both design drawings and construction details were augmented in the hall by the researcher, and every detail was located in its real physical place inside the theatre hall, (see fig. 8). The overlaid drawings either showed the design of the element or gave the work phases record.

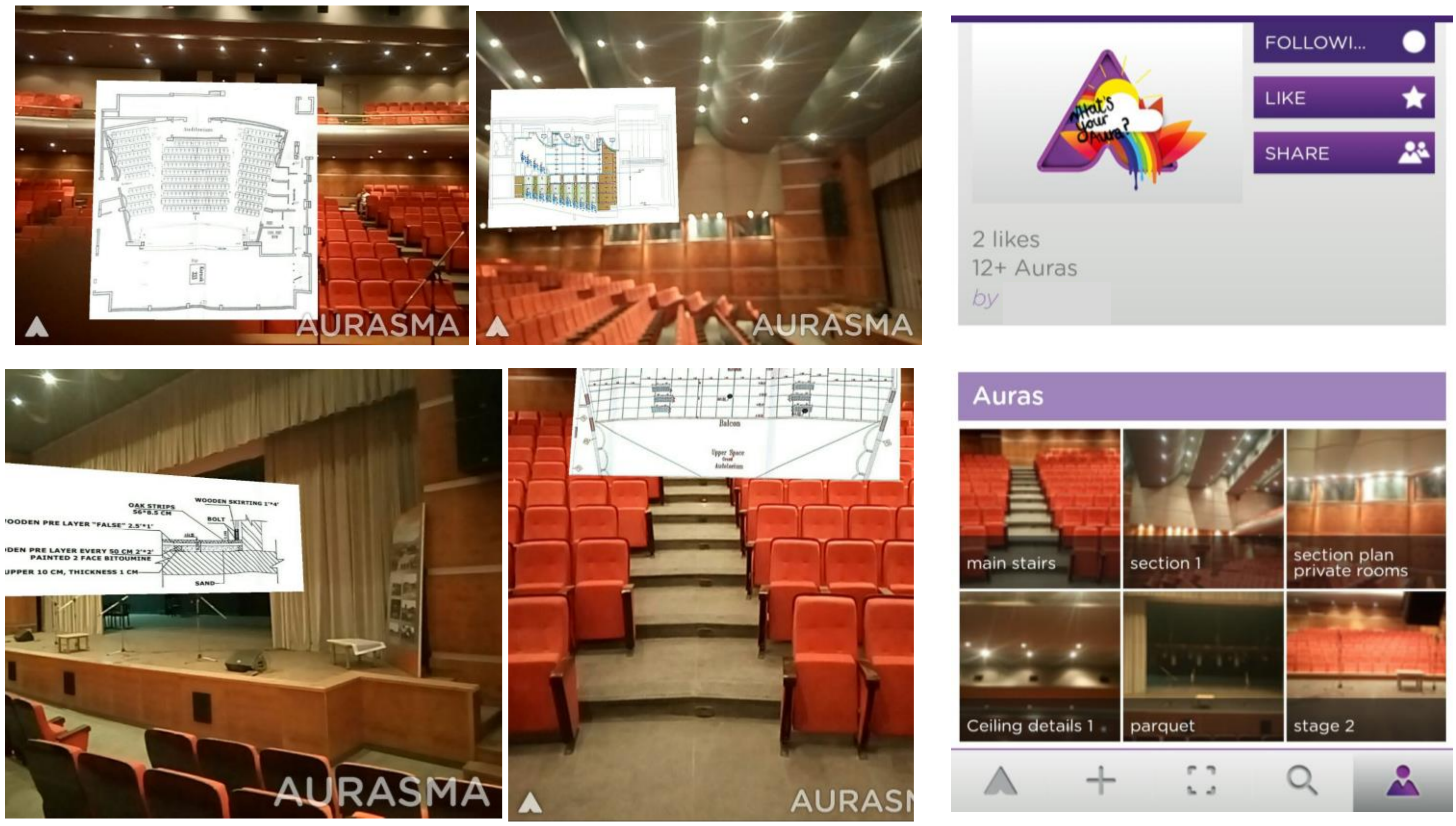


Fig 8: A, application interface connecting the physical theatre and the augmented 2D virtual content. B, research public channel showing the auras of the in situ lecture

During the registration of every 2D component in its physical place, both the virtual and physical points formulated the auras which were then saved on a public channel on the "Aurasma" application. Students were asked to install the application before their in situ lecture, and follow the mentioned public channel; through which all the prepared auras got linked to their smart devices.

The same content was explained to another group of students who took this lecture solely via a presentation at the university premises and then both groups filled the questionnaire. The AR group entered the site and circulated it then they tracked the auras and the details showed up in front of them. After experiencing Virtual Reality in situ and discussing their findings and after receiving the same scientific content of the university lecture but this time in situ through AR, the students were gathered to fill in the questionnaire. Both questionnaire results were analyzed and compared.

8.5. The Questionnaire

8.5.1. Questionnaire Content

The questionnaire consisted of 4 parts, the first measured usability according to the ISO 924 –11, the second questioned different aspects of the intended learning outcomes of both courses, while the third consisted of variable questions to asses the level of understanding for the scientific material which was taught to the students at the lecture. Eventually, the questionnaire required a drawing to be drawn by the students to further assess the perception of scientific material from a practical point of view, (see fig. 9)

Zagazig University
Faculty of Engineering - Architectural Department
3rd Year
"Architectural Design Studio 3" - "Building Construction"

Questionnaire on The Usage of Augmented Reality in Teaching Architecture

	1	2	3	4	5
Usability					
Has AR offered a better understanding of the lecture?					
Are you satisified with being taught through AR?					
Is the AR application easy to use?					
ILOs Achieved for both courses					
Knowledge and understanding					
Understanding architectural design in relation to construction					
Intellectual skills					
Integrating structural studies and building materials specifications with the design					
Professional and practice skills					
Knowing how to choose appropriate construction techniques and materials to implement designs					
Lecture Understanding Indicators					
Did you understand what the suspended ceilings in theaters consist of?					
Were stage details clear?					
Were the components of the translation room understood?					
Did you have a basic clarity for chairs distribution through the auditorium?					
Was the structure of the levels and balcony clear?					
Draw anything from what you understood at the lecture					
For Instructors only: evaluate the drawing quality					

Fig. 9: Questionnaire for evaluating the educational experiment

8.5.2. Questionnaire Discussion

The experiment was very effective as it linked the theoretical information, in the scientific material of the courses, with reality. This helped in enhancing students' perception and achieved the visual communication required between the student and the physical space while receiving the scientific information; which later transformed into knowledge after this experience. The physical building prevented faulty imagination of the details presented at the lecture. When the students were asked to give their feedback about the experiment, the majority noted that they felt that using Augmented Reality was a big development in presenting architecture in general; and specifically when joining the courses of "Architectural Design Studio 3" and "Building Construction". The students even asked for AR to be used in every subject taught at the architectural department. The students' interaction with the space brought up many queries in their minds. Many questions were asked, and when the students received the answers; they had already reached a deeper involvement in the lecture topic. This kind of questions have never been asked while the presentation used to be solely given at the university premises in the traditional way, (see fig. 10).

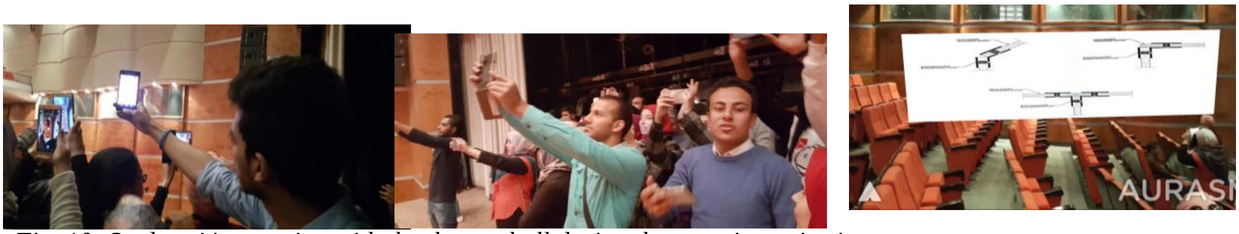
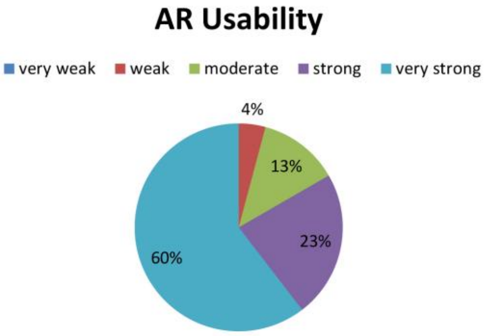
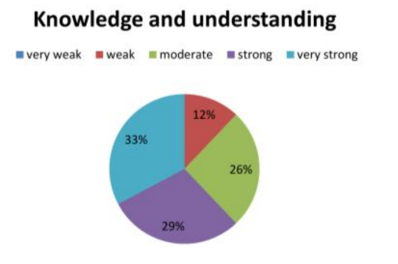
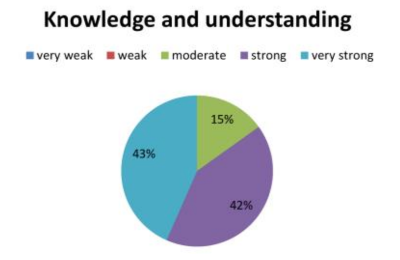
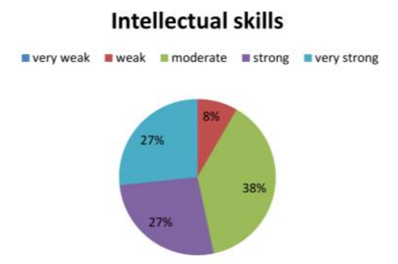
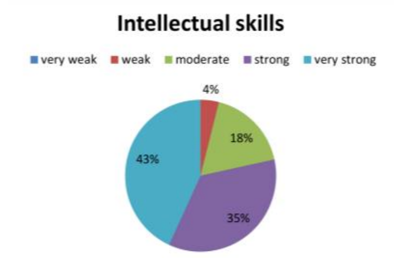
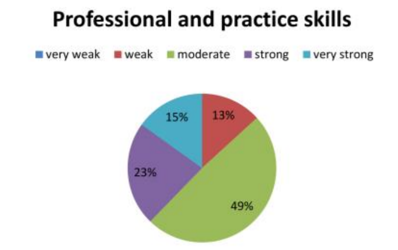
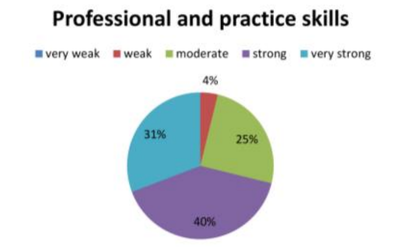
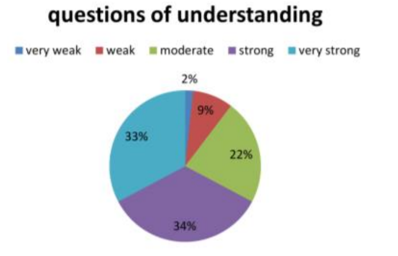
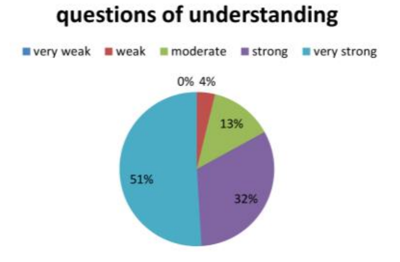


Fig. 10: Students' interaction with the theatre hall during the experiment in situ

8.5.3. Questionnaire Analysis



Precise AR questions, in terms of usability, were mentioned at the top of the questionnaire page, through which a recommendation was provided for using the technique and the application with a percentage of 60%. This percentage will affect the consideration of involving AR on a permanent basis in teaching the courses of "Architecture Design Studio 3" and "Building Construction" in the future. By analyzing the other sections in the questionnaire (ILOs and Lecture Understanding Indicators), we find:

Record Before AR	Record After AR	Notes
		In the intended learning outcomes, the percentage representing the level of knowledge and understanding increased after AR in the categories of "strong" and "very strong".
		In the intended learning outcomes, the percentage representing intellectual skills increased after AR in the categories of "strong" and "very strong" while the "moderate" category decreased.
		In the intended learning outcomes, the percentage representing professional and practice skills increased after AR in the categories of "strong" and "very strong" while the "moderate" and "weak" categories decreased dramatically.
		In the lecture understanding indicators concerning theatre design, the percentage representing the level of understanding increased after AR in the categories of "strong" and "very strong" while the "moderate" category decreased and the "very weak" category vanished.

8.6. Results

- When augmented reality was used in the educational experience, the levels of understanding and perception increased with a percentage that varied from one indicator to another.
- Most of the increase in percentages representing the levels of understanding was in the "strong" and "very strong" categories which shows how the level of understanding generally increased when compared with the other group of students who received their lecture solely at the university premises.
- Joining two courses together helped in linking the information provided in both courses and formulating architectural knowledge. This is clear when comparing the professional and practice skills record before and after using AR, which was almost doubled in the "strong" and "very strong" categories.
- The high percentage of recommending AR, as seen from evaluating the usability record, reflects that AR applications can be an official tool in teaching architecture in situ.

8.7. Conclusion

Augmented reality as a technology has achieved good results in the field of presenting information, and when it is used in education; it helps in enhancing students' abilities to understand the scientific material in a new, creative, and completely interesting context. Introducing the scientific content in situ represents an added value in architectural education; as it helps link between the site visit and the scientific lecture. It clarifies and enhances the levels of knowledge and understanding on the students' side. Professional and practice as well as intellectual skills which are generally intended learning outcomes of teaching "Architectural Design Studio 3" and "Building Construction", were all raised in this experiment; proving that the usage of AR in teaching architecture and construction can be of positive impact in achieving educational goals.

9. References

i Vianney, Lara-Prieto. Efraín, Bravo-Quirino. Miguel, Ángel Rivera-Campa. José, Enrique Gutiérrez-Arredondo. An Innovative Self-learning Approach to 3D Printing Using Multimedia and Augmented Reality on Mobile Devices. International Conference on Virtual and Augmented Reality in Education, Procedia - Computer Science, 75, p. 59:65, Elsevier, 2015.

ii Dini, G. Dalle Mura, M. Application of Augmented Reality Techniques in Through-life Engineering Services. The Fourth International Conference on Through-life Engineering Services, Elsevier, 2015.

iii Klinker, Gudrun. Stricker, Didier. Reiners, Dirk. Augmented Reality for Exterior Construction Applications, Augmented Reality and Wearable Computers, W. Barfield and T. Caudell, eds., p. 1:10, Lawrence Erlbaum Press, 2001.

iv Cadaviecoa, Javier Fombona. Goulao, Maria de Fatima. Costalesc , Alberto Fernandez. Using Augmented Reality and m-learning to optimize students performance in Higher Education, Procedia - Social and Behavioral Sciences, 46, p. 2970:2977, Elsevier, 2012.

v Henrysson, Anders. Bringing Augmented Reality to Mobile Phones. Linköping Studies in Science and Technology Dissertations, No. 1145, Department of Science and Technology. Linköpings Universitet, Norrköping, 2007.

vi Shirazi, Aezoo. Context-Aware Mobile Augmented Reality Visualization in Construction Engineering Education.B.S. The Faculty of Engineering and Computer Sciences, University of Central Florida, Orlando, Florida, 2012.

vii Kyselaa, Jiří. Štorkováb, Pavla. Using Augmented Reality as a Medium for Teaching History and Tourism, Procedia - Social and Behavioral Sciences, 174, p. 926:931, Elsevier, 2015.

viii Vassigh, Shahin. Newman, Winifred E. Behzadan, Amir. Zhu, Yimin. Chen, Shu-Ching. Graham, Scott. Collaborative Learning in Building Sciences enabled by augmented reality. American Journal of Civil Engineering and Architecture, Vol. 2, No. 2, p. 83:88, at: http://pubs.sciepub.com/ajcea/2/2/5, © Science and Education Publishing, DOI:10.12691/ajcea-2-2-5

ix Vianney, Lara-Prieto. Efraín, Bravo-Quirino. Miguel, Ángel Rivera-Campa. José, Enrique Gutiérrez-Arredondo. An Innovative Self-Learning Approach to 3D Printing Using Multimedia and Augmented Reality on Mobile Devices. International Conference on Virtual and Augmented Reality in Education, Procedia - Computer Science, 75, p. 59:65, Elsevier, 2015.

x Abboud, Rana. Architecture in an Age of Augmented Reality: Opportunities and Obstacles for Mobile AR in Design, Construction, and Post-Completion. NAWIC International Women's Day Scholarship, p. 9:11, 2013.

xi Uzunoglu, Semra Sema. Quriesh, Ariz. A Method of Adapting Construction Education in Architectural design education, Procedia - Social and Behavioral Sciences, 51, p. 546:552, Elsevier, 2012.

xii Jokela, Timo. Livari, Netta. Tornberg , Vesa. Using The ISO 9241-11 Definition Of Usability In Requirements Determination: Case Studies. at: https://www.researchgate.net/publication/242526620

xii Bevan,Nigel. Carter, James. Harker, Susan. ISO 9241-11 revised: What Have We Learnt About Usability Since 1998? M. Kurosu (ed.): Human Computer Interaction, Part 1, HCII 2015, LNCS 9169, 143-151, 2015.