International Journal of Innovative Technologies in Social Science

e-ISSN: 2544-9435

Scholarly Publisher
RS Global Sp. z O.O.
ISNI: 0000 0004 8495 2390

Dolna 17, Warsaw,
Poland 00-773
+48 226 0 227 03
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ARTICLE TITLE	THE MOTIVATIONAL IMPACT OF AUGMENTED REALITY ON ARCHITECTURE STUDENTS: A FIELD STUDY AT AN INTERNATIONAL EXHIBITION
ARTICLE INFO	Amokrane Radhwane, Gherzouli Lazhar, Atef Ahriz, Lousfane Selma. (2024) The Motivational Impact of Augmented Reality on Architecture Students: A Field Study at an International Exhibition. *International Journal of Innovative Technologies in Social Science*. 4(44). doi: 10.31435/ijitss.4(44).2024.3128
DOI	https://doi.org/10.31435/ijitss.4(44).2024.3128
RECEIVED	22 October 2024
ACCEPTED	14 December 2024
PUBLISHED	24 December 2024
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THE MOTIVATIONAL IMPACT OF AUGMENTED REALITY ON ARCHITECTURE STUDENTS: A FIELD STUDY AT AN INTERNATIONAL EXHIBITION

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ABSTRACT

This study aimed to evaluate the effectiveness of augmented reality technology in motivating architectural engineering students and improving their comprehension of complex projects. An AR- application called "builtec" was developed, displaying two architectural models: an exterior view of the building and its surroundings, and an interior view showing the internal details of one floor. The study adopted an experimental analytical approach, conducting the experiment using modern digital and tablet devices on a sample of 81 students during an international exhibition held in Algeria in 2024. Results showed significant success of the technology, with the attractiveness of the experience receiving a strong approval rate of 95%, interaction with the virtual model achieving 86% approval, and ease of technology use reaching 82%, along with positive technical aspects evaluation at 92%. The study concluded by demonstrating the effectiveness of augmented reality technology as a means to increase interaction, motivation, and enhance architecture students' understanding of complex projects. The study recommends expanding the use of augmented reality technology in educational curricula and conducting more comparative studies covering various architectural presentation techniques to identify the best technologies and practices in architectural education.

KEYWORDS

Augmented Reality, Virtual Model, Interactive Learning, Architectural Visualization

CITATION

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Introduction.

The past years have seen unparalleled technological development, which has affected many fields, including education. This has resulted in significant transformation at all levels, from primary education to the university. Shifting from a classical and traditional approach that is based on diction and indoctrination to a modern interactive approach, that focuses on tutoring using inclusion, motivation, and enjoyment (César González Mariño, 2009). Education is no longer about the negative experience of the learner acquiring information and lectures. Instead, it has become a more interactive field that attracts curiosity and inspires creativity and critical thinking.

The field of architecture in Algeria is one of the many fields that rely on traditional methods and approaches to education. At the time of writing the majority of the architecture faculties are still using miniature models, hand-drawn materials, and theoretical lectures. Such a thing will limit the students' ability to develop their skills concerning Spatial visualization and comprehend the architectural relationships inherent to large-scale projects. (Yazdani & Rashidi Mohammadi, 2013), this may result in a decrease of interaction and participation among learners, which would create a disparity between academic learning and the requirements of the modern labor market. The modern generation of students differs from the previous one in several ways, due to their upbringing in the digital era which makes them more leaning toward interactive and engaging education methods.

Amid all the contemporary technological tools including virtual reality (VR), artificial intelligence (AI), three-dimensional printing and others, the augmented reality technology stands out as a promising solution to all the academic challenges and difficulties that can be faced in the field of architecture. Despite its novelty, it offers a chance to transform learning from a theoretical experience to a tangible interactive experience that helps the learners in overcoming the difficulties previously mentioned including visualizing three-dimensional forms and comprehending intricate spatial relationships. Augmented Reality is an interactive technology that incorporates digital information with the physical environment in real-time, by adding layers of computer-generated information to the physical world providing an enhanced sensual experience. (Azuma, 1997, p. 356).

From all the above, we can ask the following questions:

- ***How does the use of augmented reality improve the comprehension and exploration of complicated architectural projects among the students of the field? And what are the advantages that are provided by the technology in the presentation of Architectural models to the students in comparison to traditional methods?***

Augmented Reality has the potential to improve the understanding and comprehension of complicated architectural projects among the students of architecture. This is achieved through its features that include providing an immersive interactive experience that allows the exploration of architectural details from a three-dimensional perspective enabling the examination of the projects from different angles while interacting with its elements directly. Which may enhance their ability to understand and comprehend spatial and inter-related design relationships. Nevertheless, this technology can face many technical difficulties and practical challenges like the necessity of high-end hardware and software, the high cost of the equipment, in addition to the obstacles related to the user experience.

Our study aims through the use of the Augmented Reality technology to present and study a new method of architectural indoctrination. This study revolves around consecutive goals, starting by evaluating the efficiency of the augmented reality technology in providing three-dimensional architectural models and analyzing the students' experience using it .it also seeks the new prospects that can be shown by using such technology to help the learners grasp and understand the complicated architectural models in an interesting interactive method. Furthermore, this research includes assessing the ease of utilizing the AR technology in presenting architectural projects. And concludes by narrowing and selecting the possible technical and practical difficulties that can intervene against this technology in the educational field of architecture.

Methodology.

This study relies on combining two complementary approaches in order to achieve the objectives of the study as well as reach accurate and comprehensive results, the first approach adopted in our research is the experimental approach, and the second is the descriptive-analytical approach.

Experimental approach: It consists in designing and applying a practical experiment using augmented reality technology within the framework of an international exhibition held in Constantine, Algeria, where an application was developed that displays two three-dimensional architectural models (a model of a building with its external surroundings and an internal model of a floor of the same project), the experiment was

designed so that students interact directly with the application through phones and digital tablets, allowing us through the second approach to measure the impact of this technology on drawing students' attention, understanding and absorption of the architectural project presented.

Descriptive-Analytic Approach: The descriptive-analytical approach is manifested in the design and application of a questionnaire consisting of five questions using a five-point Likert scale with a scale from (-2 to +2), the latter aims to collect and analyze quantitative data related to the users' experience, as the questionnaire covers multiple aspects including the level of enjoyment of the experience, ease of use, interaction with the model and others. (Questionnaire in the annexes of the article).

I. Theoretical aspect of the study

The theoretical aspect of the study (defining the Augmented Reality, types and previous studies) is crucial for the purpose of understanding the different choice that distinguished our applied experience from the used software in the creation of the application, the type of the augmented reality used to the software used to transform the presented architectural model to a three-dimensional one.

I.1. definition of augmented reality: AR has different definitions that includes the following:

✓ **Academic definition:** Augmented reality (AR) is the real-time display of the physical world, enhanced by adding virtual elements. It is interactive, works in three-dimensional space, and blends the real and digital worlds. (Carmigniani & Furht, 2011, p. 46)

✓ **Academic definition**: Augmented reality technology combines real and virtual elements to create hybrid environments where physical and digital components interact seamlessly in real time. (Billinghurst et al., 2015, p. 73).

✓ **Practical definition**: AR is a digital technology that enhances the real world by integrating interactive digital elements. It offers immersive experiences in fields like education, entertainment, and marketing. (Klopfer & Squire, 2008, p. 205).

From all the previous definitions we can conclude that the Augmented Reality is an advanced technology that blend both our real world and added digital elements, therefore we can observe the virtual content combined with the physical work in a direct instant manner throughout different mediums.

I.2. types of augmented reality: all the conducted researches in the academic field divided the Augmented Reality into two main categories with several sub-categories:

✓ **Marker-based Augmented Reality**

The first type of augmented reality relies on using visible marker that are predefined a reference points to determine the position of the virtual elements in the physical environment. This technology uses cameras, scanning the points and the following the markers to create the physical environment geometry (Larsen and al., 2011, p. 42).

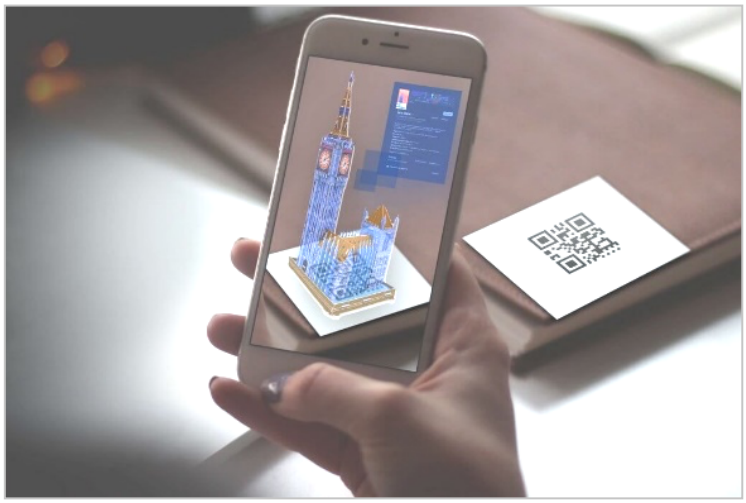


Fig. 1. An example of marker-based augmented reality
Source: Larsen and al, 2011

✓ **Markerless Augmented reality**

This type of Augmented reality is subdivided into three types:

• **Location-based AR:** This type of augmented reality relies on GPS to add interactive digital content in specific geographical locations. Once the user points the device's camera, the information is displayed.

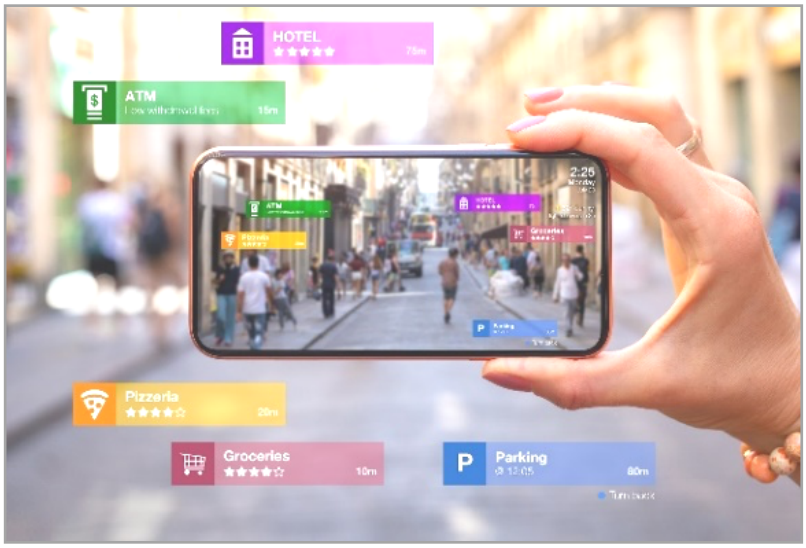


Fig. 2. An example of location-based augmented reality
Source: Wear Studio, 2024

• **Projection-based AR:** is a method that involves projecting virtual information and data into the user's physical space by using artificial light projected onto real surfaces (Poghosyan, 2019).

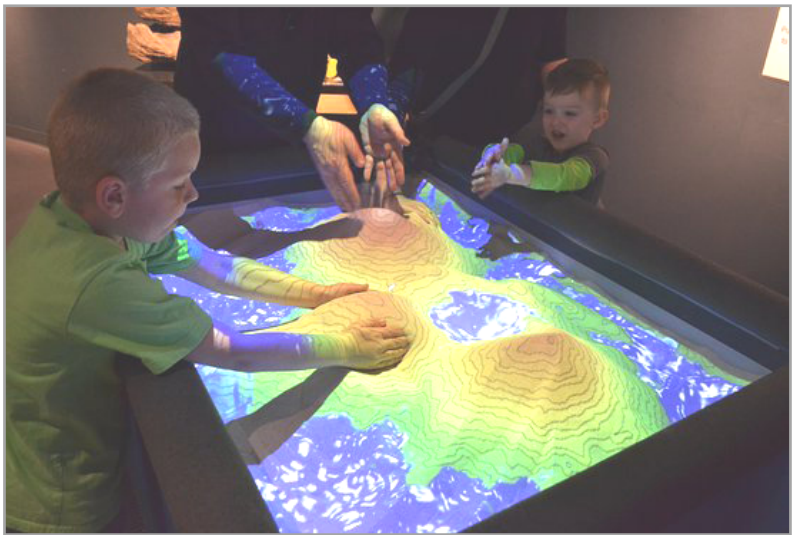


Fig. 3. An example of Projection-based AR in Geography Class
Source: Poghosyan, 2019

• **Superimposition-based AR:** This method creates a partial or complete virtual alternative view of real objects, relying on the system's ability to accurately recognize objects. (Poghosyan, 2019)

Fig. 4. An example of Superimposition-based AR in a History Field-trip
Source : Poghosyan, 2019

I.3. Prior research.

Study 01: Learning Geometric Transformations for Parametric Design: An Augmented Reality (AR)-Powered Approach

By creating an interactive AR educational application called BRICKxAR_T, the authors of this study provided a thorough analysis of the function of augmented reality in university architectural education, particularly in the areas of geometric modeling and parametric design. They came to the conclusion that augmented reality technology is an effective teaching tool that can close the gap between theoretical understanding and real-world architectural application. It greatly lessens the work required to decipher 3D models from 2D blueprints, which is a problem that most architecture students encounter. (Shaghaghian et al., 2021).

Despite that, this study did not look at the long-term impacts of educating utilizing this approach, incorporate a control gather to compare the viability of the created device with conventional strategies, or address potential impediments to generalizing this test, such as the require for educator preparing, the shifting degrees of understudy interaction with advanced instruments, or innovative openness. These variables are pivotal for the study's last appraisal.

Study 02: Employing a versatile augmented reality app to instruct basic examination

The analyst portrayed an instructive involvement in which third-year architecture understudies were instructed basic examination through the use of augmented reality innovation. In differentiate to conventional educating approaches, this project looked for to upgrade students' comprehension of how complicated auxiliary components connected with different building loads in an intuitively, three-dimensional setting. (Yao, 2018)

Utilizing two bunches of third-year students—the exploratory and control groups—the ponder utilized the test approach, in which an iPad-based increased reality application was made to survey the application's adequacy and its impact on students' comprehension and engagement. The examination created critical findings, Most imperatively, understudies were able to see the changes in loads and watch their affect on the basic behavior of the components in an intuitively and immediate way much obliged to the broad utilize of augmented reality innovation in basic examination instruction.

While the study is significant, it is constrained to an examination of the iOS operating system and does not address the long-term impact of the app on student learning.

II. Experiment Protocol.

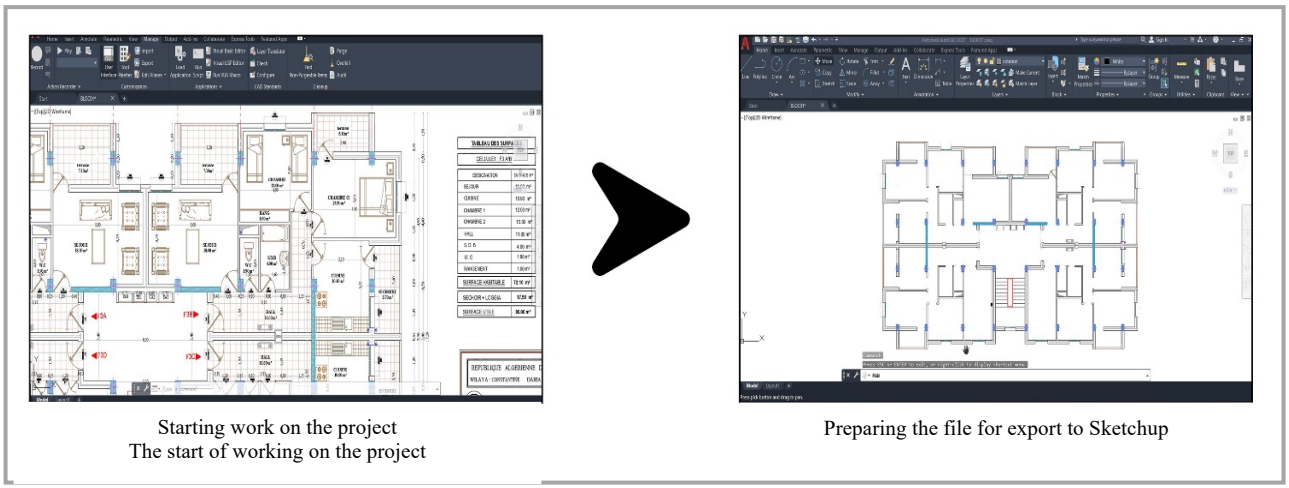
The implementation of the practical experiment went through several successive stages to ensure the success and effectiveness of the process, starting with the design phase, going through the design phase, technical development phase, implementation phase and concluding with the evaluation phase.

II.1. The design stage.

It is the foundation of our test, amid which we outlined and displayed the project to be displayed in our experience (residential buildings), and this stage can be partitioned into two steps.

✓ **two-dimensional design stage:**

During this phase, we worked on our project using AUTOCAD software to prepare it for the next stage, which is three-dimensional modeling., the last mentioned requires a streamlined arrange free of hatching, quotes, tables and all data that's not fundamental for modeling.



Starting work on the project
The start of working on the project

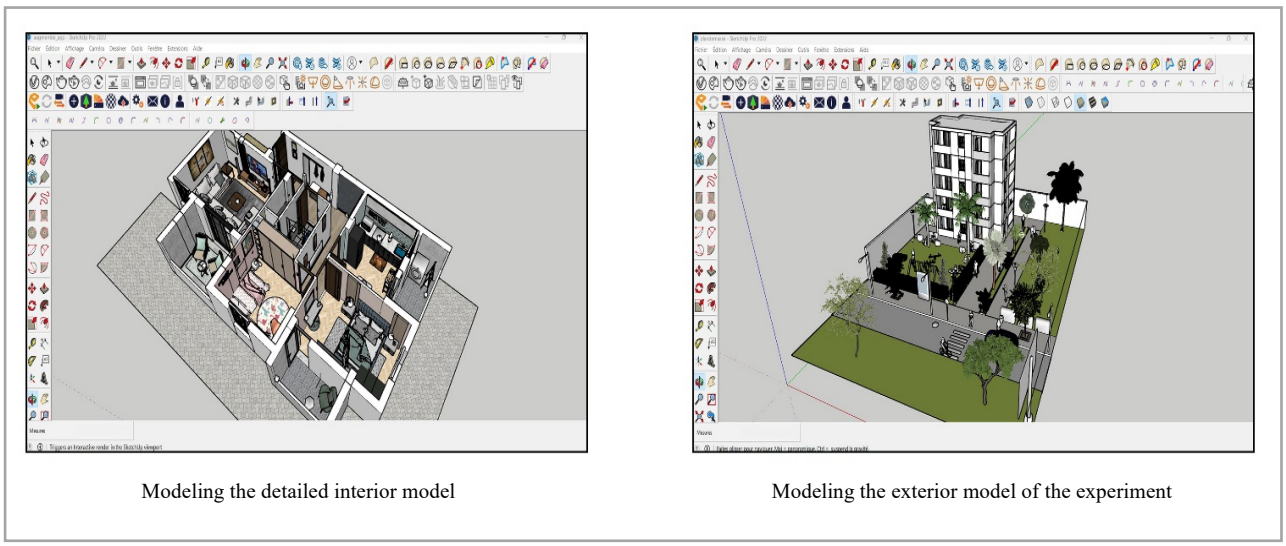
Preparing the file for export to Sketchup

Fig. 5. Two-dimensional design stages of our experimental project using Autocad
Source: Author, 2024

✓ **3D modelling stage:**

After completing the two-dimensional design phase, in this stage of our experiment, we first import the plans from AutoCAD to Sketchup. Then, as a second step, we convert the two-dimensional elements into three-dimensional models (walls, ceilings, windows, doors, and others). In the third step, we apply basic materials and textures to various project elements.

Several considerations must be taken into account before exporting the experimental file to Unity3D, including: simplifying the model, reducing the number of faces and vertices (Vertex and polygons), and ensuring the accuracy of measurements and proportions.



Modeling the detailed interior model

Modeling the exterior model of the experiment

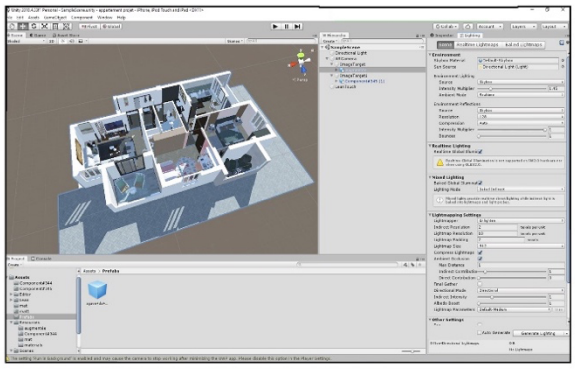
Fig. 6. Three-dimensional design stages of our experimental project using Sketchup
Source : Author, 2024

II.2. Development Phase:

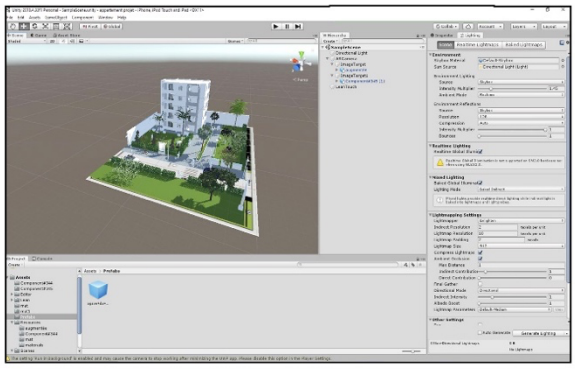
This is one of the most important parts of our experience, as it will culminate in creating the augmented reality application specific to our study. This phase can be divided into 2 stages:

✓ **Preparatory Stage:**

During this stage, we will import the three-dimensional models resulting from the design phase into Unity3D software. Here, we improve the textures by adding reflections, refraction, and bump mapping on one side, and adding natural and artificial lighting to the models on the other side. The goal of this preparatory stage is to add realism to the model during the final display within the application.



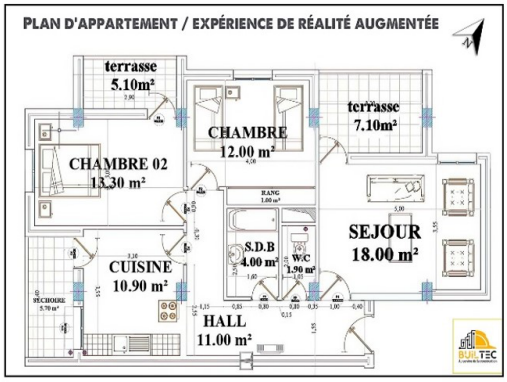
Adjusting the interior model



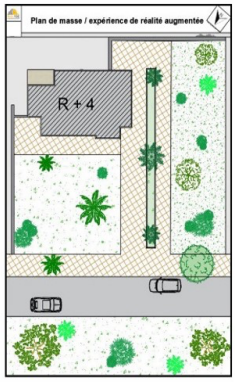
Adjusting the exterior model

Fig. 7. The preparatory phase of the development stage within Unity3D program
Source : Author, 2024

✓ **Development Phase:** In this experiment, we relied on the first type of augmented reality based on Markers (which we explained in the theoretical part of the study). To achieve this process, we used Vuforia technology to display the two architectural models using specific visual markers. In our case, these markers are the interior and exterior architectural plans.



Special tags to recognize and project the virtual model (internal and external layout) in Unity3D



Creating the application's user

Fig. 8. Development phase using Vuforia within Unity3D
Source : Author, 2024

Before making the application and to create it more user-friendly, we outlined a client interface with buttons that we programmed in C# to facilitate navigation between the different interfacing of the program. After that, we made and yield the application as an APK record on Android 8.0 to be congruous with different gadgets in case clients need to introduce the application on their gadgets. After introducing the application on the phone, we conducted extensive tests to guarantee the right and smooth of the building models and their interaction with the user's signals. (See figure 9).

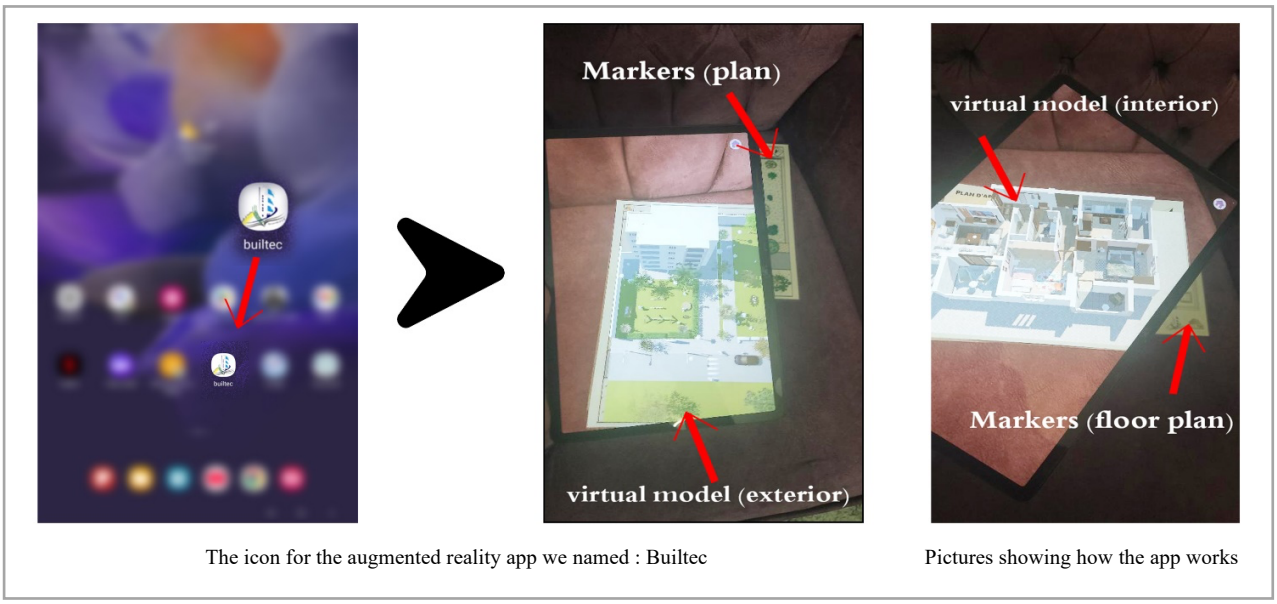


Fig. 9. A set of images showing the augmented reality application of our experiment in action.
Source: Author, 2024

II.3. Implementation stage.

This phase took place during the International Exhibition for Modern Construction and New Technologies, held at the Ahmed Bey Social Complex in Constantine from 20 to 23 February 2024, where we propelled our explore within the taking after grouping:

- Pre-installing the app on an assortment of versatile gadgets, counting smartphones and tablets of diverse sizes and determinations that back Vuforia innovation, to guarantee a consistent user experience.
- Printing the the reference markers, in this case inside and outside plans, and after that thermally laminating them to dodge harm due to rehashed utilize.
- An awfully expansive number of people, including engineering understudies, taken part within the two-day encounter, and members were separated into little bunches to guarantee that everybody had sufficient time to investigate the virtual model displayed in two stages with all its outside and inside points of interest.
- Supervisors were placed to provide direct technical support to participants on how best to use the app, making sure to rotate the devices among the participants in an organised manner to bring them closer to the technology.

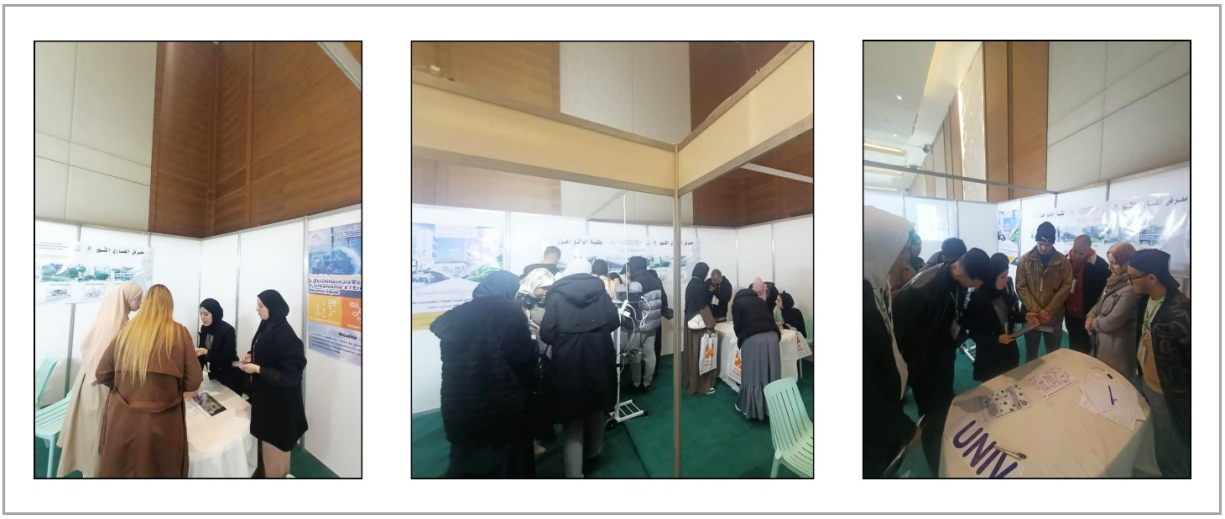


Fig. 10. A collection of photos of our experience during the exhibition
Source : Author, 2024

In a final stage, questionnaires were distributed to the students who completed the experiment to find out their responses and impressions of the experience, with a simple explanation for people who had trouble understanding the Likert scale.

In order to facilitate comprehension of our experiment, all data can be presented in the following table:

Table 1. Augmented Reality Experience Data / Source: Author, 2024

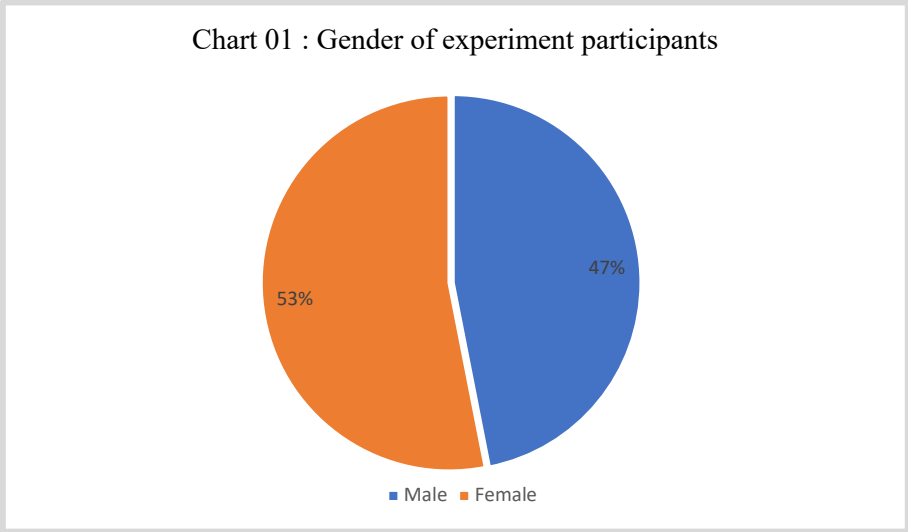
Applied Domain	Type of technology utilised	Number of participants	Experiment place	Time of the experiment	Used devices	Data collecting material	Design software used	Application Development Platform
Presentation and education in architecture	Augmented Reality AR	81 students out of 241 participants	International Exhibition of Technologies	21\20 March	Mobile tablets	survey	Autocad Sketchup	Unity 3D

III. Results of the study.

Given the high density of visitors, the conducted study spanned during the first two of the exhibit days only. A significant number of questionnaires were collected, which then we began sorting obtaining 241 forms.

During the first phase we excluded questionnaire forms that were filled by architecture engineers, company owners, civil engineers, university teachers and students from other fields as well as people who came because of their interest in the augmented reality. In the second phase we excluded forms that were not complete and incorrectly filled ones to finally obtain 81 valid forms to analyze and study.

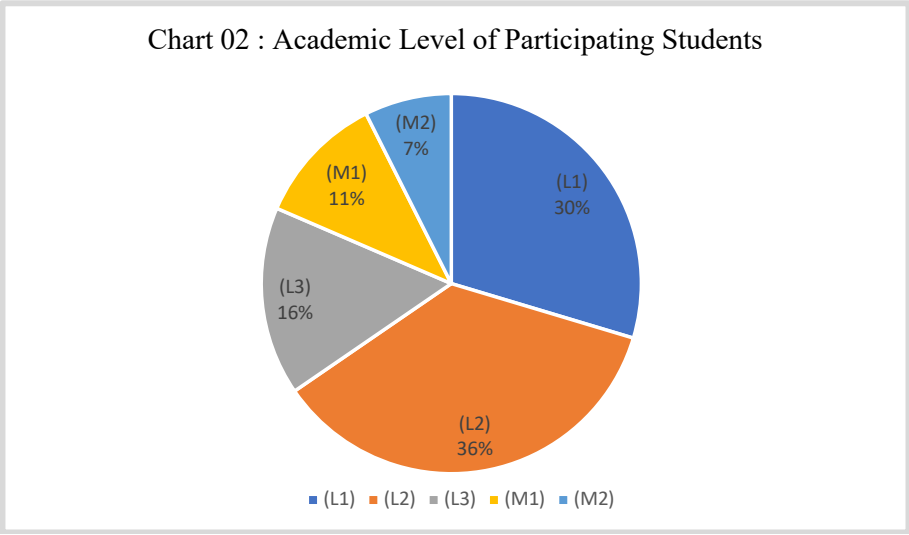
III.1. Gender.



Source : Author's elaboration based on survey data, 2024

The chart over outlines shows the distribution of architectural students participating in the experiment according to their gender. It demonstrates a relative merging within the dispersion, with a slight prevalence of females. Female understudies constitute an assessed **53%** of the entire members, whereas male understudies speak to **47%** of the considered test. This relatively adjusted gender dissemination gives a dependable sign of the representation of both genders in the experience.

III.2. The Academic level.

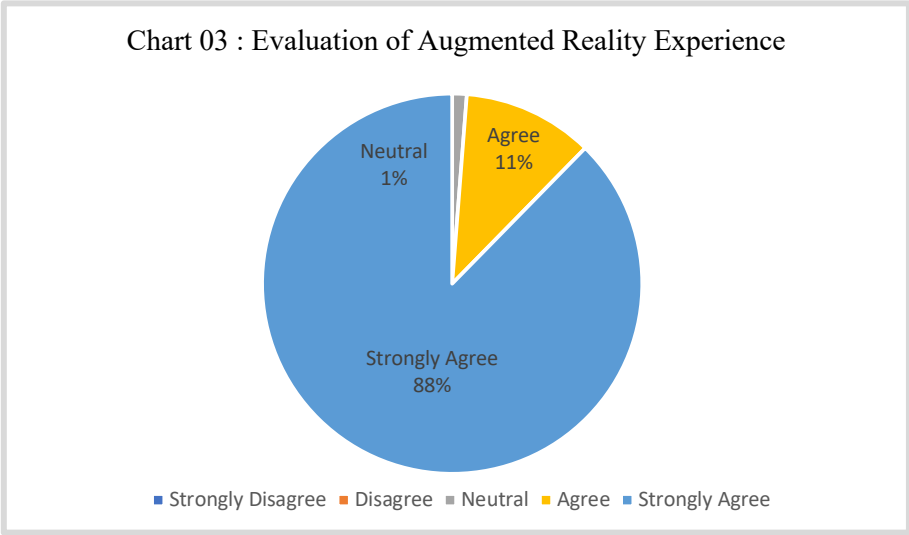


Source: Author's elaboration based on survey data, 2024

Nb : (L1) : 1st Year Bachelor's Students; (L2) : 2nd Year Bachelor's Students; (L3) : 3rd Year Bachelor's Students; 1st Year Master's Students (M1); 2nd Year Master's Students (M2).

The chart over outlines show the distribution of academic levels of students participating in the experiment. It can be watched that the biggest rate (36%) is comprised of second-year understudies (L2), taken after by first-year understudies (L1) with 30%, and third-year understudies (L3) with 16%. The extent of Master's understudies is comparatively moo, with 11% of the entire comprising first-year Master's (M1) understudies and a encourage 7% speaking to second-year Master's (M2) understudies.

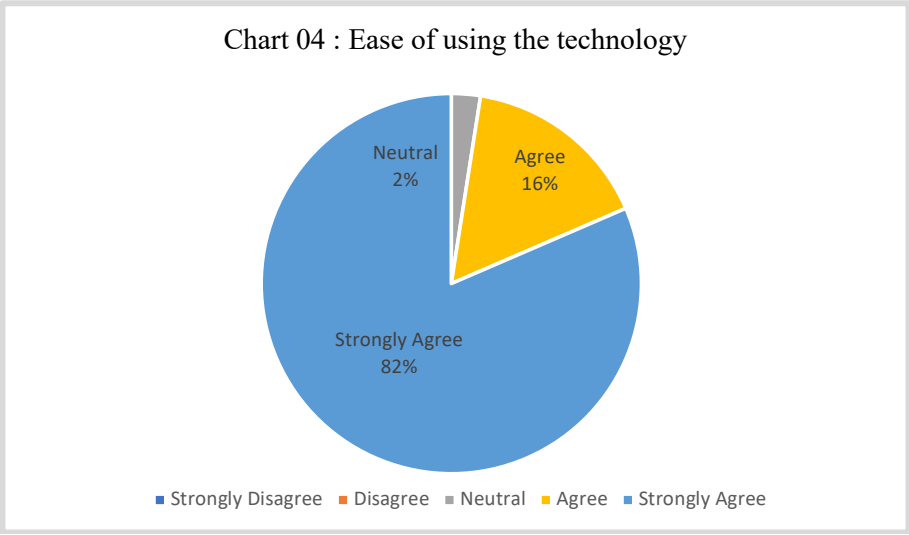
III.3. Evaluation of Augmented Reality Experience.



Source : Author's elaboration based on survey data, 2024

The chart above show the evaluation results of the augmented reality experience, which yielded a transcendently positive reaction from the members. Particularly, **88%** of the whole members demonstrated a strongly agreeing with the involvement, whereas as it were **11%** disagree and a mere **1%** remained neutral. It is critical that no negative reactions were recorded.

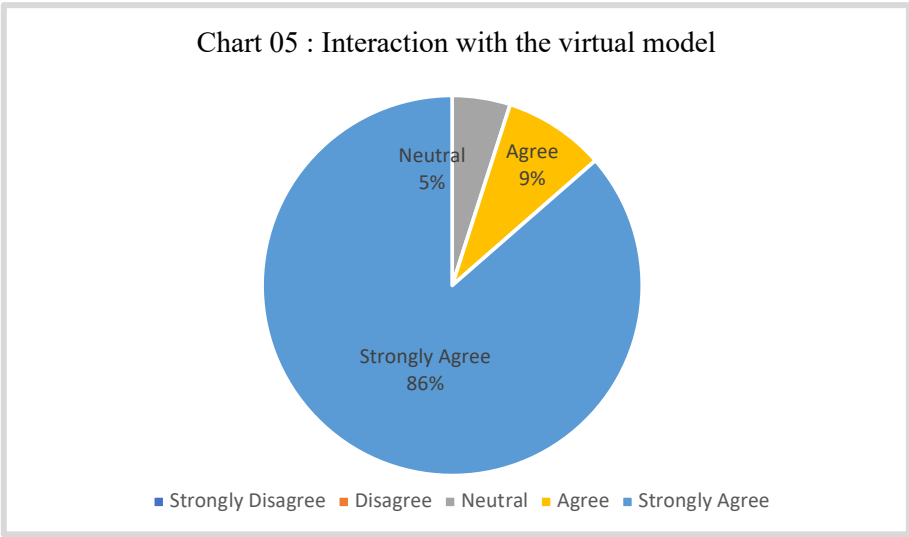
III. 4. The ease of using the technology



Source : Author's elaboration based on survey data, 2024

The chart above shows the evaluation of the AR app's ease of utilize by the trial members. The comes about for this address demonstrate a exceedingly positive reaction, with **82%** of members strongly agreeing with the ease of utilize of the innovation, whereas **16%** agreed and as it were a little rate (2%) were neutral. Strikingly, no negative reactions were recorded for this address.

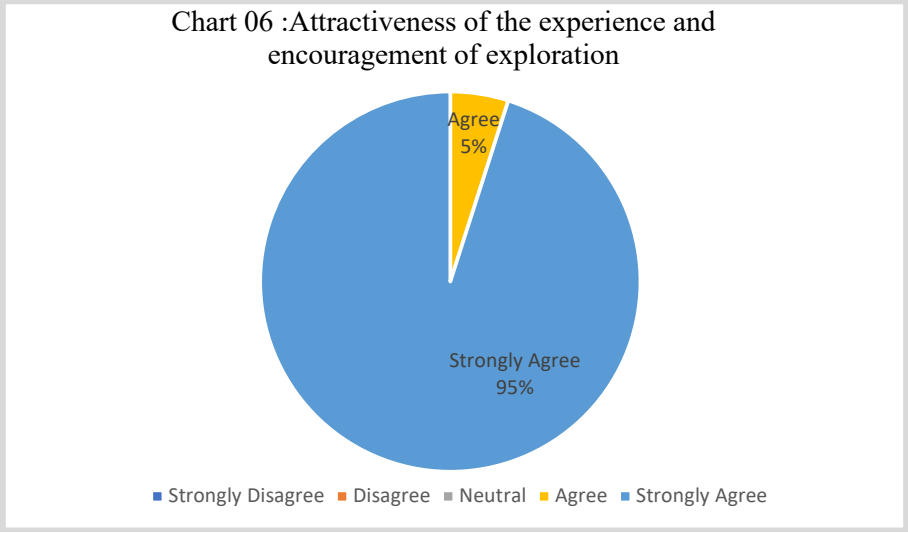
III. 5. The Interaction with the virtual Model



Source : Author's elaboration based on survey data, 2024

The chart over outlines present the interaction with the virtual demonstrate by the ponder members. The comes about show a extraordinarily positive reaction, with **86%** of the understudies communicating a strong agreement for interacting with the virtual model. Furthermore, **9%** of the members moreover shown a preference for the virtual demonstrate, whereas as it were **5%** remained neutral. It is critical that no negative reactions were watched.

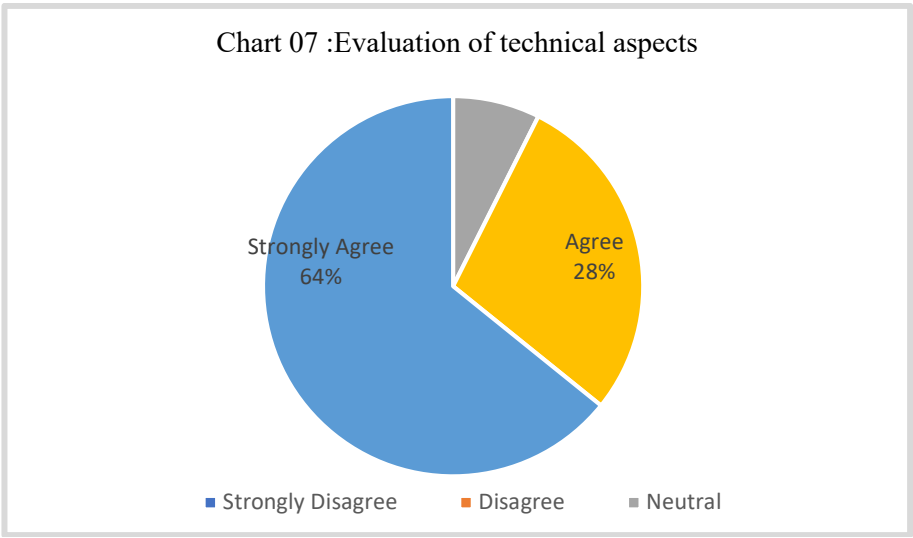
III.6.The attractiveness of the experience and encouragement of exploration.



Source : Author's elaboration based on survey data, 2024

The comes about of the assessment of the engaging quality of the test and its support of disclosure, as displayed in Chart 06, illustrate an especially positive reaction from the members. The most elevated rate of solid understanding was recorded for the thing 'strongly agree', at **95%** of the entire members. It is also notable that there were no neutral or negative responses.

III.7. The evaluation of technical aspects:



Source : Author's elaboration based on survey data, 2024

The chart above shows the assessment of the specialized viewpoints of the test. The comes about illustrated a transcendently positive reaction, with a few variety within the levels of approval. Specifically, **64%** of the full taking part understudies communicated solid understanding, whereas **28%** concurred with the quality of the specialized viewpoints and the nonattendance of bugs inside the application. Moreover, **8%** of the members shown a impartial position.

IV-Discussion of results.

✓ The generally adjusted gender dispersion gives a great sign of an break even with representation of both genders within the try as there's no predisposition within the determination of the test, which increments the unwavering quality of the comes about and permits them to be summed up to the community of design understudies.

✓ The high rate of moment and to begin with year Bachelor students (66% combined) can be clarified by the truth that these understudies are in their first steps in designing and structural plan, which makes them more fascinated by modern and advanced strategies in displaying building projects. The moo rate of Master's understudies (18% combined) may be due to their distraction with graduation projects and their center on more particular perspectives of their ponders.

✓ The exceptionally positive reaction from the members can be clarified by a few key components: the cautious choice and past encounters of the devices utilized (Poco X3 Professional and Universe Tab S7) which guaranteed a high-quality specialized encounter; the scholarly levels of the larger part of the members, to be specific to begin with and moment year understudies (66%) who are utilized to and open to unused advances; and the introduction of two diverse models of the structural extend (outside and inner show) permitted clients to have a more comprehensive understanding of the structural extend.

✓ The ease of use of the AR application amid the show can be clarified by a few variables: Firstly, the high percentage of strong understanding demonstrates the victory of the client interface plan and the ease of interaction with the app. Besides, the choice of high-performance gadgets (said prior) may play a part in enhancing the client involvement. Moreover, the age dispersion of the members may clarify the ease of adjustment to the unused innovation, given the openness of this age gather to cutting edge innovation.

✓ The high engagement of participants with the virtual model can be explained by the following factors: The success of augmented reality technology in providing an interactive experience superior to traditional paper models; secondly, the quality of the models presented, which included an external model of the building and its surroundings and a detailed internal model (with the ability to move from one model to another easily) may also have played a role in enhancing the participants' preference for the virtual model.

✓ The exceptional results (95% strongly agree) that characterized the attractiveness of the experiment and its encouragement of discovery can be explained by the following: The design and implementation of the experiment by combining two models in the same application that display an external and an internal model, which may have aroused students' curiosity and discovery, the quality of the devices used may have a role in these results, and the first and second year students who represent 66% of the sample contributed to this result, as they tend to be open and enthusiastic towards innovative educational methods.

✓ Although there were minor technical challenges faced by some users during the experiment (especially for students who are seeing AR for the first time), the 92 per cent agreement and strong agreement rate confirms the success of the technical aspect of the experiment in general.

Conclusions.

The discoveries of the ponder illustrate the impressive adequacy of AR innovation as a apparatus for upgrading comprehension and examination of perplexing building projects. This was prove by three foremost spaces:

Within the space of interaction and investigation, the discoveries uncovered tall levels of acknowledgment and engagement with virtual models in comparison to classical models. This substantiates the adequacy of the innovation in giving intelligently engineering models that can be comprehended and investigated. Within the moment space, inspiration and engaging quality, the explore yielded surprising rates, showing The capacity of AR innovation to spur understudies to engage actively with engineering projects was moreover illustrated. Within the third region, which is specialized and connected, the comes about shown that the innovation was direct to utilize and highly compelling, empowering understudies to center on understanding the structural project instead of being distracted with its complexity. These comes about affirm that **AR innovation has succeeded in showing itself as an successful instructive apparatus that makes a difference understudies get it and investigate complex structural projects in an intelligently and locks in way.**

The findings of the study also portray that the students prefers enormously the interactive virtual models over the traditional tangible models at presenting the Architectural models.

the strong positive interaction with the virtual model demonstrates the students' remarkable adaptability and engagement with the new technology, highlighting their preference for virtual models as they provide a more interactive and immersive learning experience than traditional methods.

In close agreement with our initial predictions, the final results of the study confirmed the first hypothesis: AR technology significantly improves understanding of complex architectural projects. This is demonstrated by the high level of interaction with the virtual model (86% strongly agree) and the attractiveness of the experience (95% strongly agree). Surprisingly, the anticipated technical and practical challenges turned out to be less severe than expected. The ease of use of this technology is highly appreciated (82% strongly agree) and reviews of its technical aspects receive extremely positive feedback (92%). Overall, these results confirm the research hypotheses.

Potential directions for future research:

Based on the findings of our study, we can develop directions and themes for future research that intersect with our topic:

✓ Based on the positive results in the attractiveness of the experience to people in general and students in particular (95% strongly agree), the application can be extended to the field of teaching architecture at the Algerian university.

✓ Given the positive results in the interaction with the virtual model compared to the classical model (86% strongly agree), in the future, comparative studies involving different architectural presentation techniques can be conducted to identify the best techniques and practices in architectural education.

✓ Based on the results that show the ease of use of the technology (82% strongly agree), future work can be done to develop standards and bases for integrating AR technology into Algerian curricula and prepare training programs for university professors.

Practical recommendations of the study:

✓ It is recommended that augmented reality technology be promoted for use in architectural education at Algerian universities.

✓ It is essential to provide university professors with the requisite training to enable them to master this technology.

It is essential to develop comprehensive standards and a robust foundation for the integration of augmented reality into academic curricula.

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Appendix A

Survey on Your Experience with Augmented Reality

The International Exhibition : modern buildings and new technologies _ Fourth Edition

N: ....

Date: ... / ... / ... Gender: Male □ Female

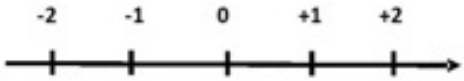
□

Job:

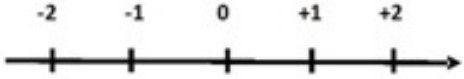
Educational level:

Place a mark (✓) next to your choice:

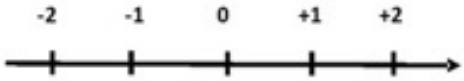
1. Did you enjoy the augmented reality experience presented today? How do you rate the experience?



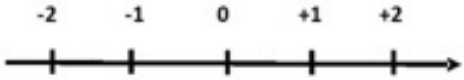
2. Did you feel comfortable and at ease using this technology?



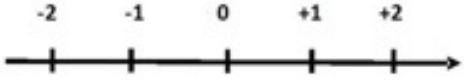
3. Did you enjoy interacting with the virtual architectural model compared to the paper model?



4. Do you feel that the experience was interesting and encourages exploration and interaction?



5. Do you consider the technical aspect of the experience successful and free from malfunctions?



Thank you for your cooperation