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Evaluating the Effectiveness of Augmented Reality (AR) in Interior Design Courses

Tianjiao Zhao, Ph.D.
East Carolina University
Greenville, North Carolina

Ri Na, Ph.D.
University of Delaware
Newark, Delaware

In the realm of construction education, the increasing utilization of Augmented Reality (AR) tools has brought forth new opportunities for enhancing spatial perception, optimizing spatial layout, accommodating design changes, and improving communication. This study aims to assess the effectiveness of mobile AR apps in these dimensions, providing insights into the transformative potential of AR technology within construction instruction. A quantitative analysis was performed by comparing the time usage with and without Augmented Reality (AR) within both the experimental and control groups in each school. A supplementary questionnaire was also undertaken in this study from two construction programs with a focus on how AR tools influence spatial comprehension and communication. This study intends to contribute valuable perspectives for integrating these technologies into contemporary educational frameworks, thereby fostering a more comprehensive learning experience for students in the construction field.

Key Words: Augmented Reality (AR), Education, Interior Design, AEC

Introduction

Today, technological devices are fully integrated into the lives of young students. A plethora of wearable devices such as Microsoft HoloLens have introduced Augmented Reality (AR) and Virtual Reality (VR) into classrooms around the world. Of these, AR technology, which requires only a screen to realize, is particularly compelling. It integrates digital information such as text, images, video, and 3D objects into the real world and displays them on a single screen. This approach enhances the user's perceptual interaction with the physical world and also subverts traditional methods of interior design presentation such as 2D sketching and physical modeling (Aalkhalidi, Izani, & Razak, 2022). The use of 3D visual presentation in AR technology plays a crucial role in visualizing our ideas (Aalkhalidi et al., 2022). More enhanced forms of knowledge transfer can help students become more motivated and focused on learning new material (Chiang, Yang, & Hwang, 2014; Nivala, Rystedt, Säljö, Kronqvist, & Lehtinen, 2012). However, to date, the use of AR technology in education in the Architecture, Engineering and Construction (AEC) industry has been limited (Aalkhalidi et al., 2022; Tan, Xu, Li, & Chen, 2022). They are mostly focused on K6-12 education (Kucuk, Aydemir, Yildirim, Arpacik, & Goktas, 2013), biology (Wang, Hu, Hwang, & Yu, 2022), and healthcare (Schild et al., 2018).

The 2D plan, one of the most common information carriers in civil and architectural engineering, often struggles to adequately and visually convey the complexity of a design (Louis & Lather, 2020). This poses a challenge to young, inexperienced AEC personnel. The traditional measurement methods also increase the time cost of the work and the error rate in the transfer of information. This study aims to investigate the impact of AR technology in teaching interior design. Using a small room renovation project as an example, this study tests the impact of AR tools in enhancing students' spatial perception and creativity, reducing time and communication costs, and smoothing the design process. The comparative study tracked and discussed time reduction between the control and test groups, while the additional benefits of Augmented Reality (AR) were explored through a questionnaire administered to the students who experienced Virtual Reality (VR) for interior design in this research.

Research Approach

The workflow of the study is shown below (see figure 1). The study consists of 5 steps. The key points of each step are detailed below.

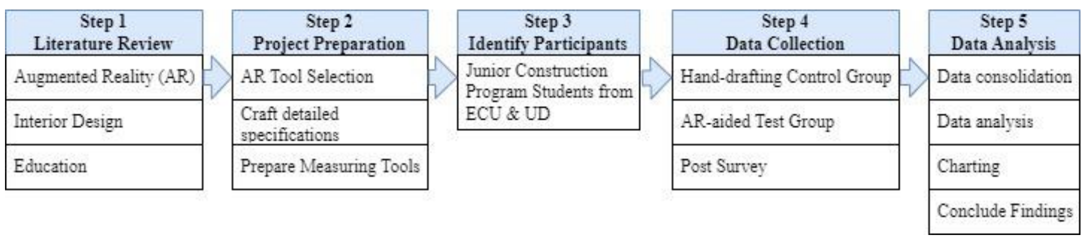

Figure 1. Study workflow

Step 1 Literature Review

This study focused on the use of low-device-requirement AR tools in the classroom. The literature review of the study included journal papers, conference publications, and a few online articles that were obtained from the following databases: IEEE Xplore, Scopus, Web of Science, and Google Scholar. Each of these databases uses Augmented Reality (AR), Interior Design, and Education as search strings to search for papers that contain these terms in the title, abstract, or keywords. "Education" is used as the core keyword to review literature and conduct research on the application of AR technology. Given the rapid iteration of AR technologies, the publication period was designated as 2008-present. The study found that the use of AR technology in construction or AEC education is far less common than in youth education or industry.

Step 2 Project Preparation

The workflow of the preparation process is shown below (see figure 2).

First, a suitable Augmented Reality (AR) tool was chosen based on considerations that prioritize ease of operation and adoption in any classroom setting. The selected tool must exhibit the following characteristics: (1) free of charge (at least for a certain period of time for at least one complete room), (2) just a cell phone; no more equipment is needed, (3) comes with intelligent measurement tools, (4) is universal for both iOS and Android systems, and (5) comes with a certain number of 3D furniture models with adjustable dimensions. These characteristics of AR tools can guarantee that students can fully and without burden perceive the possible help of AR tools in the process from measuring to designing, modifying the design, and presenting the design. The final AR mobile application chosen for this study is the Magicplan (Michael S., 2017), which fulfills all of the above requirements.

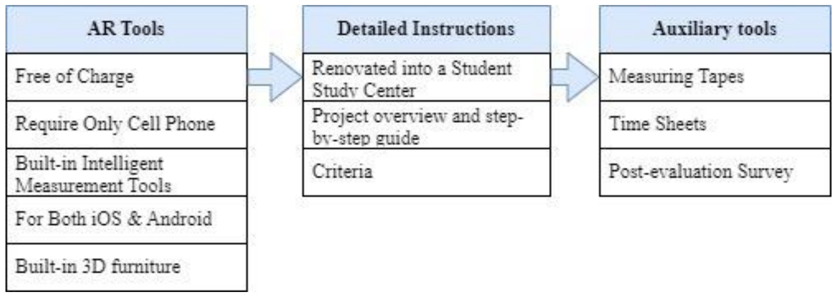

Figure 2. Preparation workflow

Next, detailed project instructions were developed. This study uses the example of renovating a classroom into a student study center. The instruction manual provides information on the project's goal, scope, significance, detailed instructions for each step, and criteria. To boost student engagement, additional incentive points were established. For example, the first group to finish and the best design will receive bonus credits. There is also a need to take full account of the differences in student numbers and site sizes on both sides of the universities and to adapt the instructions.

Finally, some auxiliary tools were prepared. For example, a measuring tape, a time-tracking spreadsheet, and a post-evaluation questionnaire.

Step 3 Identify Participants

The study identified participants from two construction programs, specifically 44 junior students from East Carolina University (ECU)’s Construction Management Program and 19 sophomore students from University of Delaware (UD)’s Construction Engineering and Management program. All students had completed a course either in plan or surveying, thus ensuring that the students had some exposure to design and surveying. The combined sample size of 63 students ensured higher reliable results for data analysis. A total of 12 control groups as well as 12 test groups were obtained by randomizing every 2-3 people. Among them, there were 8 groups from UD and 16 groups from ECU.

To streamline the study, the testing site utilized was the classroom of these students. The floor plans of the classrooms are shown in Figure 3 (left and right) respectively. The classroom space was measured at 1,597 square feet for ECU and 872 square feet for UD. Given the space constraints, only outlines and proportional sizes are shown here rather than specific dimensions.

The study was completed in two weeks for both universities, which helped the authors eliminate the learning curve that could affect the results of the study. Student participants were equally divided into control and test groups at both universities. Each group consisted of 2-3 students and were randomly assigned. Students in the control and experimental groups used the classroom at different times to avoid interfering with each other. The workflow of the control and experimental groups is shown in Figure 4. Before the groups begin the activity, the instructor will help to group them, clarify the steps of the task, and provide the required materials, which is specified as Step 0.

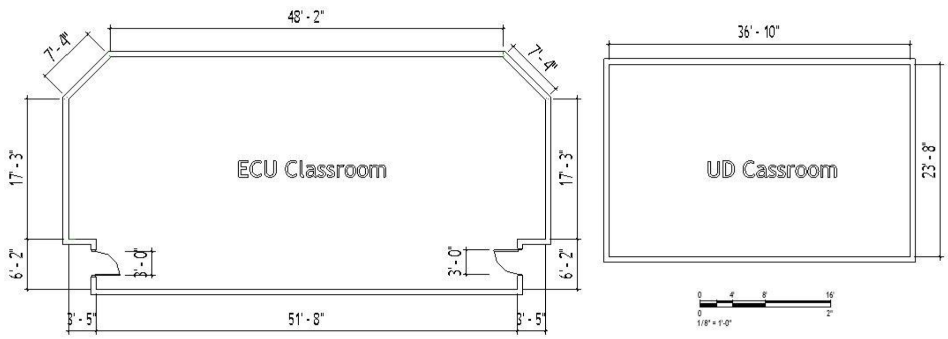

Figure 3. Classroom floor plans at ECU (left) and at UD (right)

Step 4 Data Collection

Students in the control group accomplished the following tasks in sequence.

- Step 1: Measure the classroom using a traditional measuring tape.
- Step 2: Design the study center on a 2D-floor plan (either hand-drawn or CAD-drawn). The students were provided with a list of furniture, including their 2D sketches and sizes. They can freely select the items that they would like to use in their design.
- Step 3: Add appliances as required, e.g., a wall-mounted TV. Students will need to consider the position and height of other furniture so that the TV can be placed in a suitable location.
- Step 4: Use their 2D drawings to explain their designs to other groups.

The students in the test group accomplished the following tasks in sequence.

- Step 1: Scan the classroom dimensions using the auto-scan feature of the AR app.
- Step 2: Design the furniture layout according to the built-in list of furniture models. To ensure consistency, both the control and test groups were given an identical list of furniture.
- Step 3: Add the required appliance with the built-in database. Students will need to consider the position and height of other furniture so that the TV can be placed in a suitable location.
- Step 4: Utilize the 3D views of their designs in the AR app to articulate and discuss their designs with other groups.

Students were instructed to log the start and end times for each step and complete the timesheet accordingly. Students were also prompted to provide comments on each step in their timesheets, explaining their efforts or reasons for exceeding or falling short of their expected time. The completed timesheets were then submitted to the instructor upon finishing the design assignment.

Upon completion of the study, students were asked to complete a questionnaire on the Likert scale to understand their perceptions of the use of AR tools in teaching and learning. Note that the control group students were also provided a chance to access the AR tool after they completed the project, and thus were invited to finish the questionnaire as well. The questionnaire consisted of the following 5 categories of questions:

- The impact of AR technology on spatial perception.
- The impact of AR technology on measurement.
- Impact of AR technology in aiding design and optimizing the design process.
- Impact of AR technology on improving communication.
- Impact of AR technology on overall learning outcomes.

The online multiple-choice questionnaire took three to five minutes to finish. Whereas students at UD answered the questionnaire on Canvas, those at ECU used the Qualtrics platform. The same questions were given to students at the two distinct universities.

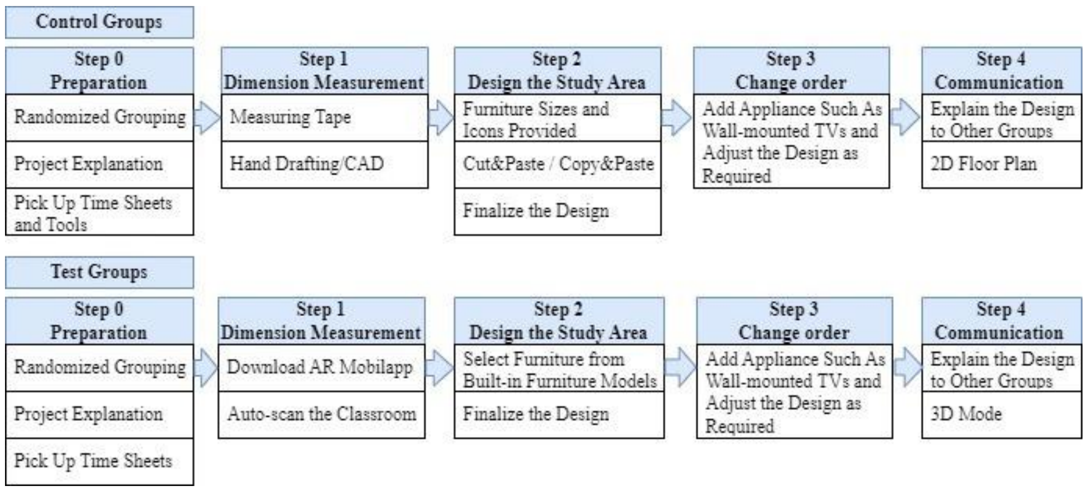

Figure 4. Control and test group workflows

Step 5 Data Analysis

The data collected for this study consisted of log time data, design drawings, student comments, and questionnaire results. Data analysis was divided into four steps: (1) Data consolidation, (2) Data analysis, (3) Charting, and (4) Concluding Findings.

Data from students at ECU and UD were analyzed separately. For each university, the time spent by its control groups in each step was compared with the time spent by its test groups in the corresponding step. The students' questionnaire results were summarized and plotted into a graph based on the percentage distribution of responses across the –2 to 2 Likert Scale. The students' comments were also discussed.

Results and Discussions

The results were categorized into log time comparison analysis, design analysis, and perspective analysis. Each of the three sections will be discussed next.

Log Time Comparison Analysis

Following the separate tallying of the time sheets for ECU and UD students, the average time spent for each step was generated, as depicted in Figure 5. The blue and orange columns in the figure represent the average time spent on each step (0-4) for the control and test groups, respectively.

As shown in Step 0, the preparation phase, both the control group and the test group picked up the materials and read the instructions, thus spending very close to the same amount of time.

In Steps 2-4, design, change design and explain design steps, the test group's and the control group's time trends are very similar, with the test group's time being significantly less than the control group, and the second step taking significantly longer than the other two steps.

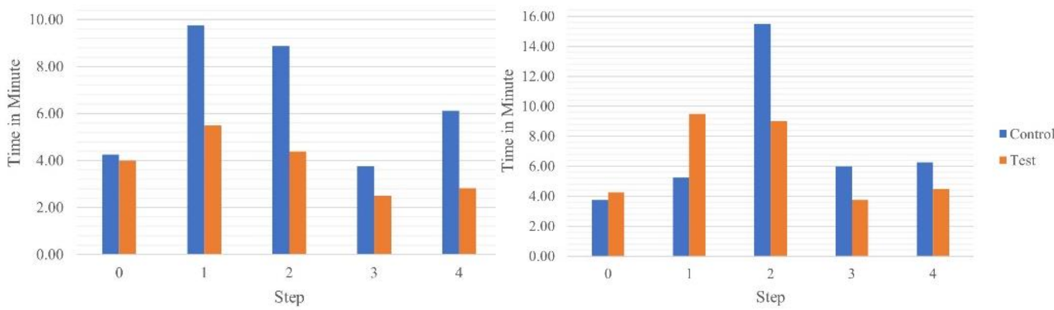

Figure 5. Comparison of time spent on each step by ECU (left) and UD (right) groups

However, in Step 1, measurement, the two data sets were significantly different. The control groups from ECU spent significantly more time on conventional measurement, i.e., tape measurements, than the test group, i.e., AR auto-scan, whereas the opposite was true for UD. Not only that, but the timing charts show that all of ECU 's control groups took significantly more time for the first step than the test groups, without exception. The authors want to specify that the classroom used for testing in ECU was twice the size of UD and had significantly more corners, thus making traditional measurements significantly more time-consuming. The authors thus conjecture that the advantage of AR-assisted measurement methods could potentially increase significantly as the size of the space, as well as the complexity, rises.

Design Analysis

Through a systematic examination of the individual designs, the authors identified a noteworthy phenomenon. Despite the flexibility in selecting furniture styles (with an identical list provided) and quantities, students exhibited a tendency. In the context of a sizable space, students leaned towards opting for larger furniture pieces, repetitively employing them to swiftly occupy the central area. Conversely, when tasked with designing a confined space, students showed a preference for a diverse array of smaller furniture, initiating the layout from the periphery and, ultimately, leaving a substantial empty area in the middle. The more refined design results in a greater investment of time. As you can see from the graph, the UD group with only about half the classroom space took about 1.7 times as long in the design activity (Step 2). This likely reflects the difference in students' design philosophies for different space sizes. Figures 6 and 7 show two representative designs for the control and test groups at the two universities, respectively.

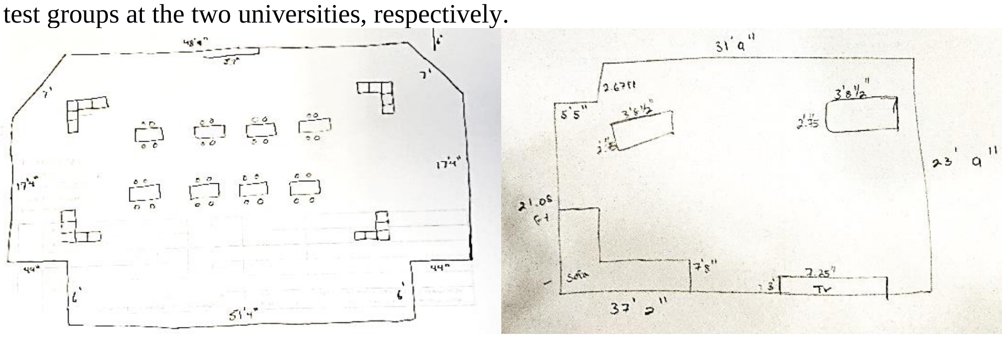

Figure 6. Examples of hand-drafting design by ECU (left) and UD (right) groups

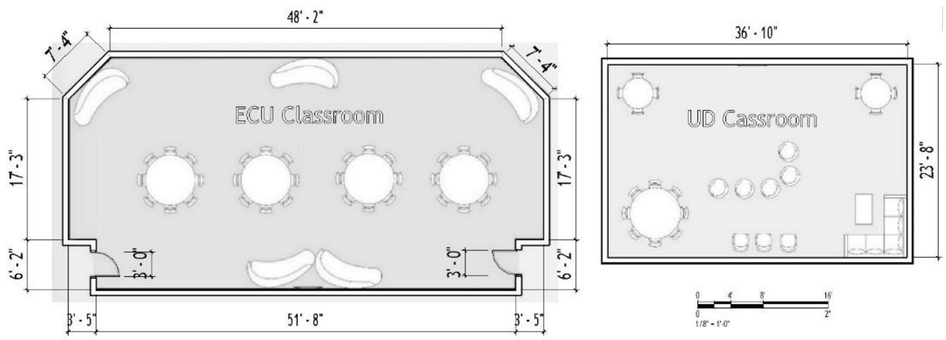

Figure 7. Examples of AR-aided design by ECU (left) and UD (right) groups

Perspective Analysis

The design of the questionnaire followed the Five-point scale of the Likert scale, that is, Strongly Agree - Agree - Neutral - Disagree - Strongly Disagree. Since there were many questions, the options were assigned values for convenience during statistical analysis. That is, Strongly Disagree is scored as -2, Disagree is scored as -1, Neutral is scored as 0, Agree is scored as 1, and Strongly Agree is scored as 2. Once again, ECU and UD students were counted separately. The weighted scores for each question were graphed based on the percentage distribution of responses across the -2 to 2 scale as shown in Figure 8.

As shown in Figure 8, students at both universities gave positive feedback about using this AR experience despite their general lack of experience with AR. Among other things, students were generally most appreciative of AR's role in enhancing interaction, perceiving spatial relationships of objects, visualizing designs, and facilitating teamwork.

Upon comparing the scores from the two universities, it is evident that students closely recognized the benefits of each aspect of AR, including the AR experience, creativity, and the streamlining of the renovation design process. Additionally, ECU's group was much less likely to recognize AR for creativity and for streamlining the refurbishment design process. Whether this is a result of ECU classrooms being too large for students to spend enough time embellishing their designs needs to be further investigated.

The authors also attempted to capture students' thoughts from the comments they left on their schedules. Most of the students marveled at the time that could be saved by the automatic scanning measurement feature of the AR as well as the reduced human error. Two students mentioned that they would like to be able to use it on the field. Another point that was mentioned most was the ease of visualization with the AR tool: "You can look at it from any angle and notice problems that you missed before"; "You can intuitively know if a piece of furniture fits in the room." "No more trying to lead the client to visualize your design, you can just show it to him".

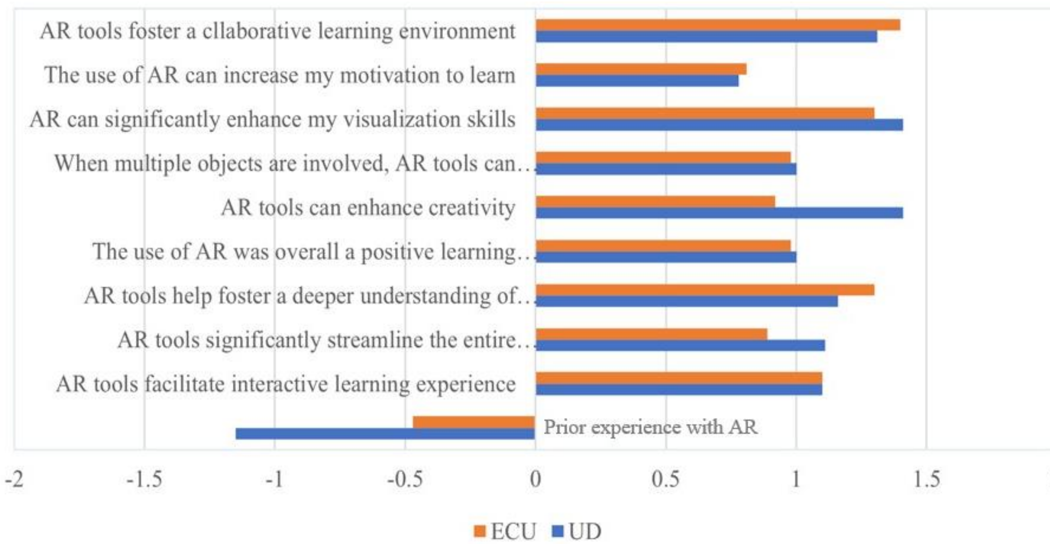

Figure 8. Questionnaire results

Conclusion

This paper contributes to the current discussion and evolving dialog around the integration of AR technology into AEC educational environments, with a particular focus on interior design courses. This paper presented a study that quantitively investigated the effectiveness of using AR in construction education. Overall, the application of the AR tool to students' performance in interior design was significantly beneficial, and the data from control and test groups from both universities indicate this conclusion. The most common stages in interior design were selected for this study: measurement, design, change of design, and design presentation. In terms of time tracking, the test group that applied the AR tool spent significantly less time on each step. Measurement and design data from larger and more spatially structured classrooms show this difference to be particularly pronounced.

In addition to the comparative study, a questionnaire was distributed to identical groups of students who took part in the research, serving as a supplementary component. The results reveal that most students acknowledged extraordinarily the help of the AR tool in enhancing spatial sense, visualization, presentation of work, and communication and collaboration. This study also prompted the authors to think about the differences that different space sizes bring to the design process and design concepts. The participants seem to be more inclined to refine their designs when dealing with smaller spaces. This could be further explored in future research. Test samples from a larger number of rooms and rooms of varying complexity may provide us with a newer and deeper understanding. Given that this study was only accelerated over a two-week period, other tasks of interior design were not covered. A more in-depth and comprehensive application of AR tools could be attempted in future studies. This would help to more fully evaluate the benefits of integrating AR tools in teaching construction classes.

From an educator's point of view, there are a number of challenges in daily teaching practice in the face of cutting-edge technologies such as AR and VR. These challenges mainly include: first, whether the new technology will impose an additional burden on students, such as the financial burden of purchasing software or equipment; second, how to use the technology to solve educational pain points, such as using the visualization function of AR to help students dramatically enhance their spatial perception thereby circumventing irrational designs that are easy to overlook based on their imagination alone; and third, how to continuously optimize the curriculum design to expand the application of this technology in education and teaching.

The authors plan to expand their research on these topics and promise to disseminate more detailed findings in further studies.

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