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3D Virtual Site Visit as an Alternative to On-Site Experience in Interior Design Education

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Abstract
This study aimed to investigate the effectiveness of 360-degree panorama-based Virtual Reality (360VR) as a tool to simulate real-world site visit experiences in interior design education. In the first stage of evaluation, the online survey was implemented to ask students about their learning experience of using 360VR. The second stage of 360 VR effectiveness evaluation focused on the objective comparison of students learning outcomes between the 360VR method and the traditional approach. The students' experience survey results indicated that 360VR and virtual walkthrough experiences benefited students' understanding of the site during the design process. Students reflected positive 360 VR experiences on their engagement in learning, special layout, visualization, and educational effectiveness. The result of the student learning outcome evaluation showed no significant difference between 360 VR compared to no site visit. However, there was a significant improvement in students' spatial planning, finish selection, and total scores when using the 360 VR method compared to an on-site visit.

Keywords
360VR, 3D scan, interior design studio, service-learning projects, learning outcome

Introduction
The on-site experience is a crucial part of learning in design education as it allows students to accurately examine the physical environment. During the site visit, students receive important information by experiencing the physical space with all senses, taking on-site measurements, photographing the space, and interacting with the users inhabiting in the space. However, site visit also involves some challenges in covering time and cost associated with long distance travelling, the uncertainty of weather, safety issues, and increase in coordination (Wolf et al., 2021). Even design education has been affected by the COVID-19 pandemic because the era of social distancing limited the students' site-visit experience.

As an alternative to a physical site visit, a 360-degree panorama-based Virtual Reality (360VR) has been implemented in a variety of sectors, not only in marketing, retail, and hospitality, but also in architecture, engineering, and construction sectors. The development of a Simultaneous Localization and Mapping (SLAM)-based mapping technology has enabled users to conveniently capture 3D indoor environments in digital format, and this technology accelerated the virtual experience spread. The 360VR also has advantages in real-world visibility different from Virtual Reality (VR) technology based on 3D modeling. In turn, the increased use of 360VR has transformed human experiences, assisting the co-existence of virtual and physical environments. However, some questions still need to be answered to implement virtual experience in educational settings regarding its effect on student performance. Thus, the goal of the presented study is to qualitatively and quantitatively examine the use of 360 VR technology in students' learning in educational settings.

Literature Review

3D Scan Technology

The 3D scan technology captures a projection of spherical images of the surrounding environment. In this process, the camera is located at the center of the image plane realizing human-eye behaviors (Pham et al., 2018). As this technology provides real-world visibility, it has been increasingly used in a variety of industries. For instance, retail, marketing, and hospitality sectors have implemented virtual showrooms and exhibits, and such 3D experience has shown the benefits of increased traffic to the store while reducing costs and carbon emissions. When real estate development and home design services provide 3D virtual property, it boosts commissions, the number of listings, and productivity while saving time (Sulaiman et al., 2020; Vazquez et al., 2021b). Additionally, architecture, engineering, and construction sectors use an advanced feature of 3D scan building information modeling (BIM) files, they could simplify design stages by reducing modeling times and measurement errors. Overall, case studies have shown the efficiency of 3D scan technology to reduce the cost, time, and environmental contaminants (Matterport, n.d.; Sulaiman et al., 2020; Vazquez et al., 2021b).

The benefit of 3D scan technology has been reported not only in various industries but also in educational disciplines. There has been a growing interest in 3D tour technology as a potential alternative to a real-world field trip. A field trip has been a widely-used learning activity as it provides real-world experiences, engages students, and promotes student-centered learning. Virtual field trips (VFTs) tackle some challenges of physical field trips such as travel distance, time, cost, the uncertainty of the weather, safety issues, and so on (Wolf et al., 2021). As 360VR is considered as a potential tool to capture field-trip visibility, there have been a growing number of research on the effectiveness of the virtual experience in education.

Controversy has existed about whether 360VR is beneficial for students learning or not. Some researchers have argued that 360VR hardly replaces real-world experiences. Seifan et al. (2020) examined the students' perception of virtual site visits versus real-world site visits. Virtual site-visit could engage and motivate students; meanwhile, students perceived virtual experiences have limitations in fully giving an idea about the site's scale and in cultivating creative and innovative thinking and problem-solving (Seifan et al., 2020). This result concluded that 360VR could be a supplement to a real site visit but cannot be a replacement.

On the other hand, other researchers have proposed VR technology supports innovative learning activity (Pham et al., 2018; Wolf et al., 2021). Specifically, Pham et al. (2018) used 360VR in construction safety education. The result of the survey with educators, construction managers, and students suggested that the 360VR technology was effective in the comfort of using devices, ease of navigation, real-world visibility, visualization, interactivity, and motivation/engagement (Pham et al., 2018). Furthermore, the student group who used VR technology (mean = 80.33, SD = 3.46) showed significantly higher scores on acquiring construction safety knowledge, compared to the student group who learned based on the traditional method of visiting a real construction job site (mean = 77.83, SD = 5.36) ($p = 0.037$) (Pham et al., 2018). Wolf et al. (2021) also found that students in environmental engineering and urban studies programs reported positive reflections on their motivation, emotion, usability, and site knowledge after the 360-based VFT.

Use of 360VR in Design Education

There have been limited reports that document the use of 360VR in design education and its effectiveness. Loddo (2021) implemented 360VR technology for a museum design project in architectural education. This case study supported that 360VR technology is beneficial in improving students' perception, design knowledge, recognition, awareness, design success, visualization, and interests (Loddo, 2021). This case focused on a museum design project; however, it suggested the potential of 360VR's advantages on the other types of design studio projects. Another study conducted in 2020 analyzed the use and effectiveness of VR to teach the Western History of Architecture (Ben Ghida, 2020). The author describes the importance of 360VR as a sustainable and "secure alternative to fieldtrips".

In summary, the effectiveness of 360VR technology in design education is an ongoing discussion, and limited reports of its effectiveness have been documented. It is necessary to document additional case studies to accumulate evidence. This study, therefore, reports the use of 360VR in an interior design studio project as an alternative to a real-world site visit. Based on the reflection on students' experiences, this study seeks to access its effects on learning engagement, visualization, usability, and educational effectiveness.

Conceptual Framework

This study hypothesizes that the 360 VR method is beneficial in design education based on two educational theories: Visual Learning Theory and Experiential Learning Model. Visual Learning theory explains visual format assists students' high-order thinking skills and learning (Patton, 1991). Visual learning engages visual aids. 360VR is an advanced technology to provide not only high-quality site information in a 3-dimensional visual format but also interactive features. Students can grab large chunks of information in intuitive leaps and remember the site condition easily and remind themselves by coming back to the site model whenever they need it.

The implementation of 360VR in studio courses as a tool to replace traditional project site visits also supports Kolb's Experiential Learning Model. According to Kolb's Experiential Learning model learners absorb and apply knowledge through a sequential multi-step process and it is not a one-time event. The Experiential Learning cycle of Kolb's model constitutes four primary stages of concrete experience, reflective observation, abstract conceptualization, and active experimentation (What is Kolb's Model, 2021; McCarthy 2010). The primary step is to experience and learn the new concept which is also the foundational step or *'concrete learning'*. The second step *'reflective observation'* is for the learner to reflect upon the previous knowledge and reconcile it with new information gained, followed by a successful third step of synthesizing this and introducing new concept also called *'abstract conceptualization'*. With the successful completion of the three primary steps, learner is then able to successfully apply this new knowledge in a contextual setting also referred to as *'active experimentation'.*

Figure 1 explains the theorical framework highlighting the primary differences between traditional site visit method and 360VR implementation. In a typical studio setting during a studio project, students are expected to work through the multi-step design process i.e. Pre-

Design, Schematic Design, Design Development and Post Design. In case of a traditional site visit process, students can only experience the site just once and will have to rely upon site photos and notes for the rest of the steps. However, with 360VR the exposure and access to site related information is same and learners are often able to reply on the original source of information throughout the four primary stages of learning as per Kolb's learning model.

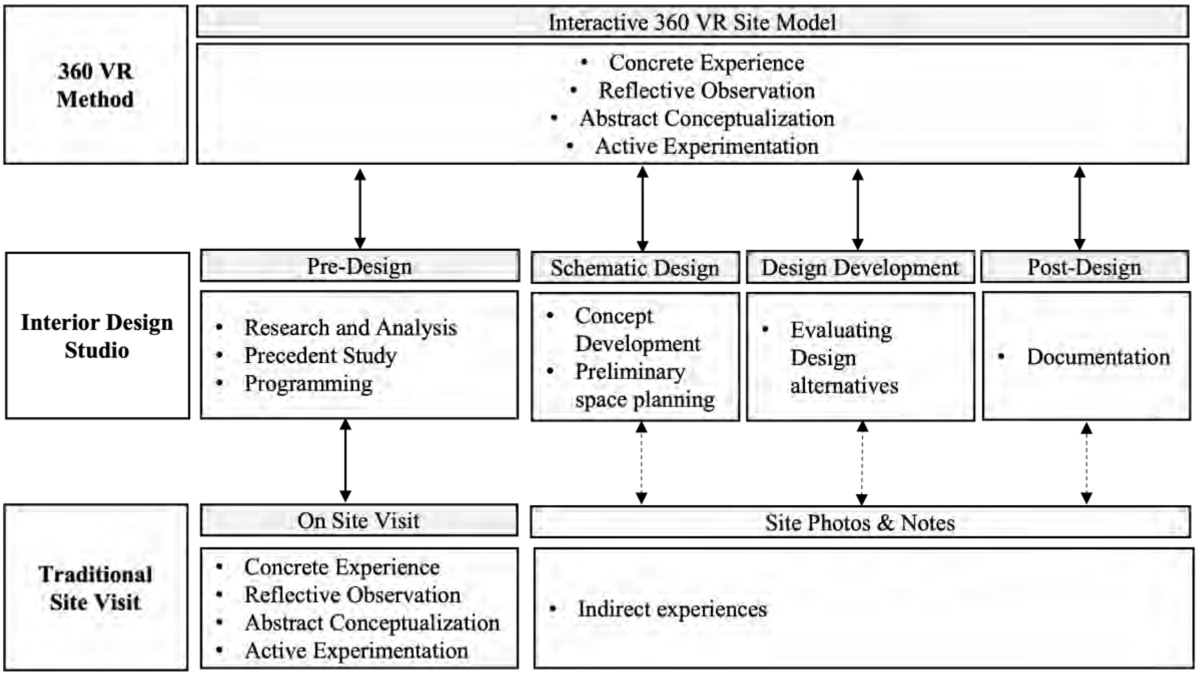


Figure 1: Theoretical Framework

Methods

The purpose of this study is to qualitatively and quantitatively examine students' virtual walkthrough experiences and identify the effectiveness of 360VR technology as an alternative to the physical on-site experience. Sub-questions include:

- Learning Engagement: How much does virtual walkthrough technology engage students in learning?
- Visualization: How does virtual technology help students understand the spatial layout of the site?
- User experience: How do students perceive current technology to be usable enough to assist their visualization of the space?
- Educational Effectiveness: How effectively does virtual technology support interior design education?
- Students Outcome:
    - o Are there significant differences in students learning outcomes between 360 VR and no site visit?
    - o Are there significant differences in students learning outcomes between 360 VR and an in-person site visit?

Participants

The participants recruited for this study are second-year Interior Design students from a University in South West United States, who have experienced interactive 3D virtual tours during their design studio projects. The study was conducted over a two-year period to include a larger group of participants and multiple projects with interactive 3D virtual tours.

Setting

For each year, as part of the second-year interior design studio, students worked on two projects. Each 8-week project is divided into several assignments, and the accumulated efforts is evaluated during their final presentation. This study uses the final presentation scores for student outcome comparison. As for the student group in Year 1, the student outcome was compared between 360VR and no site visit. In Year 2, the 360VR was compared with an in-person site visit.

The 360VR technology was implemented for service-learning projects with the actual site. Students were provided with a link to access the 3D scan of the project sites. The VR tour was accessible on computer monitors or mobile devices without Oculus Quest. Through the virtual space, students could view the walk-through video, move around to visualize the site, zoom in and out to see materials and measure architectural elements within the 3D model space.

The students worked through the entire pre-design and design process including research and analysis, precedent study, formulating the design program based on client needs, concept development, schematic design, design development, and final design presentation to the client (Karlen & Fleming, 2016). Throughout the design process, the 3D scan of the project site was available to students and was encouraged to use it as needed.

The two-service learning projects assigned to the second-year students in the two consecutive years were both assembly-type buildings with similar square footage. The first service-learning project given to the students in Year 1 was a Church building and the second service-learning project given to the students in Year 2 was an abandoned rail depot repurposed as a community gathering and display space.

Year 1 - Church Building: 360VR

This church building was assigned as the 1st studio project for the semester in Fall 2019. The Christian Science church building in Norman, Oklahoma was built in 1941 after the famous Mother Church in Boston, Massachusetts which was built in 1894. This 1941 church building is approximately 2868 sq ft. with an open floor plan and large fixed glass windows on the east and west wall. One of the major challenges as identified by the church users was the sun exposure in the auditorium on both east and west sides with very large windows which severely degraded the carpeting and some antique upholstery of wooden chairs in color and condition. Additionally, the main church and the Sunday school is not connected directly, so the students had to propose design ideas to connect the two spaces together. The 3D scan view of the church building is presented in Figure 2 below.

(a) (b)

Figure 2: Christian Science Church (a) View of 3D model created by Matterport; (b) Perspective view

Year 1 – Cosmopolitan Club Project: No Site Visit

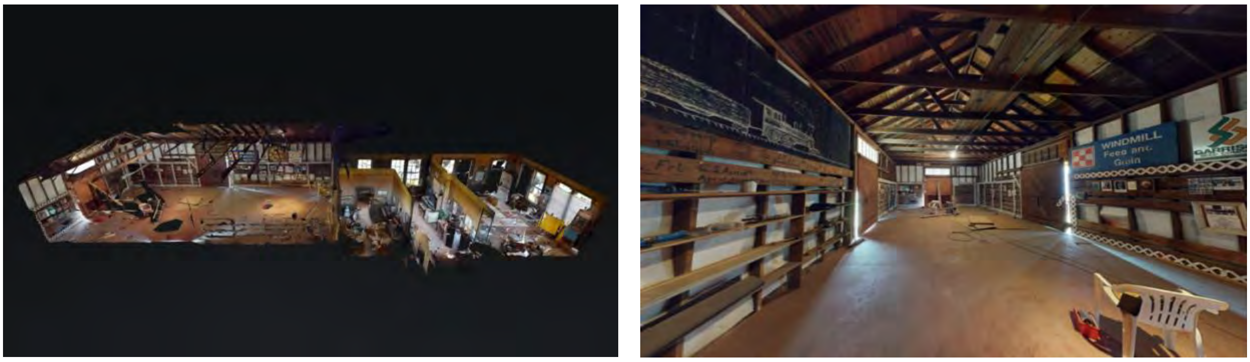
The cosmopolitan club project was assigned as the 2nd studio project for the semester in the Fall of 2019. A barn structure was provided. The building is approximately 4,000 sq ft. with one floor and then a loft area on the second floor. The program requirements included entry, lounge, main dining, private dining, manager's office, restrooms, and food service facilities. Students chose a site in a metropolitan setting in the United States, facing a heavily traveled commercial street. Students could not visit their hypothetical site in person but analyzed using photos and information available online.

Year 2 – Multisite Church Project: In-Person Site Visit

The multisite church project was assigned as the 1st studio project for the semester in the Fall of 2021. The multisite church design team selected one campus located in Norman, Oklahoma as a prototype for the upcoming lobby renovations for multiple locations. The single-story church building, built in 2017, is approximately 36,264 sq ft. and the project scope was 4,914 sq ft. A physical site was required during this project as it is beneficial for students' understanding of the site. The site visit was one time, and students used the site photos and notes for their reference for the rest period of the project.

Year 2 - Rail Depot Project: 360VR

The rail depot project was assigned as the 2nd studio project for the semester in Fall 2021. The M-K-T rail depot (also known as the Wichita Falls & Northwestern Railroad Depot) located in Vici, Oklahoma still sits on its original property by the tracks, is a one-story frame-sided building, built in 1910. The structure is one-story frame-sided with a hipped roof which now has composition shingles. This 2,112 sq ft. depot is divided into two sections: the passenger section with a waiting room and ticket booth is on the West end, with the freight section on the east. The 3D scan view of the building is presented in Figure 3.



(a) (b)

Figure 3: Vici M-K-C Depot (a) View of 3D model created by Matterport; (b) Perspective view

SLAM-based Mapping Technology

Matterport was used to capture and digitize 3D space. Matterport 3D camera consists of Simultaneous Localization and Mapping (SLAM)-based mapping sensors and a motor that revolves 360 degrees (Matterport, 2015). By scanning from multiple points at neighboring positions within 12 feet, the camera creates a 3D model exhibiting environmental data such as interior dimensions, colors, textures, etc. The mapping accuracy of Matterport is slightly lower than LiDAR-based methods; however, it is considered a reliable tool to generate centimeter-accuracy mapping results within a medium size indoor environment (Chen et al., 2018).

Measures

In the first stage of evaluation, the online survey was implemented to ask students about their learning experience of using 360VR. The survey was distributed after the design projects were completed, and administration time was approximately 10 minutes. The survey measured 4 categories using 15 questions: learning engagement, 3D spatial layout, user experience, and educational effectiveness. Each item in learning engagement was measured using a five-point Likert scale (1 = almost never, 2 = seldom, 3 = sometimes, 4 = often, and 5 = very often). For the items under 3D spatial layout, user experience, and educational effectiveness, a five-point Likert scale scored 1 = strongly disagree, 2 = somewhat disagree, 3 = neither agree nor disagree, 4 = somewhat agree, and 5 = strongly agree. For qualitative analysis which captures students' thoughts, two open-ended questions were asked: (1) please list the probable courses where similar virtual 3D spaces can be effectively used, and (2) please provide any additional comment/feedback.

The second stage of 360 VR effectiveness evaluation focused on the objective comparison of students learning outcomes between the 360VR method and the traditional method. For the first student group in Year 1, a service-learning project with 360VR methods was taught before the other hypothetical project with a traditional approach. Inversely, the second student group in Year 2 was taught using 360VR methods after being taught by traditional methods. For both groups, the same instructional pedagogy was implemented regarding the design process. Students were assigned to submit their final design solutions and evaluated by the same criteria.

Data Analysis

The data were analyzed using SPSS version 27. The students' experience survey data collected in the first stage of the evaluation was illustrated by descriptive statistics, including mean and standard deviation (SD) values. Paired *t*-test, also called a dependent t-text, was used for statistical comparisons in the second stage of the evaluation. The analysis compared mean differences on the same dependent variables when each group of students learned under two different methods, 360 VR and traditional methods. Students' outcome scores, including total score, spatial planning, and finish selection scores were measured as dependent variables. P value ≤0.05 was considered statistically significant.

Results

Students' Experience of 360VR Technology

The total sample of 18 students in the second year of an interior design program at a Univeristy in the southwest US. In detail, eleven responses were collected from Year 1 group and five responses from Year 2 group.

Learning engagement measured how students were motivated and engaged in the learning and site analysis through 360VR technology. For five questions, students showed, in general, positive engagement in learning. 3D spatial layout section assessed whether the 360 VR helped students visualize the space. The result revealed students' holistic understanding on the spatial information of the site. Students could develop a sense of space and visualize the space. 360 VR was also useful to identify building components and materials through 360VR. User experience asked if students could easily navigate the application during the virtual site visit using 360VR. It was noted that students highly evaluated the visual clarity of the space on 360VR. They also positively answered that the tool was user-friendly. The lowest score was reported about minimal movement lag during the use of application, however, the score still suggested an acceptable quality of user experience. Lastly, educational effectiveness considered students' satisfaction with the use of 360VR in learning design process. Students were overall satisfied with the 360VR and mostly agreed their knowledge of design and construction would improve through the 360 VR technology. Table 1 below summarizes the survey results.

Table 1: Survey Results – Students' learning experience on the use of a 360 VR

		Year 1 Church Project (n = 11)		Year 2 Rail Depot Project (n = 7)	
Construct	Measure	Mean	S.D.	Mean	S.D.
Learning Engagement	I participated actively (or attempted to)	4.7	0.5	4.6	0.5
	I saw the value in the activity	4.8	0.7	4.9	0.4
	I felt the time used for the activity was beneficial	4.6	0.7	4.9	0.4
	I enjoyed the activity	4.6	0.7	4.0	1.0
	I rushed through the activity	1.6	0.5	2.4	0.7
3D Spatial Layout	I developed a sense of space in the 3D virtual space	4.9	0.3	4.9	0.4

	I could visualize the building components through the virtual space	4.9	0.3	4.9	0.4
	The virtual space conveyed information about the materials used and components of the building	4.8	0.7	4.6	0.7
User Experience	The navigation application was user friendly	4.8	0.4	4.7	0.5
	I could easily find my way around in the application	4.7	0.5	4.7	0.5
	The visual clarity of the space was excellent	5.0	0	4.3	0.5
	There was minimal movement lag on the simulation experience	4.4	0.7	4.0	0.5
Educational Effectiveness	You are satisfied with the learning through the 3D virtual space	4.9	0.3	5.0	0
	The 3D virtual space will be favorable for tool for learning about building materials	4.7	0.7	4.5	1.1
	Your knowledge on design and construction will increase if we use similar virtual 3D spaces during instruction	4.8	0.4	4.7	0.7

Qualitative results also reflected the students' positive experience as the quantitative survey results indicated. For the question about the probable courses where similar virtual 3D virtual spaces can be effectively used, students responded *"Any interior design studio. Especially during the pandemic, physically visiting the project might not be feasible."* Students also suggested interior construction, interior materials and finishes, interior lighting, architectural history, and environment and human behavior. These responses supported that the 360VR supported students' visualization of building materials.

Students made additional. positive comments that imply the advantages of 360VR in design learning: *"I absolutely loved it. Could not speak higher of it. I always found it difficult to recall exactly how the space looked so having a reference was a big asset."* and *"It was great for setting up final perspectives as well."*

Another student comment further emphasized the importance and the effectiveness of the 360 VR as an effective visualization tool *"This was very helpful as we were not able to visit the project in person. It helped me visualize the space and how users moved through it which wasn't as easy to visualize in the photos alone."*. Students also indicated that the 360VR was also *"great for setting up final perspectives as well"*. It is also important to note that every student who student who commented on the effectiveness of 360VR only provided positive comments.

The Effect of VR on Students' Learning Outcomes

The objective evaluation of 360 VR effectiveness was accessed based on students' learning outcomes, including their final projects' total, spatial planning, and finish selection scores. Table 2, Figure 4, and 5 show the differences in students' outcome scores between 360VR and no site visit and on-site visit.

For the students' group in Year 1 where 360VR was used before the hypothetical project with no site visit, a paired sample t-test did not report a significant difference between outcome scores. There was no significant difference in total scores between no site visit and 360VR methods ($t(26) = -0.755$, $p = .457$, $d = 2.37$, 95% CI [-1.28, 0.592]). Spatial planning score of no site visit was not significantly different from 360VR methods ($t(26) = -1.968$, $p = 0.060$), although a strong effect size was found ($d = 2.94$, 95% CI [-2.27, 0.049]). Finish selection scores were also not significantly different between the two methods ($t(26) = -0.647$, $p = 0.523$, $d = 3.42$, 95% CI [-0.926, 1.778]).

In the Year 2 group where 360VR was used after the project with on-site visit methods, there has been a significant improvement in students' total scores from 15.72±1.77 (on-site visit) to 17.62±1.63 (360VR method) ($t(33) = -7.869$, $p < .001$), with a large effect size ($d = 1.41$, 95% CI [-1.77, -.857]). Spatial planning scores increased from 15.75 ±.1.88 (on-site visit) to 17.43 ± 2.12 (360VR method) ($t(33) = -5.648$, $p < .001$), with large effect size ($d = 1.74$, 95% CI [-1.37, -.56]). For the finish selection scores, students' scores went up from 15.69 ± 1.77 (on-site visit) to 17.81 ± 1.57 (360VR method) ($t(33) = -7.335$, $p < .001$), showing a large effect size ($d = 1.69$, 95% CI [-1.71, -.80]).

Table 2: Differences in Students' Outcome between Traditional and 360VR Methods: Paired Sample t-test

Group	Students' Outcomes	360VR*		No Site Visit		t	Cohen's d	*p*
		Mean	S.D.	Mean	S.D.			
Year 1 (n=27)	Spatial Planning	15.69	2.46	16.80	1.38	-1.968	2.94	.060
	Millwork & Finishes	16.63	3.94	16.20	1.88	0.647	3.42	.523
	Total	16.16	2.71	16.50	1.17	-0.755	2.37	.457
	Students' Outcomes	On Site Visit		360VR**		t	Cohen's d	*p*
		Mean	S.D.	Mean	S.D.			
Year 2 (n=34)	Spatial Planning	15.75	1.88	17.43	2.12	-5.648	1.74	<.001
	Millwork & Finishes	15.69	1.77	17.81	1.57	-7.335	1.69	<.001
	Total	15.72	1.77	17.62	1.63	-7.869	1.41	<.001

Note. The scores are out of 20.* The project using 360VR method was implemented before the no site visit experience in Year 1; ** The project with 360VR was used after on-site visit method in Year 2.

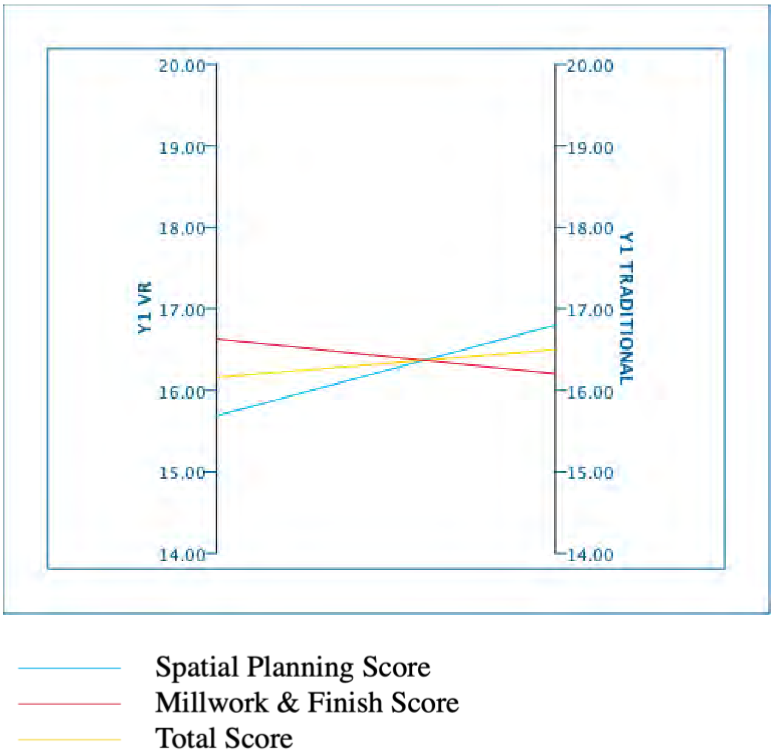


Figure 4: Mean Differences Between 360VR and No Site Visit

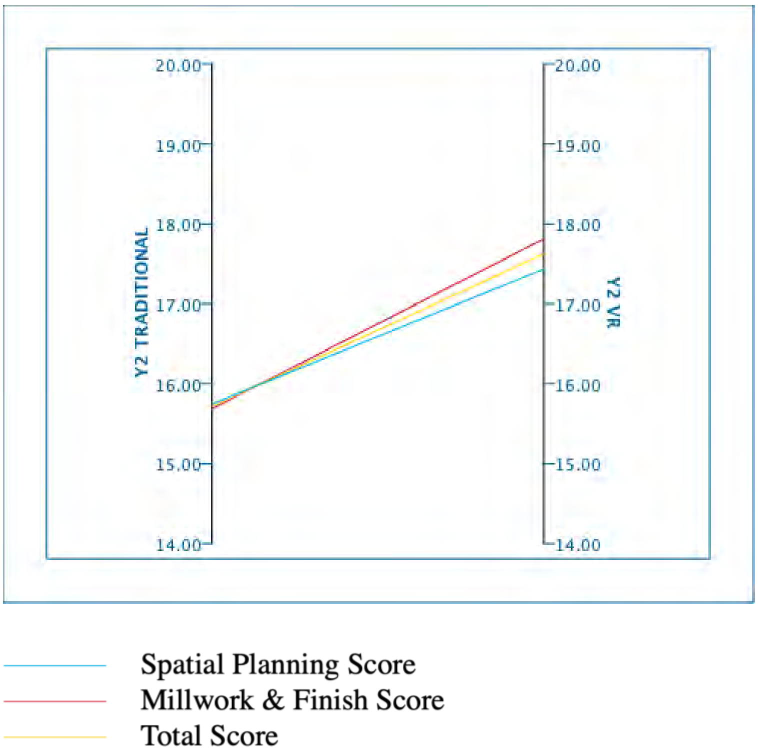


Figure 5: Mean Differences Between On Site Visit and 360VR

Discussion

This study aimed to investigate if the 360-degree panorama-based Virtual Reality (360VR) could be an effective tool to simulate real-world site visit experiences in interior design education. The students' experience survey results indicated that 360VR and virtual walkthrough experiences benefited students' understanding of the site during the design process. Students reflected positive experiences on their engagement in learning, spatial layout, visualization, and educational effectiveness. The result of the student outcome evaluation showed a significant improvement in students' spatial planning, finish selection, and total scores when the 360VR method was used after the traditional approach.

In the Year 2 group, students' learning outcome scores increased when using the 360 VR method compared to on-site visit experiences. Not only did the total score on their final presentation, but the increased scores also included spatial planning and material selections. This data support Loddo's (2021) assertion that 360VR is a useful tool for visualizing environments, design elements, and materials, as well as understanding circulation. Specifically, clear visualization of building materials and distance-measuring features enhanced the virtual experience. These features also support other pedagogical interventions such as lectures, charrettes, discussions, and analysis since it is accessible anytime for students throughout the design process.

Meanwhile, there were no significant differences between the 360VR method and the hypothetical project with no site visit. It is also important to note that the practice effect could influence the students' outcome comparison. Practice effect refers to the change or improvement in performance resulting from repeated practices in a within-subject design (American Psychological Association, 2022). In the Year 1 group in which 360VR was implemented first followed by traditional methods, no significant difference was found in students' outcomes. Meanwhile, the Year 2 group where the two methods were inversely implemented showed significant improvements in learning outcomes. When considering the difference rate in outcome scores, the data suggests that 360VR could positively influence both groups; however, further investigation is necessary.

Lastly, this study conducted a post-experience survey. Comparison studies between pre and post-experiences, or between virtual and real-world experiences will broaden the current study's findings. Also, the 360VR technology used in this study was available to students by computer monitors or mobile devices. Future studies can investigate 360VR technology with emerging tools such as wearable devices, VR glasses, and Oculus Quest. With technological development, the immersive experience is expected to be high-quality and seamless with the lighter weight of devices and lower costs. The different 360VR effectiveness in educational outcomes can be further discussed according to the device types.

Conclusion

Students' understanding of the existing site condition is crucial in their design process. According to visual learning theory, students grasp knowledge when information is provided in a visual format (Patton, 1991). Aligning with the theory, a site visit has been a crucial part of the design project as it promotes students' imagination, provides sensory experiences, and allows accurate measurement. 360 VR technology has the potential to support such pedagogical needs. This study only involved a small sample and particularly focused on two case projects, the church renovation, and the rail depot project for the 360VR method. However, this case study could suggest a basis of explaining how other types of design projects can use 360VR in the visualization of the space. Further studies with various design project types will expand the understanding of the students' virtual experiences.

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