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Bringing Cultural Heritage into the Classroom: How 360-Degree Videos Support Spatial Cognition, Learning Performance and Experience Among Architecture Students

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Abstract

Architectural education programs are rapidly expanding the use of immersive technologies worldwide. An increasing number of architecture schools have incorporated 360-degree videos as one of the accessible and cost-effective immersive tools. Despite their availability and ease of use, research on their effectiveness as a learning tool in architectural pedagogy remains limited and mostly focused on architectural design education. Few studies have discussed their application in theoretical courses and their potential to support cognitive understanding of architecture. Learning cultural heritage is considered a foundation of architectural theory. This study examines how the utilization of 360-degree videos, compared to conventional 2D videos, supports spatial cognition, learning performance and experience in cultural heritage education among undergraduate architecture students. An educational experiment was conducted with 89 students in their second year of the architecture degree at the Applied Science Private University, Jordan. Both 360-degree videos and conventional 2D videos were inserted as learning tools within the curriculum of History of Architecture 1 and 2 courses. A mixed-research-method framework, including observation and a post-test survey, was carried out. Using SPSS and Excel programs, the data were analyzed through a set of statistical analyses such as paired-sample *t*-tests, AHP, and basic descriptive analysis. The findings demonstrate that students were highly immersed and motivated when using 360-degree videos. Compared to conventional 2D videos, 360-degree videos enhanced students' spatial cognition, performance, engagement, and participation levels in both face-to-face and online courses. These results suggest that 360-degree videos can serve as a sufficient, low-cost, and equipment-free learning tool, responding to the urgent need to utilize technologies in both theoretical and practical architectural pedagogy.

Keywords: 360-degree videos; conventional 2D videos; architectural pedagogy; cultural heritage; spatial cognition; learning performance; participation and engagement

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1. Introduction

The younger generation has been highly involved with technology since their early years. In fact, it is demonstrated that students in the current generation are not the ones for whom our educational system was first built [1]. Following the COVID-19 pandemic, educational institutions worldwide faced increased pressure to shift their teaching process online in record time and adopt new teaching methods and media [2]. This situation was found to be very stressful and demanding for both educators and students [3].

As a result, a variety of teaching approaches that are more engaging, motivating, and enjoyable for students emerged in both regular face-to-face and online lectures [2,4–7]. Consequently, many immersive, virtual, and novel technologies have been inserted into our educational systems [8]. These technologies provide simple and quick access to information and services [1,9], particularly in fields that either are hard to be present in or difficult to explain, such as medicine [3,10,11], or require site visits and fieldwork, such as architecture, engineering, and construction [7,8,12]. Nonetheless, numerous educational institutions, especially in developing countries, remain incapable of funding immersive technologies such as VR and AR, despite the increasing demand for innovative pedagogical methods that are aimed towards student-centered learning and enhancing engagement through immersive experiences [6,13]. This is where 360-degree video was utilized with significant potential [1,13].

Many studies have suggested employing 360-degree videos as a sufficient and affordable learning tool [1,13,14]. This technology offers a similar experience to virtual reality but does not require costly or complicated equipment [13]. These 360-degree videos can capture a real-world place using inexpensive 360° cameras, compared with VR, which often requires either the purchase of pre-made instructional programs or the creation of 3D models and simulations with specialized software [15]. Furthermore, 360-degree video displays are almost free (smartphone + computer display), while VR headsets are approximately 300 times more expensive per student and need additional equipment (Table 1). This difference makes the integration of VR into educational institutions far more expensive and complicated [5,15]. By contrast, students can access 360-degree videos on a regular smartphone or through a web browser, enabling them to explore and learn with minimal barriers [1,13]. This advantage makes 360-degree videos a practical and accessible option, particularly in contexts where resources are limited [16].

Table 1. Cost comparison: 360-degree video vs. VR immersive technology in educational environments. Source: Author based on [11,15] and online services platforms.

Category	360-Degree Video	Virtual Reality (VR/AR)
Content Preparation	360° camera at USD 500–600 (mid to advanced) to capture immersive video of real environments	Purchased content from app stores or platforms or created by 3D modeling and simulation tools (e.g., Unity, Unreal Engine, Blender); costs vary. Simulation can exceed USD 5000.
Display Device (per student)	Smartphones, tablets, Google Cardboard-style (less than USD 5) or existing PC/monitor (no extra cost).	USD 250–1500 (mid to advanced) VR headset (e.g., Meta Quest 3S).
Software/Platform	Insta360 mobile app or Studio (a free desktop program) with no extra cost. Playback via YouTube 360 or any simple video player.	Depends on the used educational platforms or 3D modeling/simulation software.
Teacher Training	Minimal (basic video creation knowledge)	Moderate to extensive (VR environment setup).
Reach	High (easily shareable, re-usable content)	Moderate, headset for each student.
Maintenance	Low (occasional camera battery/lens replacement; cardboard viewers almost disposable)	Medium to high (frequent updates, tech support, repairs).

Architecture has a particularly strong need to incorporate more immersive technologies into its courses [7,8,17]. Since the field of architecture prioritizes spatial cognition and

experience, virtual technologies can be effective in comprehending abstract, dynamic, or non-intuitive concepts [7]. Such technologies allow students to envision and engage with many architectural designs in ways that conventional methods such as text, images, or 2D videos cannot provide [17].

Spatial cognition involves the mental processes used to perceive, interpret, and remember spatial environments [18–21]. In architectural education, these skills are essential for design thinking, understanding the interactions between users and space, interpreting architectural elements, and experiencing spatial configurations effectively [18,20]. As an ambassador of architectural experiential research, Steven Holl stresses the direct experiential nature of architecture and its influence on individuals [22]. He believes that architectural comprehension has its foundation not at the level of abstraction but in the understanding of basic elements such as materials, light, color, size, details, and patterns of activity [22]. These components represent the visual attributes of architecture, often seen as superficial attributes [17,22]. Yet, they create the basis through which individuals form spatial experiences of architectural space [22]. By observing these elements, the observer constructs a perceptual experience of the entire spatial environment [19,20,22]. Consequently, observing these attributes can indicate the extent of spatial cognition [17,19,22]. From this perspective, spatial cognition arises from the embodied perception of architectural elements and characteristics [19,22]. This phenomenological paradigm in architectural pedagogy corresponds with the utilization of immersive media, including 360-degree videos. By recording authentic material qualities, lighting conditions, forms, and sequences of spatial configurations, 360-degree videos may allow students to experience architectural elements in a way that goes beyond what conventional 2D videos can offer.

The use of emerging tools such as virtual and immersive reality has been shown to enhance spatial abilities, positively impacting design performance, spatial perception, and overall learning outcomes [8,18,19,23]. However, despite these advances, the application of immersive technologies and their potential across all areas of architectural education is still largely concentrated in design studios [7], where students learn design problems and processes. In contrast, the theoretical courses that teach the various architecture schools, styles, and philosophies continue to rely mostly on traditional teaching methods [7,17]. Within the architectural learning system, the study of architectural history is recognized as fundamental theoretical understanding, which includes the cognitive basis of both the design process and technological foundation [24]. Examining historical building types and architectural schools allows students to cultivate a thorough comprehension of the interdisciplinary knowledge, as well as the architectural, physical, and visual characteristics that shaped these traditions [24]. This knowledge builds a crucial base for architecture students to enhance aesthetic sensibility, creativity, and refine their design problem-solving skills [7,17]. In this context, employing accessible immersive technologies to enhance students' spatial cognition of cultural heritage sites and buildings represents a promising approach to deepening their understanding architectural attributes. Such methods can positively influence cognitive memory, engagement, and performance. Among these technologies, 360-degree video stands out as an alternative affordable immersive tool, helping students understand experience cultural heritage and its architectural features within their authentic environmental settings.

The main question that was the driving force of this study is as follows:

Does the use of 360-degree videos enhance spatial cognition, learning performance, learning experience, and level of engagement compared to conventional 2D videos?

This overarching question can be divided into the following sub-questions:

- RQ1. To what extent do students improve their spatial cognition and learning performance using 360-degree videos compared to conventional 2D videos?

- RQ2. How does the use of 360-degree videos impact students' learning experience in terms of
  - RQ2a. Engagement and participation;
  - RQ2b. Satisfaction and motivation.

Therefore, the aim of this study is to assess the spatial cognition, learning performance and learning experience of architecture students through the use of 360-degree recorded videos, presented as an alternative immersive tool to conventional 2D video formats in higher architectural education. Based on the data collection and analysis, the findings of this study may pave the way for uncovering the potential of more immersive, yet affordable, tools, such as 360-degree videos, within architectural education programs. Moreover, understanding these technologies can support instructors and lecturers in developing curricula that better integrate multi-innovative technologies into both practical and theoretical architectural courses.

2. Background

For a long time, education has relied on text, images, and 2D videos for better student engagement and active learning [13,25–27]. Conventional 2D videos have been shown to be effective learning tools in higher education, supporting student engagement, active learning, self-directed learning, and tutoring [13], while complementing traditional classroom methods. However, to meet the goals and demands of modern education, several blended educational strategies have recently emerged to further promote students' learning experiences and outcomes [5,15]. One such technology is 360-degree videos. Unlike conventional 2D videos that primarily use graphics and text, 360-degree videos can improve immersive learning, especially in situations where students cannot access certain locations [1,28]. This immersive effect is accomplished using a 360-degree video camera to capture panoramic images of a scene [29,30]. These videos can be viewed on flat screens, such as mobile phones, or through VR headsets. Compared with conventional 2D videos, 360-degree videos are omnidirectional, enabling viewers to pan and rotate in a full circle [1] or swipe the screen to change viewing angles [9]. They can either be recorded from the real-world environments or generated digitally. Importantly, viewers have the ability to look around in multiple directions and choose what to observe, providing a wide range of angles and perspectives in contrast to the 2D video, which offers restricted perspectives and an abstract experience [31].

The 360-degree videos are being used in a variety of applications and fields, including medical science [23,28,32,33], physical training and sport [34], construction [8,35], and cultural heritage and tourism [8,36]. They have also increasingly become an important tool in higher education [1,13,32,37,38]. According to many researchers, 360-degree videos expand the learning environment's perspective and increase the potential of active learning [5,8]. Some studies have drawn comparisons between 360-degree videos and immersive technologies such as virtual and augmented reality, which are still in the early stages of adoption as primary learning platforms in higher education due to their high cost and lack of laboratory design expertise [8,9,16].

Findings show that 360-degree videos are a less costly, more accessible, and more realistic choice for the students [1,8,30]. It has a positive impact on participants' perceptions and learning behavior where they can explore authentic contexts with real-world experiences [13,17,39]. In accordance with many studies, learners using 360-degree videos can see everything within the camera's field of view, making it easier to create more dynamic, immersive, engaging, and realistic experiences with complete visual and auditory immersion, advantages not typically afforded by conventional 2D videos [1,13]. Participants using

360-degree videos described feeling as "if they were genuinely there" and "disconnected from the real world" [13].

Although occasional issues such as physical discomforts (e.g., vertigo and dizziness), poor video quality, and technical problems have been reported when using the 360-degree videos [36,40,41], students have expressed a strong preference for the immersive experience that 360-degree videos provide, indicating increased levels of interest, engagement, and satisfaction in the process of knowledge gaining [1,42]. Despite the availability of evidence of their effectiveness in education, the use of 360-degree videos in architectural institutions worldwide remains in its early stage, and further empirical research is needed [8,17]. Educators in architectural schools are continuously re-evaluating how architecture is taught, particularly in relation to understanding space and form in design studios and the forces shaping architectural principles and concepts. In this context, new methods and tools, such as immersive technologies, are increasingly being explored [8,19]. Currently, however, the application of these technologies in architectural education is primarily concentrated on design studio courses, while their use in theoretical courses, such as the history of architecture, remains inadequately examined [17].

In teaching the history of architecture, where different historical periods and styles are studied, a fundamental skill should be taught, which is the ability to mentally reconstruct the historical spaces [17,19,22]. In other words, abstracting proportions, forms, and materials allows students to spatially experience these spaces and enhance their spatial sense and cognition. Understanding cultural heritage in its context, whether through actual visits or immersive tools such as VR, AR, and 360-degree videos, is crucial, as architecture cannot be fully read without its contexts and the forces [7,43]. Furthermore, experiencing the cultural heritage buildings and sites, even virtually, evokes spatial awareness and cultural sensitivity among architecture students [10,38]. This kind of spatial cognition is not just a technical ability but a tacit form of knowledge, one that cannot easily be conveyed through text or numbers [17]. Immersive tools, such as 360-degree videos, are particularly well suited to strengthening this kind of knowledge, as they allow students to "be in" the space and to overcome the limitation of geographical distance and institutional budgets [8]. Despite this, the focus in architecture education remains mainly on design learning and processes [17,18], the empirical application of immersive technologies in building construction [8], or the exploration of the cultural heritage preservation and protection through individual case studies [16,41,44]. Few other studies have examined the impact of 360-degree videos on spatial cognition and experience [17,19]. For instance, Gómez (2021) explored the potential of using 360-degree videos to enhance spatial perception among architecture students compared with 2D conventional videos and 3D digital models [19]. The study found that 360-degree videos affected significantly the perception of architectural spaces, particularly in understanding proportion, orientation, forms, and materials, while also achieving a greater sense of presence [19]. However, this study, similarly to many others, relied mostly on students' subjective perspectives to measure the performance of tested methods and was limited to investigating individual cases, which restricts the generalizability of the findings. Guo et al. (2024) presented stronger evidence supporting the benefits of using 360-degree technology to enhance spatial cognitive abilities in architectural education [17]. They concluded by emphasizing the importance of conducting further studies that examine not only students' learning experiences but also their cognitive abilities in both practical and theoretical architectural courses [17]. Student involvement, motivation, and active participation are widely seen as critical contributors to the learning process [1,41,45]. However, testing the impact of 360-degree videos on participation and engagement among architecture students is still not widely investigated [1,7,17]. Many educational theories advocate the application of 360-degree videos in the teaching of architectural history class.

In accordance with Kolb's Experiential Learning Theory (1984), 360-degree video facilitates learning experience and engagement by replicating the authentic experiences inside cultural heritage sites [46]. Kolb's theory highlights the methodology of learning through concrete experience, reflection, conceptualization, and experimentation [46]. Immersive 360-degree videos may enable students to have a concrete experience of the historical settings, stimulate reflective analysis from various points of view and enhance the comprehension of architectural features, elements, and spatial configurations. In this manner, students can transition from passive observation to active investigation, reflection, and conceptualization in learning architecture using immersive applications such as 360-degree videos. The process may improve spatial cognition and engagement while mitigating obstacles such as cost, distance, or preservation constraints [8,46,47]. The presence theory also underlines the sensation of "being there," which improves attention, motivation, and emotional engagement [48]. Mayer's Cognitive Theory of Multimedia Learning (2001) evokes the combination of visual–spatial details with storytelling or commentaries, which improves cognitive processing and memory retention [49]. Taken together, these learning theories support the argument that engaging students in architectural history classes through the use of 360-degree videos can strengthen their cognitive knowledge, engagement, and active participation.

3. Materials and Methods

A prospective pilot study of one and a half years involving 89 architecture students was performed using 360-degree videos and conventional 2D videos.

3.1. Students' Profile

Over the three teaching semesters (Figure 1), the majority of participants (n = 89) were in their second year of the five-year undergraduate degree program in architecture. The age range of the students was 19 to 21 with a mean age 19.28. Of the total number of participants, 61.8% of the students were female, and 38.2% were male (Table 2).

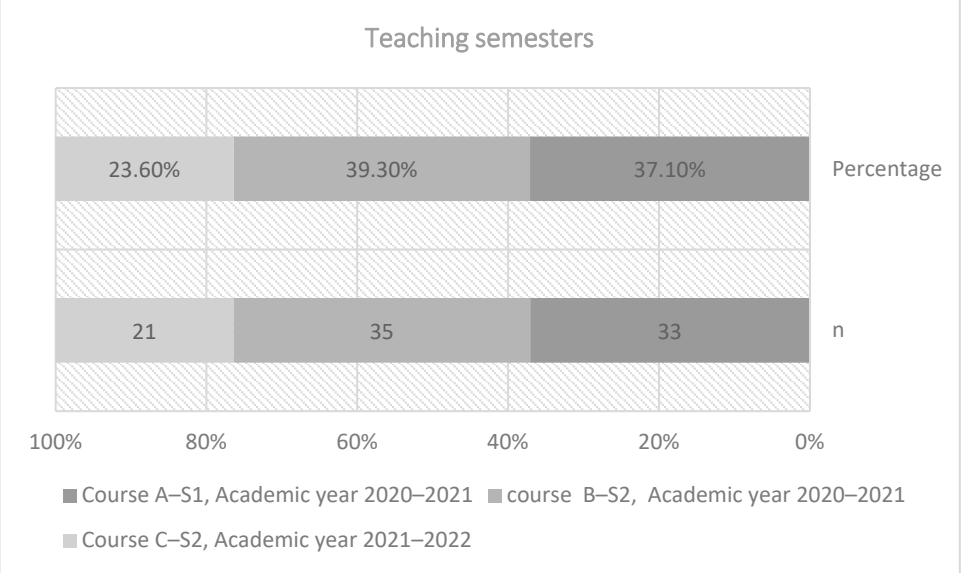


Figure 1. The proportion of students who participated in each teaching semester.

Table 2. The students' profiles. Educational Level: Undergraduate Students, Enrolled in History of Architecture Course 1 and 2.

Participants Students' Profile	Total	Age			Gender	
		19	20	21	F	M
Course A, S * 1, Academic year 2020–2021	33	28	4	1	20	13
Course B, S2 Academic year 2020–2021	35	27	6	2	21	14
Course C, S2 Academic year 2021–2022	21	15	3	3	14	7
Total Number	89	70	13	6	55	34
Percentage		78.60%	14.60%	6.74%	61.80%	38.20%

* Semester.

3.2. Study's Experiment Setting and Procedure

Students were enrolled in History of Architecture 1 and 2 courses, both of which are core courses in the bachelor of science (BSc) program in architecture at the University of Applied Science Private University (Figure 2). The content of the courses is essentially focused on exploring the features and elements of different cultural heritage buildings and sites from various civilizations. History of Architecture 1 covers periods from prehistoric civilizations to the Roman civilization, while History of Architecture 2 spans from early Christianity to Enlightenment architecture. To successfully complete the courses, students had to pass exams, quizzes, and essays. History of Architecture 1 is offered for registration only in the fall semester, whereas History of Architecture 2 is offered in the spring semester.

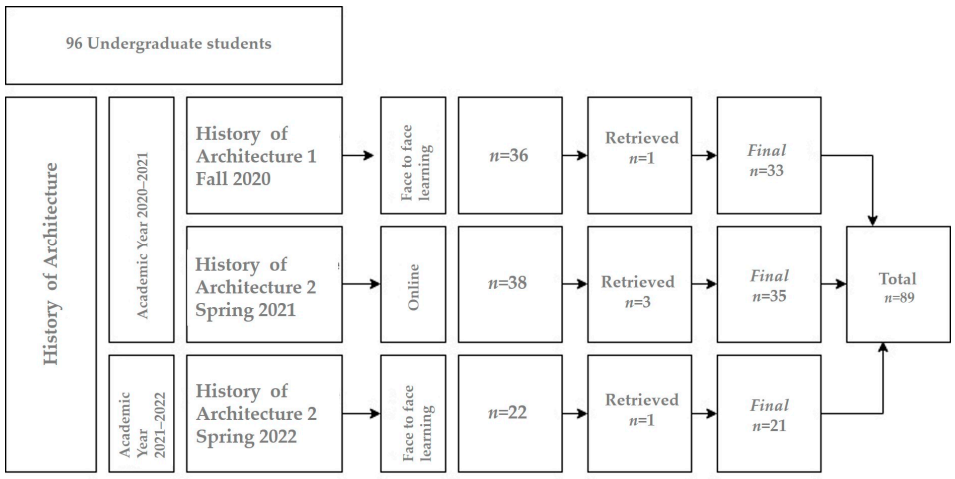


Figure 2. The number of students in the three included courses.

We conducted the study over three semesters (Figure 2) to gather a sufficient number of students for the assessment of spatial cognition, learning performance and experiences using 360-degree videos, following the recommendation of previous studies [8,38]. We followed the same data collection and analysis procedure for the three semesters. The lecturer, who taught the three courses also served as one of the researchers and supervised the study experiment. Each course lasted for fifteen weeks, with lessons held twice per week. In total, twenty classes were assigned to each course: ten employed 360-degree videos, while the remaining ten used conventional 2D videos. The distribution between 2D and 360-degree videos was determined by the availability of online videos related to the different cultural heritage sites. Both types of videos were sourced from YouTube, educational platforms, and tourism websites. Unlike the 360-degree video, the 2D conventional video was not interactive. They included static images and sometimes supplemented with 2D illustrations and textual descriptions of specific cultural heritage

buildings. Prior to the beginning of each course, students were informed that the lectures would be delivered either using 360-degree videos or conventional 2D videos, with a schedule specifying the exact timing and dates. This measure was very essential for accurately assessing their level of engagement and attendance.

Both History of Architecture 1 and 2 courses are traditionally delivered face-to-face classes. However, in spring 2021, the History of Architecture 2 course switched to an online synchronous format due to COVID 19. The course was handled similarly, except for redirecting student involvement. To maximize participation, students were invited to turn on their cameras during class sessions. This shift presented a valuable opportunity to assess the effectiveness of 360-degree videos in online courses compared to conventional 2D videos.

Students normally can watch 360-degree videos via PCs [37,50], mobile devices [51], or head-mounted displays (HMDs) [52]. In this study, however, students first watched 360-degree videos from the instructor's PC, followed by a class discussion held during and after the video exploration. After each lecture, the videos were shared with the students, with the possibility of navigating the video by clicking and dragging the various scenes using a mouse device connected to their PC or smartphone's inbuilt gyroscope. A similar procedure was applied when using 2D videos. The duration of both 360-degree videos and 2D videos varied somewhat between five and ten minutes, depending on if they illustrated a building or contextual setting. One reason that may explain the short duration of the videos is that some people experience some physical discomfort (e.g., dizziness) or fatigue if 360-degree videos are too long [38]. The 360-degree and 2D videos were carefully selected to be highly comparable to ensure that differences in learning outcomes were caused by the video format rather than the content. The video featured case studies of historical architecture, highlighting similar architectural features, spatial arrangements, and environmental characteristics. The presentation of the architectural elements, including materiality, form, and spatial organization, was consistently similar across the two media, and the video duration was kept as consistent as possible. The only intentional variation covered was the display method. To achieve a comparative analysis and maintain methodological consistency, the post-test questions were also designed to assess students' understanding of two different buildings or historical contexts. The selected examples for both the 360-degree videos and conventional 2D videos were therefore comparable (see Figures 3 and 4).

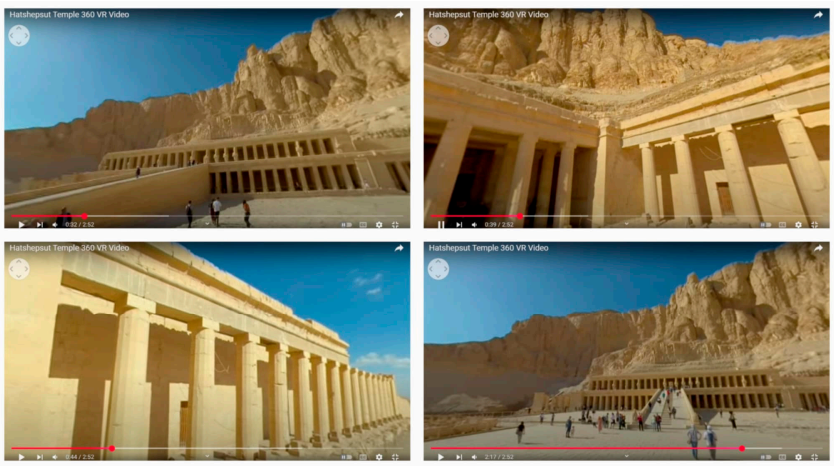


Figure 3. The Temple of Hatshepsut illustrated using a frame from360-degree video. Source: IDV Digital Agency, YouTube Channel [53].



Figure 4. The Temple of Mentuhotep II illustrated using a frame from2D conventional video. Source: Bravo channel, YouTube. [54].

The methodology of this study deliberately departed from the traditional control group framework to ensure that each student of three courses evaluated the differences between the two formats and directly engaged with both the 360-degree videos and conventional 2D videos.

3.3. Measurement Tools and Data Collection

To investigate the assessment variables of the study, various research instruments were used to collect study data based on the reviewed studies. These included systematic observation [16,55], tests [38], and structured questionnaires (post-test) [9,13,36]. Together, these instruments were used to assess students' performance and outcomes, engagement and participation, and overall learning experience (Figure 5).

A. Measuring students' spatial cognitive variables

We investigated the mean score and mean increase in students' final tests results to assess how employing 360-degree videos affected students' understanding of spatial cognition in relation to cultural heritage, including architectural elements and features.

At the end of the three courses, final tests were conducted. Each test consisted of four types of questions on spatial cognitive variables: color and texture, design elements, building materials, and architectural features. To provide a fair comparison of results, the questions comprised an equal number of buildings from both 360-degree and 2D video lectures during the semester.

B. Measuring students' engagement (attendance, involvement and participation)

We set up an experiment to examine how using 360-degree videos in the lectures affected students' engagement and involvement of students over three semesters. At the start of each course, students were told through a table in the course curriculum that there will be 20 lectures across the semester that will use 360-degree and 2D videos. At the end of each lesson, we notified students whether the upcoming lecture would employ 2D or 360-degree videos. To evaluate students' participation, including interaction and personal initiative during discussions, the lecturer employed systematic observation [55]. We recorded the number of students who asked and answered questions, as well as those who contributed to the discussion, based on lecture records. We used the same experimental setup in all three courses to make sure the measurements of student participation are the same. This method made it easier to compare between the two technologies in terms of participation and effectiveness.

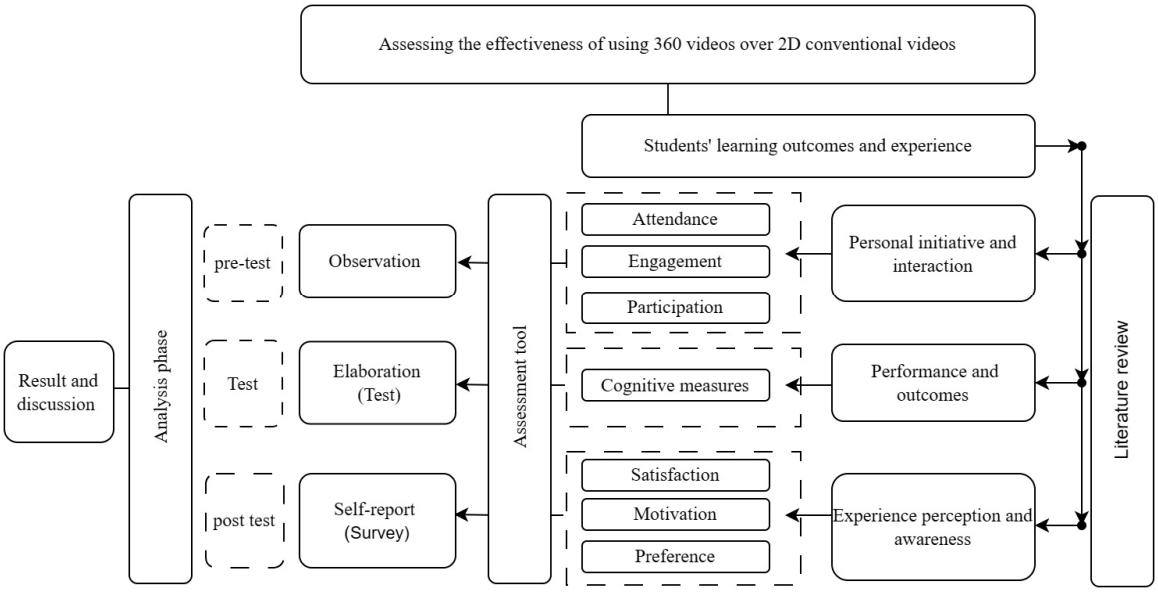


Figure 5. The flow of the study.

C. Measuring students' motivation and satisfaction level

We investigated students' satisfaction, motivation, and preferences by conducting a structured questionnaire that was distributed immediately after their final test [13,36]. A total number of 89 questionnaires were returned and analyzed. The questionnaire was composed of two sections of multiple-choice and Likert-scale questions. The first section related to the students' demographic profiles (e.g., age and gender) and contained both open- and closed-ended questions. The second section included Likert multiple-choice statements (ranging from 5 = strongly agree to 1 = strongly disagree) and questions (ranging from 5 = excellent to 1 = inadequate). The last question assessed the level of satisfaction, with a range from 1 (strongly satisfied) to 5 (strongly dissatisfied). Two measurement scales were applied: a nominal scale for demographic data, and the 5-point Likert scale (ordinal) for learning-related variables. The Statistical Package for Social Sciences (SPSS) was used to code survey data.

3.4. Data Analysis

We used mixed data analysis methods to investigate learning performance and experience. The data gathered from systematic observation and survey responses were categorized, coded, and analyzed using SPSS Statistics 23. The number of attendees and absentees was recorded, and the percent increase in student participations and contributions was calculated using the simple percent increase equation:

$$\% \text{ increase} = (\text{M } 360 - \text{M } 2\text{D})/\text{M } 2\text{D} \times 100$$

After we entered all of the test results into Microsoft Excel 2019, we computed the mean score and mean increases to analyze the students' final test performance. The Data Analysis ToolPak in Excel was applied to calculate the paired-sample *t*-test [13] to compare the results between the two media. For each variable, two performance scores were generated from the students' responses: one for the building taught using 2D video and one for the building taught using 360-degree video. By averaging the scores of all students in a course, we determined the mean score for each variable. This process made it possible to find statistically significant differences between the 2D and 360-degree media, ensuring that the outcomes are not solely determined by personal preference but also by

measurable performance [13]. Moreover, we examined the mean scores across the three courses using a simple post hoc Analytic Hierarchy Process (AHP). The aim of applying the AHP analysis was to supplement the *t*-test analysis and give a more objective weighting of the learning variables [56,57]. This allowed for the creation of a complementary multi-criteria perspective that considered all variables at once (Table 3). This consistent approach enabled a more precise comparison of student involvement levels and the overall efficacy of the two technologies employed in each course.

Table 3. The four cognitive measures (*m*) used in this AHP method.

Cognitive Measures	***m***
Color and Texture	1
Building Materials	2
Design Elements	3
Architectural Features	4

For each course and each cognitive measure, a 2 × 2 pairwise comparison matrix was made. The mean test scores were used to derive local priorities by normalizing the columns and averaging the rows. The final measure-level priorities were found by creating an average of these across the three courses. These priorities were then weighted equally and combined to make global priorities.

$$ratio_{mc} = \frac{Mean\ 360_{mc}}{Mean\ 2d_{mc}}$$

For each measure (*m*), the 2 × 2 pairwise matrix *A* is calculated for all courses (*c*):

$$A_{\mathrm{mc}} = \begin{bmatrix} 1 & r_{mc} \\ 1/r_{mc} & 1 \end{bmatrix}$$

Each element of the matrix is divided by the sum of its column to normalize:

$$Normalized_{mc} = \frac{a_{mc}}{\sum_{p=1}^{n} a_{mc}}$$

Then, the local priority weights w_{mc} for 2D and 360° videos within the course and each measure are calculated:

$$w_{mc} = \sum_{q=1} n \times Normalized_{mc}/n$$

where n = 2, and p = 360, 2D.

With the equal measure weights (0.250), where the equal importance of the four measures is equal, the local priority for the three courses was calculated by computing the average across courses:

$$wp_m = \frac{1}{3}\sum_{c\ A,B,C} \times wp_{mc}$$

Finally, the global priorities are calculated:

$$Wp = \sum_{m=1}^{4} v_m \times wp_m,\ m\ =\ 1,\ 2,\ 3,\ 4 \text{ and } v_m\ =\ 0.25$$

Finally, we applied simple descriptive statistics analysis, such as means and standard deviations, using SPSS Statistics 23 to analyze the results of the survey's Likert questions and assess the learning experience from the students' point of view [9,13,16,31].

4. Results

4.1. Students' Spatial Cognition and Learning Performance

The results of the students' final test regarding the spatial cognition in three courses show an increase in mean scores in the four cognitive measures related to cultural heritage when 360-degree videos were used during the semester (Table 4). For questions on the color and texture of cultural heritage buildings, the mean percentage rise in courses A, B, and C was 12.15%, 5.9%, and 10.3%, respectively, with a total increase of 9.45%. For building materials, the increases were 5.27%, 6.42%, and 9.10%, resulting in a combined mean increase of 7.02%. Regarding design aspects (including light, forms, and shapes), the mean percentage increase was 11.54%, 8.19%, and 9.10% in the three courses, with overall increase of 9.61% when using 360-degree videos. Finally, architectural features, the increases were 9.76%, 6.56% and 8.16%, respectively, with a total mean increase of 8.16%.

Table 4. Cognitive measurements, 2D videos versus 360-degree videos.

	2D Video (Type 1)			360-Degree Video (Type 2)						
	Mean Score%			Mean Score%			% of Increase			Mean % of Increase
	Course A	Course B	Course C	Course A	Course B	Course C	Course A	Course B	Course C	
1: Color and Texture	67.88	69.06	67.90	76.13	73.15	74.90	12.15%	5.9%	10.3%	9.45%
2: Building Materials (exterior and interior)	71.78	69.53	69.25	75.56	74.00	75.75	5.27%	6.42%	9.10%	7.02%
3: Design Elements (ex. light, form, and shape	70.38	67.44	69.20	78.50	72.97	75.50	11.54%	8.19%	9.10%	9.61%
4: Architectural Features	67.19	67.26	71.05	73.75	71.67	76.85	9.16%	6.56%	8.16%	8.16%

Total n(A) = 33, n(B) = 35, n(C) = 21.

Figure 6 shows the students' scores in the three courses regarding the four cognitive measurements. The outcomes show that employing 360-degree videos is beneficial for both in-person and online learning courses where they improved the students' scores on the four cognitive measures in the three History of Architecture courses compared to the 2D videos. However, the impact of the use of 360-degree videos in online course is marginally reduced compared to in-person courses.

The results of the three courses' paired t-tests on three cognitive measures using 2D and 360-degree videos provided strong evidence against the null hypothesis, with extremely small p-value in the three courses compared to widely used significance levels such as 0.05 (Table 5). In course A, B, and C, the absolute values of the t-statistics for all measured variables exceeded the crucial t-value (2.0395, 1.6923, and 1.729, respectively). This leads us to reject the null hypothesis and support the alternative hypothesis that using 360-degree videos in teaching cultural heritage has a positive impact on all cognitive measures, including design elements, principle, and visual characteristics. The upper and lower values of the confidence intervals for the mean difference across all courses demonstrated the alternative hypothesis' certainty with a 95% confidence level. For further analyzing the students' four cognitive measures, we conducted a post hoc AHP, using both 2D conventional videos and 360° videos in the three courses (Table 6). In Course A, the 360° video showed a better result than the 2D method. For 360° videos, local priorities ranged from 0.5233 to 0.5286, whereas for 2D videos, they ranged from 0.4714 to 0.4872. The same pattern was seen in Course B. The 360° video showed higher local priorities, which ranged from 0.5144 to 0.5197. The 2D approach showed lower local priorities, which ranged from 0.4803 to 0.4856. Finally, for Course C, the 360° priorities ranged from 0.5196 to 0.5245, while the 2D priorities ranged from 0.4755 to 0.4804. The 360° video method shows better overall performance than the 2D video method, based on all four cognitive metrics across three courses.



Figure 6. Students' score for the four cognitive variables in the three History of Architecture courses using the 360-degree videos vs. the 2D videos.

Table 5. The result of performance in the three cognitive measures using a paired-samples *t*-test.

Assessment	Course	*n*	Mean 2Dv	Mean 360v	Mean of D	Std. Deviation	Std. Error	95% Confidence Interval of Difference		*t*	df	*p* (T ≤ t) Two-Tail
								Lower	*Upper*			
Color and Texture	A	33	67.88	76.13	8.42	5.01	0.87	6.65	10.2	−9.364	31	1.50×10^{-10}
Building Materials			71.78	75.56	3.78	2.03	0.36	3.05	4.51	−10.54	31	8.82×10^{-12}
Design Elements			70.37	78.5	8.13	3.15	0.56	6.99	9.26	−14.59	31	1.96×10^{-15}
Architectural Features			67.19	73.75	6.56	3.76	0.66	5.21	7.92	−9.87	31	4.30×10^{-11}
Color and Texture	B	35	69.06	73.15	4.09	1.76	0.3	3.47	4.7	−13.51	33	5.32×10^{-15}
Building Materials			69.53	74	4.47	2.22	0.38	3.69	5.24	−11.74	33	2.47×10^{-13}
Design Elements			67.44	72.97	5.53	1.96	0.34	4.85	6.21	−16.47	33	1.76×10^{-17}
Architectural Features			67.26	71.68	4.41	2.11	0.36	3.68	5.15	−12.22	33	8.53×10^{-14}
Color and Texture	C	21	67.9	74.9	7	2.9	0.65	5.64	8.36	−10.78	19	1.53×10^{-9}
Building Materials			69.25	75.75	6.5	3.25	0.73	4.98	8.02	−8.93	19	3.11×10^{-8}
Design Elements			69.2	75.5	6.25	2.47	0.55	5.09	7.41	−11.32	19	6.851×10^{-10}
Architectural Features			71.05	76.86	5.8	2.19	0.49	4.77	6.83	−11.83	19	3.25×10^{-10}

Table 6. The result of the post hoc AHP analysis of the four cognitive measures.

Cognitive Measure	Course	360 Mean	2D Mean	Ratio r (m, A)	360 Local Priority	2D Local Priority
Color and Texture	A	76.13	67.88	1.1215	0.5286	0.4714
Building Materials		75.56	71.78	1.0527	0.5128	0.4872
Design Elements		78.50	70.38	1.1154	0.5273	0.4727
Architectural Features		73.75	67.19	1.0976	0.5233	0.4767
Color and Texture	B	73.15	69.06	1.0592	0.5144	0.4856
Building Materials		74.00	69.53	1.0643	0.5156	0.4844
Design Elements		72.97	67.44	1.0820	0.5197	0.4803
Architectural Features		71.67	67.26	1.0656	0.5159	0.4841
Color and Texture	C	74.90	67.90	1.1031	0.5245	0.4755
Building Materials		75.75	69.25	1.0939	0.5224	0.4776
Design Elements		75.50	69.20	1.0910	0.5218	0.4782
Architectural Features		76.85	71.05	1.0816	0.5196	0.4804

A comparison was achieved by averaging the local priorities of all three courses, presuming that each measure is of equal importance (v_m = 0.25). The final global priorities suggest that students performed marginally better in general when using 360° videos in all cognitive measures and courses (Table 7).

Table 7. Averaged local priorities and global priority for the four cognitive measures.

Cognitive Measure	Avg 360 Priority	Avg 2D Priority
Color and Texture	0.5225	0.4775
Building Materials	0.5169	0.4831
Design Elements	0.5229	0.4771
Architectural Features	0.5196	0.4804
Global Priority (W)	0.5205	0.4795

To support the results of the post-test outcomes, we analyze students' perspectives on using the two types of videos. A total of 76% of respondents agreed or strongly agreed that employing 360-degree videos improved their learning experience and helped them understand architectural elements and features. Only 5.9% had negative responses, while 4.7% were neutral (Table 8). Furthermore, 78% of responses were positive about their performance in their final test and scored better in questions related to architecture presented by 360-degree videos; 8.2% were indifferent, and 7.1% felt the opposite.

Table 8. The effect of using 360-degree video on the understanding of cultural heritage buildings.

	Choices	Frequency	Valid Percent %	Cumulative Percent %
	Strongly Agree	61	71.7	71.7
	Agree	15	17.7	89.4
	Neutral	4	4.7	94.1
	Disagree	2	2.4	96.5
	Strongly Disagree	3	3.5	100
Valid		85	100	
Missing		4		

Statement: I subjectively thought that I understood the building better using 360-degree videos than using conventional 2D image videos.

Furthermore, most of the students (84.7%) felt they consumed less time studying the buildings that were explained using 360-degree videos compared to the buildings explained using conventional 2D videos. Only 7.1% disagreed or strongly disagreed and 8.2% felt neutral (Table 9).

Table 9. The effect of using 360-degree video on study time.

	Choices	Frequency	Valid Percent %	Cumulative Percent %
	Strongly Agree	58	68.2	68.2
	Agree	14	16.5	84.7
	Neutral	7	8.2	92.9
	Disagree	2	2.4	95.3
	Strongly Disagree	4	4.7	100
Valid		85	100	
Missing		4		

Statement: I took less time studying the buildings interpreted using 360-degree videos over the buildings using 2D videos.

4.2. Students' Learning Experience

We assessed students' engagement and involvement in the classroom over the three semesters using both 2D and 360-degree videos (Table 10). As shown in Table 6, there is an increase in attendance in the lectures where 360-degree videos were used compared to 2D videos across all three courses. The mean attendance in Course A rose from 29.7% with 2D videos to 31.8% with 360-degree videos. The mean attendance rate for online Course B slightly increased from 19.8% to 20.2%, while, in Course C, it increased from 31.9% to 33.7%.

The participation rate and contribution to discussions were also observed in the study (Table 11). Compared to when 2D videos were utilized, the student involvement in responding to the lecturer's questions and discussions improved by 38% after employing 360-degree videos. The average amount of discussion and social activities in the lectures significantly increased from 33.4 to 64.7, with an increase of 93.7%.

Table 10. Attendance in the three courses using 360-degree videos vs. 2D videos.

	Type											**Count**	**Mean**	**%**
	Type 1-2D													
Course A—Total no. of participants 33	Attendance	31	30	29	30	30	29	30	30	29	29	297	29.7	90%
	Absence	2	3	4	3	3	4	3	3	4	4	33	3.3	10%
	Type 2-360 degree													
	Attendance	33	32	32	30	32	32	31	31	32	33	318	31.8	96.4%
	Absence	0	1	1	3	1	1	2	2	1	0	12	1.2	3.6%
	Type 1-2D													
Course B—Total no. of participants 35	Attendance	34	34	32	32	32	32	31	31	31	30	319	31.9	91.1%
	Absence	1	1	3	3	3	3	4	4	4	5	31	3.1	8.9%
	Type 2-360 degree													
	Attendance	34	34	33	34	35	34	33	34	34	32	337	33.7	96.3%
	Absence	1	1	2	1	0	1	2	1	1	3	13	1.3	3.7%
	Type 1-2D													
Course C—Total no. of participants 21	Attendance	21	20	21	19	19	20	18	21	20	19	198	19.8	94.3%
	Absence	0	1	0	2	2	1	3	0	1	2	12	1.2	5.7%
	Type 2-360 degree													
	Attendance	21	21	20	20	21	19	19	20	21	20	202	20.2	96.2%
	Absence	0	0	1	1	0	2	2	1	0	1	8	0.8	3.8%

Students were asked to assess their level of engagement using both 2D and 360-degree videos. A total of 94.6% of the students believed that they were more engaged using 360-degree videos to explore cultural heritage buildings compared to 2D videos (Table 12).

When students were asked whether they preferred using 360-degree videos as a learning tool over 2D videos, participants (n = 85) gave good responses. A total of 76.5% indicated high agreement, 14.1% agreed, and 5.9% were unsure about it and felt neutral, while only 3.5% disagreed (Table 13).

Reflecting on whether students felt motivated using 360-degree videos compared to 2D videos, 71.8% of the respondents felt that 360-degree videos significantly increased motivation for learning; 24.7% were motivated, and 3.5% did not feel they were more motivated at all (Table 14).

Table 11. Observation: Interaction and personal initiative using 360-degree videos vs. 2D videos.

		Total No. of Participation (Questions and Answer)	Total No. of Contribution to Discussion
Course A	Type 1 *	92	31
	Type 2 *	132	67
Course B	Type 1	98	37
	Type 2	129	72
Course C	Type 1	86	32
	Type 2	120	55
Mean	Type 1	92	33.4
	Type 2	127	64.7
% of increase		38%	93.7%

1 *: 2D videos. 2 *: 360-degree videos.

Table 12. The level of engagement.

	Choices	Frequency	Valid Percent %	Cumulative Percent %
	Strongly Agree	61	71.7	71.7
	Agree	21	24.7	96.4
	Neutral	1	1.2	97.6
	Disagree	2	2.4	100
	Strongly Disagree	0	0	
Valid		85	100	
Missing		4		

Statement: I was engaged more using 360-degree videos than using 2D image videos in History of Architecture courses.

Table 13. The preference of using 360-degree videos over 2D videos.

	Choices	Frequency	Valid Percent %	Cumulative Percent %
	Strongly Agree	65	76.5	76.5
	Agree	12	14.1	90.6
	Neutral	5	5.9	96.5
	Disagree	3	3.5	100
	Strongly Disagree	0	0	
Valid		85	100	
Missing		4		

Statement: subjectively thought that I prefer using 360-degree videos than using traditional image videos (2D videos) in my learning experience.

In addition to feeling motivated, students enjoyed using the 360-degree videos over the traditional ones in their learning process. Over 90% of responses expressed their enjoyment of using this tool more than they did 2D videos. Fewer than 5% did not enjoy it (Figure 7).

To assess students' satisfaction levels with using 360-degree videos, we asked them about the contribution of this tool to their learning experience. Favorable feedback from

participants was given. A total of 80% of them acknowledged that it made a significant contribution, 10% thought it was good, and 7.1% thought it was mediocre. No one felt it was an inadequate instrument to learn about cultural heritage, and just 2.4% considered it a fair contribution (Table 15).

Table 14. The evaluation of learning experience using 360-degree videos vs. 2D videos—motivation level.

	Choices	Frequency	Valid Percent %	Cumulative Percent %
	Strongly Agree	61	71.8	71.8
	Agree	21	24.7	96.5
	Neutral	0	0	96.5
	Disagree	3	3.5	100
	Strongly Disagree	0	0	
Valid		85	100	
Missing		4		

Statement: I feel more motivated using 360-degree videos than 2D image videos.

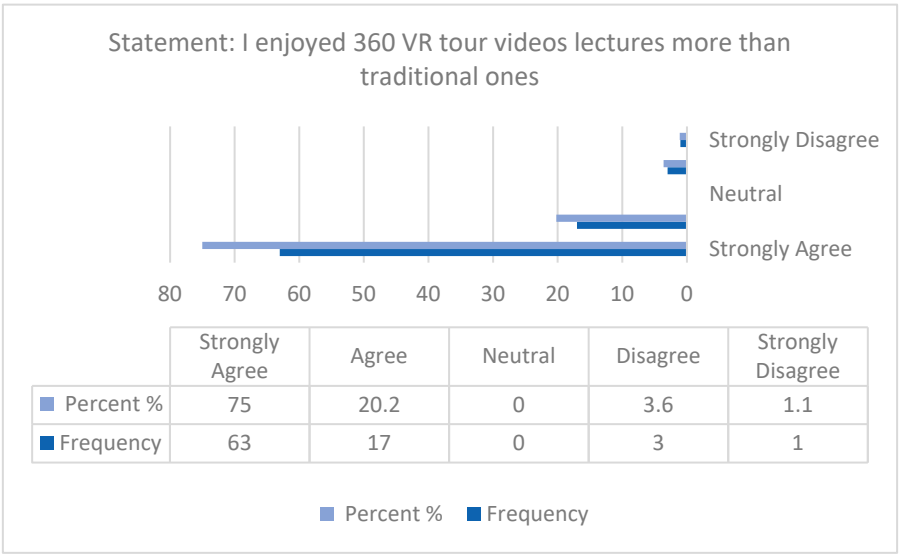


Figure 7. Percentage and frequency of enjoyment level using both 360-degree videos and 2D videos.

Table 15. The contribution of 360-degree videos as learning tool. **Question**: How do you think 360-degree videos contributed to your learning experience?

	Choices	Frequency	Valid Percent %	Cumulative Percent %
	Excellent	68	80	80
	Good	9	10.5	90.5
	Average	6	7.1	97.6
	Fair	2	2.4	100
	Insufficient	0	0	
Valid	Total	85	100	
Missing		4		

According to the responses to the questionnaire, more than 90% of the students were satisfied with using 360-degree videos. A total of 2.4% of them responded with uncertainty and 2.4% felt dissatisfied (Figure 8). Ultimately, the vast majority of students strongly advocated using 360-degree videos in other architectural classes (Table 16).

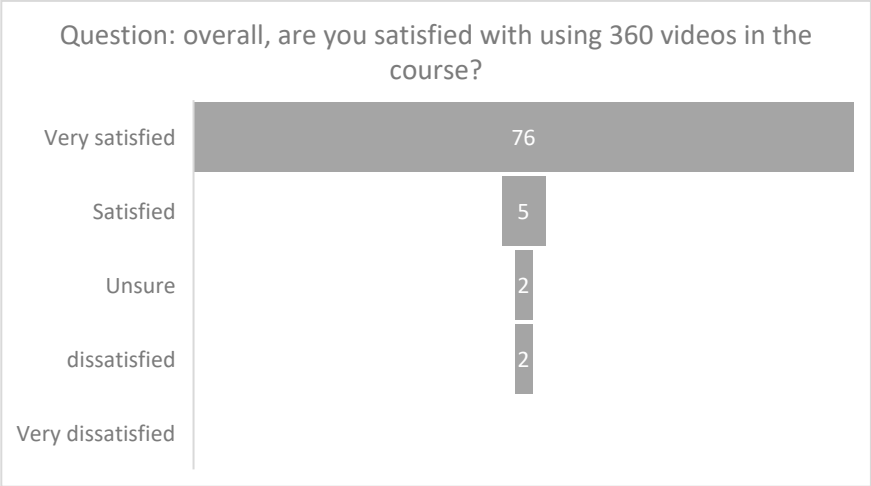


Figure 8. Satisfaction with using 360-degree videos in the course.

Table 16. Recommendation using 360-degree videos.

	Choices	Frequency	Valid Percent %	Cumulative Percent %
	Strongly Agree	76	89.4	89.4
	Agree	7	8.2	97.6
	Neutral	2	2.4	100
	Disagree	0	0	
	Strongly Disagree	0	0	
Valid		85	100	
Missing		4		

Statement: I recommend using 360-degree videos in other courses.

5. Discussion

The findings of this study provide new insights into how adopting available online 360-degree videos can enhance students' spatial cognition, learning performance and overall experiences in learning cultural heritage. Our outcomes demonstrated that the 360-degree videos created a positive effect on spatial cognition and learning performance compared to conventional 2D videos, aligning with the findings of previous studies [13,17,37]. Similarly, our results are consistent with the studies comparing learning impacts, engagement, and participation of using 360-degree videos with conventional tools such as 2D videos [31,58].

Educational theories, including Kolb's theory and the presence theory, support these findings [46,48]. This study showed higher engagement and attentiveness using 360-degree videos with students' feedback providing highly favorable responses. Most of the students considered this tool very entertaining, engaging, and beneficial for learning However, unlike what was predicted, students' performance on cognitive measures showed only a slight enhancement with 360-degree videos compared to 2D conventional videos. This may be due to students being able to review the videos more than once at home before

the test, highlighting a methodological limitation. This suggests that future studies could employ more controlled experimental settings, such as administrating a short sketching test immediately after viewing both types of videos alongside pre- and post-test measures.

Our results also indicate that the importance of using the 360-degree videos extends beyond test outcomes or recalling details like colors, textures, or design elements. Consistent with the studies that have shown that immersive technologies can boost students' engagement, motivation, and sense of presence in the learning environment [1,13,52], the real strength of 360-degree videos in architectural education lies in enriching the overall learning experience and making it more engaging and meaningful.

The study's findings also demonstrated that using 360-degree videos is beneficial for both in-person and online learning courses, with slightly less of an impact in online courses. This is expected as the level of engagement and participation tends to be higher in person-to-person classrooms, as supported by recent studies [59]. However, this finding provides solid evidence of the value of using immersive technologies, such as 360-degree videos as affordable tools in online courses, particularly those require more cognitive abilities, such as understanding the cultural heritage and architectural styles and schools. The study also stressed the importance of applying and testing more affordable learning tools and media in both practical courses, such as design studios, and theoretical courses to measure different learning outcomes. Moreover, future studies could widen the scope of these experiments to include a sufficient number of participants and explore additional aspects of learning outcomes based on the content of the architecture courses. Additionally, comparisons between immersive technologies, such as 360-degree videos, and AI-based learning tools could provide new insights to architecture pedagogy. While the findings are promising, there are some limitations to this study. Students' familiarity with 360-degree videos may have varied, which could have influenced how engaged they were. The resolution of available 360-degree videos themselves also varied, which could have affected both engagement and learning outcomes. In addition, the study focused only on the history of architecture students at the same academic level, so the results may not be generalizable to other academic levels or programs.

6. Conclusions

Recently, immersive technologies have received a growing amount of attention in all disciplines for their realistic and engaging characteristics. One of these technologies, 360-degree videos, have become increasingly popular due to their realism, cost-friendliness, availability, high-quality visualization, environmental validity, and simplicity of use. Despite the potential of 360-degree videos, few studies have demonstrated their effectiveness in teaching architecture outside architectural design studios.

The History of Architecture is one of the fundamental courses in which students learn the foundation of architectural knowledge. For architecture students, engaging with cultural heritage, either in person or via immersive technologies such as 360-degree video, is essential for comprehending the spatial cognition of the historical elements within their cultural and environmental context. This study explored the contribution of using 360-degree videos in non-design architectural courses, such as History of Architecture, by introducing students to the cultural heritage buildings and comparing the results with those of conventional 2D videos. The study assessed spatial cognition, learning performance and learning experience.

The findings show that the 360-degree videos significantly improved attentiveness and participation among architecture students. Compared to conventional 2D videos, they also improved students' learning experience and performance. The results demonstrate the enormous potential of 360-degree videos in educational fields, particularly those requiring

a greater sense of presence and immersion, such as architecture, building construction, and cultural heritage. While there is increasing demand for VR and AI technologies and applications, 360-degree videos remain a highly competitive tool, requiring less equipment, preparation, and costs.

The main contribution of this study is to extend the knowledge in cultural heritage education using different types of media and to highlight the potential of using 360-degree videos as an affordable learning tool in architectural education. This research is considered a call to invest in creating more 360-degree videos about historical and modern architecture and making them available online to help students better understand spatial and aesthetic characteristics. Further research could be conducted to explore more affordable visualization media and compare their effectiveness with 360-degree videos in architectural education.

Although these findings are significant, they are applicable primarily to the present condition of educational institutions, given the rapid spread of AI tools. Further research is needed to investigate innovative ways to integrate immersive technologies and AI-based tools to enhance architecture education experiences. Further research is needed to investigate innovative ways to integrate these technologies for enhanced educational experiences.

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