

Fuzzy Delphi Analysis for the Development of UIS Mobile Virtual Tour Application

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ABSTRACT

The purpose of this study was to determine design elements in developing a mobile virtual tour application at University Islam Selangor (UIS) and to validate it through expert review. With students increasingly turning to online resources as the first point of contact in exploring colleges or universities, there is a demand for virtual tour apps that are also fun and interactive. Many of the applications available today, however, don't meet the user's needs. There were two main steps in this study: highlighting the key design elements from the literature and obtaining expert validation with the Fuzzy Delphi Method. A group of 10 experts in multimedia, virtual reality (VR), user interface design, three-dimensional animation, and mobile application development took part in an assessment related to 21 design items distributed in seven main categories. The Fuzzy Delphi analysis showed a threshold value of 0.113 and an expert agreement of 86%, which was considered a strong consensus on included elements. The findings clearly show that the most critical factor is interface design (UI/UX), which all experts agreed on. Other key features are legible text and information, cute 2D graphics, the ability to view sequences of images in full 360-degree rotation, and right sound FX. 3D objects and some immersive experiences, on the other hand, scored lower and are in need of more technical development. This research paper indicates that providing an effective virtual tour application based on intuitive design, easy understanding of the displayed information, appealing visual images, and navigational flexibility. These validated items provide a solid basis for developing a user-centred virtual tour that is applicable to prospective students effectively.

Keywords: *Virtual tour application; expert validation; design elements; user interface; Fuzzy Delphi Method*

INTRODUCTION

In the digital era, mobile technology, such as cellular phones and digital communications, enables us to access an extensive range of information in new ways. Experiences integrating information in mobile and digital environments are increasingly complex. At the same time, mobile technologies can now deliver more advanced and immersive information than ever before. These developments also provide more flexible access to information, improving direct communication. They combine diverse information in spatial and digital formats with various interaction modes, actively engaging users with the content. The growing population of mobile app users, along with their increasing expectations for usability, customization, and enhanced user experience, is transforming customer behavior. Additionally, the growing adoption of digital multifunctional technologies allows for more task automation.

The technological advances have encouraged higher education institutions to adopt mobile-based solutions that enable access and provide enhanced user interaction. Today, virtual tour technology has become one of the key innovations facilitating distant exploration in academic buildings, campus facilities, and engagement between those inside an educational system. Mobile virtual tour applications

are not simply informational tools. They have become a platform for prospects, parents, and a wide array of other external stakeholders to get involved with the campus. This enhanced engagement is particularly crucial for institutions aiming to showcase campus culture and facilities to a geographically diverse audience (Garcia et al., 2023; Samala et al., 2024; Rohizan et al., 2019). The development of a specialized mobile virtual tour represents an important step toward enhancing institutional communication, understanding better where facilities are located on campus, and helping prospective students make informed choices.

Despite the growing interest in virtual tours, driven by recent technological advancements, current applications often exhibit limitations in design quality, usability, and the ability to fully replicate real-world experiences. Many existing virtual tour platforms, particularly those relying on 360-degree videos or basic panoramic images, often lack the interactive elements and adaptive features necessary for truly immersive and personalized user journeys (Garcia et al., 2023; Osman et al., 2020). This is especially relevant given the widespread nature of mobile technologies and the increasing digital literacy of prospective students, who expect sophisticated and interactive digital experiences (Fadellelmoula, 2022). Furthermore, though there is an increasing emphasis on virtual environments for learning, validated design requirements of mobile-based virtual tour systems are at present still a bit thin on the ground. Indeed, it can be seen that there is a gap between the technology available to virtual tour applications and user needs, expectations, and experience preferences.

Despite this, a significant research gap still exists within the literature, whereby although a number of research studies have investigated the implementation of virtual tour technologies in different scenarios, a significant lack of systematically validated design frameworks has been identified, which specifically address mobile campus virtual tour application design. The design of most existing virtual tour applications is mostly based on ad-hoc design principles, which might not necessarily address the particular needs within an educational setting. This also means that application development is being carried out with designing principles that are not grounded in scientific fact, which can result in unsuccessful application design from a user perspective, as a result of which the application might not serve as an effective means of communicating university offerings. This is particularly a problem within the University Islam Selangor (UIS), which has a significant need to communicate university offerings to potential students via a mobile platform.

In this paper, the study addresses this gap using the Fuzzy Delphi Method to systematically identify and validate critical design elements in a campus-based mobile virtual tour application. The Fuzzy Delphi Method offers an appropriate means for establishing valid design frameworks without standardized guidelines because it facilitates the establishment of expert consensus that acknowledges the uncertainty within subjective judgments. The methodology used here is focused on seeking expert consensus regarding the nature of the design elements, and this approach provides a strong scientific underpinning to the development of successful mobile virtual tour applications in higher education contexts. This paper aims to achieve three objectives: (1) to identify the key design factors of the UIS virtual tour application through comprehensive literature analysis (2) to validate these factors through expert consensus using the Fuzzy Delphi method, and (3) to propose evidence-based design recommendations for guiding the design and development of user-centered campus virtual tour.

LITERATURE REVIEW

Virtual Tour Applications in Tourism and Higher Education

The tourism industry benefited greatly from the rapid development of mobile technology and the growing need for immersive digital experiences, which has resulted in mobile virtual tour applications becoming as much a vital tool for improving visitor engagement as they are a necessary means of access. Mobile virtual tour applications are a genre that merges various forms of technology, including mobile computing, virtual reality, augmented reality, and location-based services; they are intended to provide users with informative, interactive experiences of real physical places across the globe without restrictions in location. In the 21st-century travel experience, tourism applications for mobile devices

have become an indispensable necessity. The emergence of mobile virtual tour applications in higher education has garnered significant interest as universities pursue more accessible and interactive methods for campus introduction.

Interactive virtual tours that utilize 360-degree visuals, intuitive navigation features, and clearly presented information significantly enhance users' comprehension of environments and strengthen their engagement with digital content (Rahadiani et al., 2023; Garcia et al., 2023; Salah et al., 2023). According to Kim and Hall (2019), they can be anything from a navigator, a provider of information, and a storyteller to an interactive virtual explorer. When planning and developing such an application, it is necessary to consider both user needs and technological capabilities so that the context of users' satisfaction with their experience can be thoroughly studied. A recent study by Yung and Khoo-Lattimore (2019) points out that a mobile application for tourism can only be successful when it balances elegance with ease; hence, any functions ought to be designed so as not to confuse the user.

Moreover, the COVID-19 pandemic further increased the adoption of virtual tour technology as educational institutions, cultural institutions, and well-known tourist sites had to find ways to keep audiences engaged virtually. Guttentag (2010); Jung et al. (2016) identified the benefits of virtual tours, such as being a travel planning tool, providing alternative experiences for those unable to travel, and serving as an educational resource that incorporates contextual information about locations and artifacts.

Virtual Tours in Higher Education

Application development for virtual university tours is still a developing area with its own distinct challenges and opportunities, given that applications of this type must meet the needs of multiple user groups. Compared to other static web applications or leaflets, applications for virtual university tours should manage information delivery more engagingly for both current and prospective students. Research by Warsinke et al. (2025) discovered that AR applications for university tours, as well as Virtual Reality applications, result in low task loads that produce significant levels of enjoyment for users, in addition to vastly improving telepresence for Virtual Reality application users. This is significant since it reveals that applications with cutting-edge technology do not necessarily constitute more difficult user interfaces.

VR-based tours enhance immersive presence more effectively than 2D presentations, thereby boosting users' enjoyment of VR and their future intentions to engage with VR or visit the featured destinations physically (Hoang et al., 2023). It is significant for universities to identify that the ultimate application of such applications is transforming virtual visitors into students enrolled with the university. Applications of Virtual Reality not only need to be informative but must also be persuasive in their role of persuading students to join the university. Virtual tourism, particularly through 360-degree virtual tours, has been shown to provide a universally accessible means of engaging with culture and exploring heritage sites from home, especially during periods of travel disruption (Shikhri et al., 2023). This aspect of accessibility has wide-ranging implications for accessibility in higher education.

It reduces geographic and financial barriers that have traditionally limited campus visits to individuals with sufficient resources and mobility. This accessibility has been particularly important in higher education, where virtual campus tours have become an important mechanism for recruiting students so prospective students can experience facilities in a digital environment (Garcia et al., 2023). Moreover, the move to virtual campus tours is not just a technology-based shift but, more importantly, represents a paradigm shift as universities present themselves to a digitally native populace of students who are demanding an easy, engaging, and on-demand digital experience. Together, such studies substantiate the importance of high-level virtual tour functionality for enhancing user engagement, satisfaction, and real-world behaviour in higher education settings, and thus justify systematic expert-based priority selection using techniques such as Fuzzy Delphi.

The Fuzzy Delphi Method: Rationale and Technical Advantages in Design Validation

Fuzzy Delphi Method (FDM) is a measurement tool proven to achieve expert consensus in agreeing on components and elements required in the development of modules to solve problems in terms of precision and uncertainty (Padzil et al., 2021). The method incorporates an expert's contribution to reach an appropriate consensus on predefined criteria, which is an important process during model or system development (Dawood et al., 2020). According to Suzianti et al. (2021) the Fuzzy Delphi Method is an analytical method combining the conventional Delphi Method with Fuzzy Theory, offering a decision-making process based on the contribution of experts with maintenance of confidentiality for objectivity. There are several technical advantages to selecting the Fuzzy Delphi Method over traditional Delphi methods as an option to design validation studies.

Firstly, due to the traditional Delphi method, not only are multiple rounds of questionnaires involved, but they are also time-consuming and often cause fatigue of the expert in questionnaires, which would result in high dropout rates. In comparison, with Fuzzy Delphi, consensus measurement is not overly regulated, and it only takes a short period of time, and is generally one or two rounds (Liu et al., 2023). Second, typical Delphi does depend on fixed numerical values (e.g., Likert scales) that force a consensus of experts into generating precise responses, regardless of their uncertainty. This is the point the Fuzzy Delphi resolves by using Triangular Fuzzy Numbers (TFN) that encapsulate the nature of imprecision and uncertainty in human judgment through three values: minimum, most likely, and maximum (m_1 , m_2 , m_3). Rather than single-point estimates, experts are able to identify uncertainty ranges with this mathematical construct, leading to more nuanced and realistic consensus measurements.

From a technical standpoint, the Fuzzy Delphi Method has an analytical advantage over design validation. Calculating the threshold value (d) provides an objective measurement of expert agreement, which cannot be achieved by simple percentage agreement in traditional methods. If the threshold value is $d \leq 0.2$, consensus among experts is strong with little ambiguity. Furthermore, the defuzzification process, which transforms fuzzy values into crisp score using formula $A = (m_1 + m_2 + m_3)/3$, allow a clear ranking and prioritization of design elements. This is particularly valuable because in design studies, there are often multiple elements to be evaluated and prioritized on their relative importance. The Fuzzy Delphi Method is especially rational in design research, as the essence of design decisions involves subjective judgments that are always uncertain regarding issues such as visual and usability factors and user experience.

In the context of mobile application design, the importance of certain visual elements, interaction patterns, or technical features can be viewed differently by different experts. Fuzzy logic is well adapted to deal with such variability, still achieving measurable consensus, and hence is ideal for the validation of design frameworks where absolute certainty can rarely be attained. The structured expert agreement is a good basis for verifying design decisions of complex application development. Second, its handling of small-sized expert panels (10-15 experts) without loss of validity makes the method especially practical in specialist design domains where large panels of qualified experts are difficult to identify. This means that it is important to validate through experts, although some would say that the opinions of end-users should be accorded with equivalent importance. In the development of mobile applications, the use of the Fuzzy Delphi Method has seen some adoption in recent years. Suzianti et al. (2021) further explain that the Fuzzy Delphi Method combines the traditional Delphi approach with Fuzzy Theory, enabling collective decision-making grounded in expert judgment while maintaining anonymity and encouraging objectivity. It is with the Fuzzy Delphi Method that this study requires the validation of elements or constructs of a module through the consensus of experts, as the design process suggests the need for structured expert agreement.

The Fuzzy Delphi Method was chosen due to its flexibility in handling complex research questions and the ability to deal with intricate expert opinions for the validation of proposed constructs and elements (Liu et al., 2023). The Fuzzy Delphi Method was chosen due to its flexibility in handling interdisciplinary research questions and its ability to accommodate diverse expert perspectives. This, however, depends not on simple majority voting but rather on a sophisticated analysis that takes into

account the degree of fuzziness in expert judgments. In particular, this is the case with technology-driven applications where design elements cut across a number of disciplines such as interface design, multimedia content, user experience, and technical implementation, which all differ in their respective emphases and requirements for special expertise. Thus, the application of the Fuzzy Delphi Method in this research is not only methodologically appropriate but actually strategically required to ensure the virtual tour module would be evidence-based through experts, meet user needs, and is capable of supporting informed design decisions in subsequent development. The technical advantages of handling uncertainty, providing objective consensus measures, and enabling efficient expert consultation make it the best option for validating design elements within the context of developing a mobile virtual tour application.

METHODOLOGY

Research Design

This study employs a Design and Development Research (DDR) approach to construct and validate the design elements for the UIS Mobile Virtual Tour Application. DDR is commonly used in studies that involve the creation, refinement, and evaluation of models, frameworks, or applications. The research was conducted in two phases:

Phase 1: Identification of Design Elements

Relevant design components were identified through literature analysis and user needs.

Phase 2: Validation Using the Fuzzy Delphi Method

The proposed elements were evaluated and validated by a panel of experts using the Fuzzy Delphi technique.

The Fuzzy Delphi method was chosen because it enables expert consensus to be obtained efficiently and objectively, particularly when working with small expert groups. This method ensures that the final design elements are accurate, relevant, and suitable for integration into the UIS Mobile Virtual Tour Application.

Instrument

The main research instrument is an expert questionnaire designed to assess the relevance, clarity, and suitability of the proposed design elements. The instrument enables experts to evaluate each item using linguistic scales, which are subsequently converted into Triangular Fuzzy Numbers (TFN) for analysis. The questionnaire aims to determine the necessity of each design element, obtain expert consensus regarding items to be included in the design framework, and identify elements to be accepted, modified, or removed based on Fuzzy Delphi criteria (threshold value $d \leq 0.2$; agreement level $\geq 75\%$). This structured evaluation ensures that the final design framework is scientifically validated, relevant, and effective for developing the mobile virtual tour application.

Population and Sample size

The population consists of experts in multimedia, virtual reality (VR/AR), user interface design (UI/UX), 3D animation, and mobile application development. These experts were selected based on their specialized knowledge and experience directly related to the development of interactive applications. A total of 10 experts participated in this phase, in accordance with the recommendation by Cheng & Lin (2002), who state that 10–15 experts are adequate for consensus analysis using the Fuzzy Delphi method.

Sampling Method

This study employed purposive sampling, ensuring that only individuals who possess substantial experience and expertise in relevant fields were selected as expert respondents. This method is appropriate as it focuses on selecting respondents who can provide accurate and meaningful input regarding the design elements of the application.

Expert Selection Criteria

The experts were selected based on the minimum academic qualification of a Master's degree in a related field such as Multimedia, Information Technology, or Interactive Design. Additionally, experts required at least five (5) years of experience in AR/VR, application development, user interface design, or research related to educational technology, as well as involvement in the development or evaluation of multimedia systems/applications, either in industry or academia.

Data Collection Procedure

The data collection for this study was conducted through a physical, face-to-face expert session. All ten experts were invited to a designated venue and were briefed on the purpose, scope, and procedures of the study. Before completing the questionnaire, the researcher provided a clear explanation of the items, the evaluation scale used, and the overall importance of expert input for the development of the UIS Mobile Virtual Tour Application. Each expert was then given a printed questionnaire consisting of the proposed design elements to be evaluated using the Fuzzy Delphi method. Experts completed the questionnaire individually and independently during the session to avoid influence or bias among participants. The researcher remained present to address any procedural questions but did not interfere with the experts' judgment. Upon completion, all questionnaires were collected on the same day and checked for completeness. The responses were subsequently transcribed and converted into digital format for further analysis using the Fuzzy Delphi technique.

Data Analysis Technique: Fuzzy Delphi Method

The expert responses were analysed using the Fuzzy Delphi Method, which combines the traditional Delphi approach with fuzzy logic to obtain objective expert consensus. Linguistic ratings from the experts were converted into Triangular Fuzzy Numbers (TFN) and processed through three main steps:

- i. Threshold Value (d): Determines agreement among experts.
- ii. Items with $d \leq 0.2$ are accepted.
- iii. Percentage of Consensus: Measures the proportion of experts who agree on an item.

A minimum of 75% agreement is required. Defuzzification converts fuzzy values into a single score to rank the importance of each item. Items that do not meet the threshold or consensus criteria are revised or removed. The Fuzzy Delphi Method provides a more accurate and systematic evaluation of expert judgment, making it suitable for validating design frameworks and identifying essential components for the UIS Mobile Virtual Tour application.

FINDINGS AND DISCUSSIONS

Expert Consensus Analysis Using the Fuzzy Delphi Method

The Fuzzy Delphi analysis is a systematic approach used to obtain consensus among experts regarding a particular construct or research element. This method combines the Delphi theory with fuzzy logic, which allows subjective evaluations to be translated into more objective and precise quantitative forms. In this study, the Fuzzy Delphi method was used to assess the level of agreement among 10 experts on 21 items within seven main elements of application design, namely Text and Content, 2D Graphics and Visuals, 3D Objects, 360° Display, Audio and Sound Effects, Interface (UI/UX), and Immersive.

Respondent Demographic Analysis

1. Gender

The figure below shows the percentage of respondents by gender.

Table 1.0: Percentage of Gender

Gender	Number	Percentage (%)
Male	5	50%
Female	5	50%

2. Educational Level

Table 2.0: Percentage of Educational Level

Educational Level	Number	Percentage (%)
Master's Degree	10	100%

3. Field of Expertise

Table 3.0: Percentage of Field of Expertise

Field of Expertise	Number	Percentage (%)
Application Development	1	10
Graphic Design, Mobile Application Development, and Multimedia	1	10
Graphic Design, UI/UX Expert, Multimedia	1	10
Audio and Video, Multimedia	1	10
AR/VR, 3D Animation, Graphic Design, and Multimedia	1	10
Graphic Design and Multimedia	1	10
3D Animation, Audio and Video, Multimedia	1	10
Multimedia	1	10
AR/VR, Graphic Design, Audio and Video, Multimedia	1	10
UI/UX Expert and Multimedia	1	10

1. Text and Content Element (Items 1–3)

Based on the threshold value for Table 4.0, all three items under the text and content element show d values ≤ 0.2 , specifically 0.055, 0.098, and 0.055. All these values meet the acceptance criteria of the Fuzzy Delphi method (<0.2). In Step 7, the percentage of agreement for all three items reached 100%, indicating full consensus on the quality of the text and content in terms of message clarity and accuracy of information. Based on the expert ranking analysis (Step 8), the element obtained Rank 5, showing that the text and content aspect is considered important but does not fall within the highest priority category.

Table 4.0: Fuzzy Delphi Analysis Results for Items 1-3

Item / Element	Triangular Fuzzy Number Condition		Fuzzy Evaluation Process Condition				Expert Agreement	Element Accepted	Ranking
	Threshold Value (d)	Expert Group Agreement (%)	m1	m2	m3	Fuzzy Score (A)			
1	0.055	100%	0.58	0.78	0.98	0.78	ACCEPTED	0.78	5
2	0.098	100%	0.56	0.76	0.96	0.76	ACCEPTED	0.76	10

3	0.055	100%	0.58	0.78	0.98	0.78	ACCEPTED	0.78	15
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2. 2D Graphics and Visual Element (Items 4–6)

The threshold d values in Table 5.0 for items 4 to 6 are 0.055, 0.128, and 0.098. All values are below 0.2, indicating a high level of agreement. The percentage of consensus for each item is 100%. Based on the ranking, this element falls between Rank 5 and Rank 12, showing that the visual aspect received moderately high recognition from the experts.

Table 5.0: Fuzzy Delphi Analysis Results for Items 4-6

Item / Element	Triangular Fuzzy Number Condition		Fuzzy Evaluation Process Condition				Expert Agreement	Element Accepted	Ranking
	Thresh old Value (d)	Expert Group Agreement (%)	m1	m2	m3	Fuzzy Score (A)			
4	0.055	100%	0.58	0.78	0.98	0.78	ACCEPTED	0.78	5
5	0.128	100%	0.54	0.74	0.94	0.74	ACCEPTED	0.74	12
6	0.098	100%	0.56	0.76	0.96	0.76	ACCEPTED	0.78	10

3. 3D Object element (Items 7-9)

The threshold d values in Table 6.0 for items 7–9 are 0.183, 0.220, and 0.244, respectively. Only item 7 is accepted, while the other two items are rejected. Based on the ranking, this element is positioned at the lower levels (Rank 18–21), indicating a low level of importance within the overall system.

Table 6.0: Fuzzy Delphi Analysis Results for Items 7-8

Item / Element	Triangular Fuzzy Number Condition		Fuzzy Evaluation Process Condition				Expert Agreement	Element Accepted	Ranking
	Thresh old Value (d)	Expert Group Agreement (%)	m1	m2	m3	Fuzzy Score (A)			
7	0.183	100%	0.48	0.68	0.88	0.68	ACCEPTED	0.68	18
8	0.220	0%	0.42	0.62	0.82	0.62	ACCEPTED	0.62	21
9	0.244	0%	0.44	0.64	0.84	0.64	ACCEPTED	0.64	20

4. 360 display element (Items 10-12)

The threshold d values in Table 7.0 for items 10–12 are 0.147, 0.055, and 0.183. All items are accepted. The expert consensus percentage is 100%. Based on the ranking, this element shows moderate variation, occupying Rank 16 and Rank 17.

Table 7.0: Fuzzy Delphi Analysis Results for Items 10-12

Item / Element	Triangular Fuzzy Number Condition		Fuzzy Evaluation Process Condition				Expert Agreement	Element Accepted	Ranking
	Threshold Value (d)	Expert Group Agreement (%)	m1	m2	m3	Fuzzy Score (A)			
10	0.147	100%	0.520	0.720	0.920	0.720	ACCEPTED	0.72	16
11	0.55	100%	0.580	0.780	0.980	0.780	ACCEPTED	0.78	5
12	0.183	100%	0.500	0.700	0.900	0.700	ACCEPTED	0.70	17

5. Audio and Sound Effects Element (Items 13-15)

The threshold d values in Table 8.0 for items 13–15 are 0.128, 0.147, and 0.128. All items are accepted with a 100% consensus rate. Based on the ranking analysis, this element is placed at Rank 12, indicating a moderate level of importance in the user experience.

Table 8.0: Fuzzy Delphi Analysis Results for Items 13-15

Item / Element	Triangular Fuzzy Number Condition		Fuzzy Evaluation Process Condition				Expert Agreement	Element Accepted	Ranking
	Threshold Value (d)	Expert Group Agreement (%)	m1	m2	m3	Fuzzy Score (A)			
13	0.128	100%	0.54	0.74	0.94	0.74	ACCEPTED	0.74	12
14	0.147	100%	0.54	0.74	0.94	0.74	ACCEPTED	0.74	12
15	0.128	100%	0.54	0.74	0.94	0.74	ACCEPTED	0.74	12

6. Interface element (UI/UX) (Items 16-18)

The recorded threshold values in Table 9.0 are 0.000, 0.000, and 0.055. All items are fully accepted. A threshold value (d) of 0.000 indicates perfect consensus among experts, meaning there is no divergence in expert judgment. In the Fuzzy Delphi Method, a value of $d \leq 0.2$ is acceptable; therefore, $d = 0.000$ represents the strongest possible agreement and justifies full acceptance of the item. All three items achieved 100% expert consensus. This element is placed at Rank 1, making it the most important element in the entire system in terms of design significance and priority.

Table 9.0: Fuzzy Delphi Analysis Results for Items 16-18

Item / Element	Triangular Fuzzy Number Condition		Fuzzy Evaluation Process Condition				Expert Agreement	Element Accepted	Ranking
	Threshold Value (d)	Expert Group Agreement (%)	m1	m2	m3	Fuzzy Score (A)			
16	0.000	100%	0.60	0.80	1.000	0.80	ACCEPTED	0.80	1

17	0.000	100%	0.60	0.80	1.000	0.80	ACCEPTED	0.80	1
18	0.000	100%	0.60	0.80	1.000	0.80	ACCEPTED	0.80	1

7. Immersive elements (Items 19-21)

The threshold values in Table 10.0 for items 19–21 are 0.104, 0.129, and 0.220. Based on the results, the first two items are accepted, while item 21 is rejected. In terms of ranking, item 19 is placed at Rank 9, item 20 at Rank 9, and item 21 at Rank 19. This indicates that the immersive element is important but still requires improvements in terms of technical and interactive aspects.

Table 10.0: Fuzzy Delphi Analysis Results for Items 19-21

Item / Element	Triangular Fuzzy Number Condition		Fuzzy Evaluation Process Condition				Expert Agreement	Element Accepted	Ranking
	Threshold Value (d)	Expert Group Agreement (%)	m1	m2	m3	Fuzzy Score (A)			
19	0.104	100%	0.588	0.792	0.992	0.791	ACCEPTED	0.79	4
20	0.129	100%	0.548	0.792	0.948	0.763	ACCEPTED	0.76	9
21	0.220	100%	0.456	0.656	0.856	0.656	ACCEPTED	0.65	19

The findings of this study reveal a high level of expert consensus on the proposed design elements for the UIS Mobile Virtual Tour Application, with an overall threshold value of 0.113 and an agreement rate of 86%, confirming the validity of the design framework. Interface design (UI/UX) emerged as the most critical element, achieving perfect consensus ($d = 0.000$), highlighting the central role of intuitive navigation, consistency, and usability in mobile virtual tour applications, which is consistent with prior studies emphasizing user-centered interface design as a key determinant of engagement and satisfaction (Garcia et al., 2023; Osman et al., 2020).

Text and content, 2D graphics, 360° display, and audio elements were also strongly supported by experts, indicating the importance of clear information delivery, visual clarity, and supportive multimedia in enhancing user experience, as reported in previous virtual tour and tourism studies (Rahadiani et al., 2023; Kim & Hall, 2019). In contrast, 3D objects and immersive elements received comparatively lower consensus, reflecting expert concerns regarding technical complexity, performance constraints, and potential cognitive load for mobile users, a finding that aligns with Warsinke et al. (2025), who cautioned against excessive reliance on advanced immersive features without first establishing strong usability foundations. Overall, these results suggest that effective mobile virtual tour applications in higher education should prioritize usability, interface design, and content clarity, while adopting immersive technologies selectively to ensure a balanced, user-centered experience.

CONCLUSION

This study provides a clear understanding of user needs for the development of the Virtual Tour UIS mobile application. The results show that most respondents are young, tech-savvy, and highly interested in exploring the campus virtually. Awareness of University Islam Selangor (UIS) is high, and social media is their main source of information. Although only a few have used virtual tour apps before, almost all expressed interest in using the Virtual Tour UIS, indicating strong demand. The descriptive analysis shows that respondents strongly agree with the proposed heuristic design principles, expecting an application that is user-friendly, easy to navigate, visually clear, and functional. The Fuzzy Delphi analysis further confirms strong expert consensus, with an overall threshold value of 0.113 and an

agreement level of 86%, showing that the proposed elements are relevant and well accepted. UI/UX was ranked as the most important element, followed by text and content, 2D graphics, 360° display, audio, and sound effects. These elements enhance clarity, visual communication, and interactivity. However, the 3D objects and immersive elements received lower consensus, showing the need for further technical refinement. Overall, the findings highlight the need to prioritize interface design, content clarity, visual elements, and interactivity in developing the Virtual Tour UIS. The results provide a strong foundation for creating a more effective, engaging, and user-centered application, and serve as a guide for improving future, more immersive versions of the system.

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