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Fuzzy Delphi Approach Determining Elements in Mobile Learning Model for Adult Learners

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ABSTRACT

Mobile learning, also known as m-learning, has been popular recently due to the portability, ease of use, and affordability of mobile devices. M-learning can take place anywhere and at any time. Furthermore, adult learners face challenges due to the increasing use of technology and the ageing population. Current design guidelines for smartphones for older adults can be challenging to implement and interpret. Little research has been done on mobile learning elements before application development. Different frameworks of the mobile learning model apply specific principles and endorse the theory of demographics and other related variables. This study addresses the gap in pre-application research on mobile learning elements, focusing on adult learners. This study uses the Fuzzy Delphi Method (FDM) with ten experts and the result from the analysis threshold score was (d) ≤ 0.2, the percentage consensus of the expert was more than 75%, and the average fuzzy score (A) for all the elements is 0.5 and above. Results indicate that seven proposed elements (usability, navigation, touch gestures, andragogy, scaffolding, content, and layout) are important for adult learners. It is suggested that these FDM-identified components be included in a mobile learning design model to improve the educational experience for this particular group of learners. This study provides insightful information on particular elements that are necessary to successfully create mobile learning experiences for adult learners.

Keywords:

Mobile learning model; Adult learners; Fuzzy Delphi technique

1. Introduction

Today mobile learning (m-learning) is popular in the education field, and many researchers have realized the potential to use mobile technologies to reinforce learning. M-learning provides new forms of promoting understanding by mobile devices, for example, desktop and laptop computers, smartphones, and cell phones. Mobile devices are generally affordable, portable, and flexible. According to Statista, in 2022, the number of smartphone users worldwide was 6.648 billion, meaning almost half of the planet's people own a smartphone. This figure is up considerably from 2017 - 2022 and has been a 49.89% increase in the number of people with smartphones [1].

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M-learning was introduced in business, university, and military industries. Besides, M-learning enables learners to access learning materials anytime and anywhere using the Internet and mobile devices. It has become a new educational tool for assisting learners in ubiquitously acquiring knowledge and skills. Furthermore, M-learning can be of well-adapted educational content for effective visualization on mobile devices' small screens [2].

The adult learner is different from the children learner. There are three stages of adulthood: the first stage of adulthood is emerging adults 18-25 years old, the second stage is young adults 26-39 years old, and the last is mature adults 40-59 years old [3]. Most of them are married, have children, and come from various social, ethnic, and educational backgrounds. The characteristics of adult learners, referred to as andragogy, differ from the assumptions of the features of kid learners, which are referred to as pedagogy. The adult learner wants and needs to know why they need to learn something and how the lesson will benefit them. They are more motivated when they understand what they are expected to learn [4].

Since the 1930s, English readers have used andragogy, which Malcolm Knowles popularized [5]. Andragogy focuses on how adults learn. Andragogy includes six assumptions:

i. the learner needs to know why they need to learn something
ii. the learner (self-concept)
iii. adult learning experiences
iv. readiness to learn
v. orientation to learn
vi. motivation to learn

Adult learners face challenges due to the increasing use of technology and the ageing population [6]. Education could also be a crucial issue that significantly affects older adults' performance once they interact with technology [7]. There are a few challenges encountered in implementing mobile learning. Mobile and screen resolution dimensions are often an enormous issue that must be overcome. Due to the complexity of the numerous devices' small sizes for older learners, tasks involving new technology-based items take longer to complete [8].

As people get older, their cognitive and physical abilities begin to weaken, which may prohibit them from using a tablet or smartphone properly. This point is supported by Salman *et al*., [9] that deterioration in physical and cognitive characteristics is joint in elderly adults, affecting elderly adults, and this affects their ability to use smartphone applications. Additionally, the quantitative findings show that there are still challenging gestures for older adults with relatively low success rates [10]. Current design guidelines for smartphones for older adults can be challenging to implement and interpret. As a result, application developers do not have a defined set of guidelines for designing smartphones for older adults [11].

According to Sabri *et al*., [12] there is a lack of information regarding mobile learning for adult learners. Little research has been done on mobile learning elements before application development. Different frameworks of the mobile learning model apply specific principles and endorse the theory of demographics and other related variables. Understanding and including the suitable elements of mobile learning to improve applications and add valuable features to the user is essential.

Hence, this study's goal is to use the Fuzzy Delphi method to determine the elements of a mobile learning model for adult learners. To determine the elements, the following six (6) processes must be completed:

i. determining the experts
ii. selecting a linguistic scale
iii. getting the average value
iv. determining the value of 'd'
v. get a percentage consensus and (vi) get the fuzzy evaluation.

There were three research questions in this study, which are:

i. What elements should be included in the mobile learning model for adult learners?
ii. What are the threshold values (d), percentage agreement and fuzzy score (A) of the FDM based on the consensus reached by experts?
iii. What are the rankings of those elements based on the consensus reached by experts?

The structure of this paper is designed to address the elements of a mobile learning model for adult learners. The following sections are divided into the methodology, the findings and results obtained through the Fuzzy Delphi Method and expert consensus, followed by a discussion of the implications of these findings. At the end of this study was concludes with the key insights and recommendations for the effective incorporation of identified elements into mobile learning design for the benefit of adult learners.

2. Methodology

This study determines the element of a mobile learning model for adult learners by using the Fuzzy Delphi method (FDM) proposed by [13]. FDM is a quantitative technique that combines the traditional Delphi Method with a fuzzy set numbering theory to provide an acceptable standard [14]. Expert questionnaires will be a helpful tool for data gathering in the Delphi method when interviews are not feasible due to time constraints and group arrangements [15,16]. The FDM ensures accuracy and verifies the elements via consensus among experts [17]. This method was chosen because it is practical due to saving cost and time and reducing the total number of surveys compared to the traditional Delphi method [18].

2.1 Procedure for Fuzzy Delphi Method

The initial step in the evaluation process was to conduct a literature review. The purpose of the literature review was to retrieve all the relevant studies about mobile learning for the adult learner. From the literature review, the questionnaire was designed. Next, the researcher identified the experts, and they were reached either by email or call. The appointment was made with those who willingly took part in the research. The experts fill in their background information and start to answer the questionnaire. After the expert completed the evaluation, the data was analysed using FDM. Figure 1 shows the flow of the procedure for FDM.

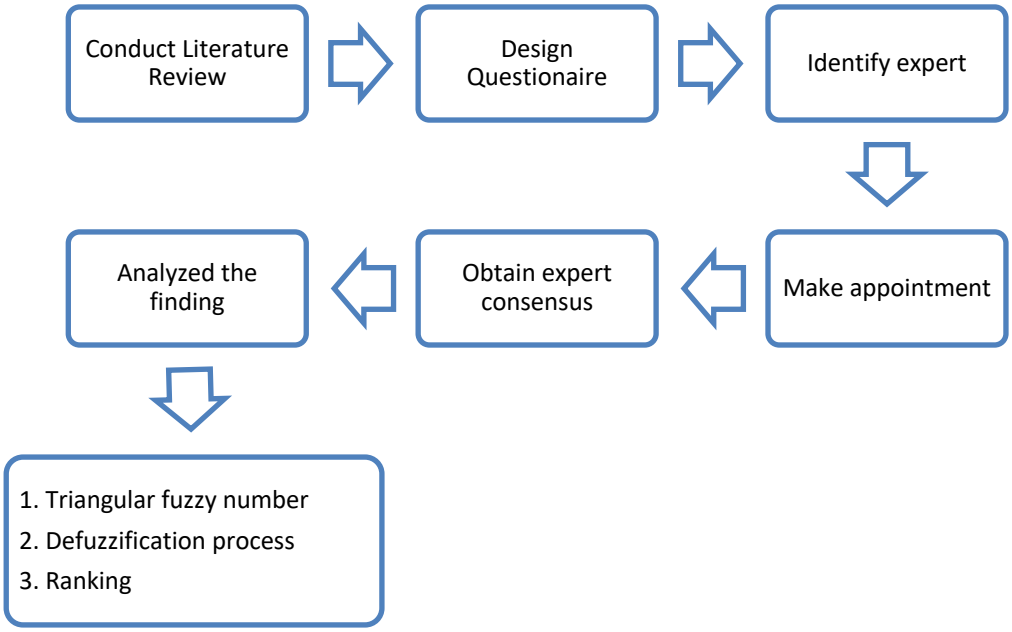

Fig. 1. Procedure for Fuzzy Delphi Method

2.2 Data Analysis Using FDM

Below are the steps used in determining the elements in the model of mobile learning using the FDM technique.

2.2.1 Step 1: Determining the experts

Ten experts were invited to answer the questionnaire. For the expert selection, the appropriate suggested number of experts in FDM is 10 – 15 [19]. Therefore, ten experts are suitable for this study to determine the elements of the mobile learning model. The invited ten experts with in-depth knowledge of information technology and mobile learning. Table 1 shows the details of the experts participating in the survey, including position, expertise field, and year of experience.

Table 1
Description of the Experts

Number of Experts	Position	Expertise	Year of Experiences
Expert 1	Lecturer	Information Technology	More than 10 years
Expert 2	Senior Lecturer	Information Technology, Human-Computer Interactions, E-Learning & Education	More than 10 years
Expert 3	Lecturer	Mobile Learning / App, Information Technology, Human-Computer Interactions	More than 10 years
Expert 4	Researcher	Mobile Learning / App, Information Technology, Human-Computer Interactions, Higher Education, UI/UX designer.	Less than 5 years
Expert 5	Senior Lecturer	Mobile Learning / App, Information Technology, E-Learning & Education	Less than 10 years
Expert 6	Lecturer	Information Technology	More than 10 years
Expert 7	Lecturer	Mobile Learning / App, Information Technology, Human-Computer Interactions	More than 10 years

Expert 8	Lecturer	Mobile Learning / App, Information Technology	More than 10 years
Expert 9	Lecturer	Mobile Learning / App, Information Technology	More than 10 years
Expert 10	Lecturer	Human-Computer Interactions, E-Learning & Education, Higher Education	More than 10 years

2.2.2 Step 2: Select a linguistic scale

In this stage, all linguistic variables are transformed into Triangular Fuzzy Numbers (TFN) by arranging the values of m_1, m_2 and m_3. The value of m_1 indicates the lowest value, m_2 indicates a reasonable value, and m_3 indicates the highest value. Figure 2 describes the TFN values of m_1, m_2 and m_3.

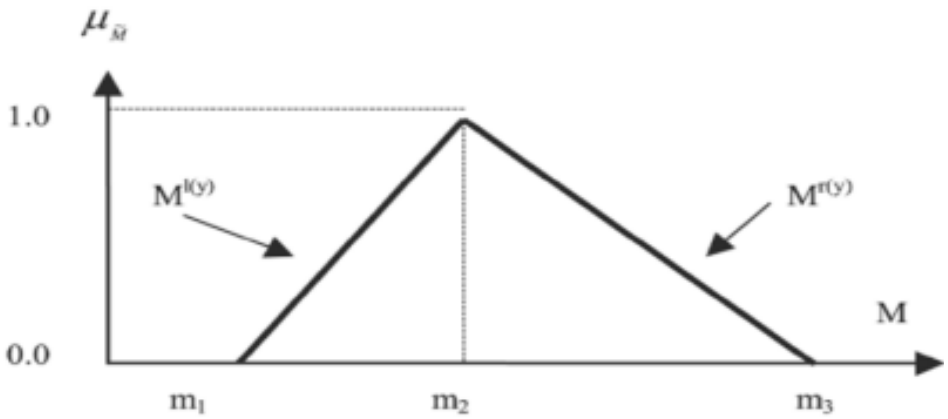

Fig. 2. TFN values of m1, m2 and m3

TFN is used to produce a fuzzy scale similar to the Likert scale to convert the linguistic variable to a fuzzy number. The questionnaire was designed to elicit a response based on a five-point Likert Scale; 'Strongly Disagree', 'Disagree', 'Not Sure', 'Agree', and 'Strongly Agree'. Table 2 shows the relationship between the Fuzzy Scale and Likert Five-point Linguistic Scale.

Table 2
Relationship between Five-Point Linguistic Scale and Fuzzy Scale

Variable	Fuzzy Scale	Likert Scale
Strongly Disagree	(0.0, 0.0, 0.2)	1
Disagree	(0.0, 0.2, 0.4)	2
Not Sure	(0.2, 0.4, 0.6)	3
Agree	(0.4, 0.6, 0.8)	4
Strongly Agree	(0.6, 0.8, 1.0)	5

2.2.3 Step 3: Getting the average value

The average weight was determined according to the formula prescribed. This step is known as the average response of each fuzzy number [20].The vertex approach has been used to compute the distance between the average $\sim r_{ij}$ and $\tilde{r}_{ij}$ and the distance between the average $\tilde{w}_{ij}$ and $\tilde{w}_j^k$, k =1,.,K

for each expert [21]. The distance between two fuzzy numbers $\tilde{m} = (m_1, m_2, m_3)$and $\tilde{n} = (n_1, n_2, n_3)$is computed by using the following formula:

$$d\left(\tilde{m}\tilde{n}\right) = \sqrt{\frac{1}{k}[(m_1 - n_1)^2 + (m_2 - n_2)^2 + (m_3 - n_3)^2]}$$

2.2.4 Step 4: Determining the threshold (d) value

The threshold value is significant when assessing the degree of agreement between experts [22]. If the value of d is <0.2, then all the experts agreed [23]. However, if the value of d is >0.2, the procedure must be repeated. Table 3 shows the data interpretation using the threshold (d) value.

Table 3
Data interpretation using the threshold (d)value

Threshold (d) value	Descriptions	Interpretation
d ≤ 0.2	The threshold (d) value is equal to or less than 0.2.	Accepted
d ≥ 0.2	The threshold (d) value exceeds 0.2.	Rejected OR carried out the second round, which only included experts who had disagreements.

2.2.5 Step 5: Get a percentage consensus

The agreement of the expert group is referred to as the consensus group. A consensus of 75% would be required to show an agreement among the experts [24]. If the consensus is below 75%, the second round should be implemented to ensure the experts' consensus is at least 75%.

2.2.6 Step 6: Get a fuzzy evaluation. Fuzzy Score (A) ≥ α-cut = 0.5

One technique for determining an item's rating is Fuzzy Evaluation. Due to the complicated numbering and alternative method of selecting the ranking using a mathematical formula, the process is quite challenging. This method is often called the defuzzified process. The value of α-cut, 0.5, is used to calculate the fuzzy score (A). The measured item is rejected if the fuzzy score (A) is less than 0.5, according to the expert group's consensus. The item is considered to be accepted if the expert group's consensus determines that the item's value is greater than or equal to 0.5 [25,26]. Following is the formula to defuzzify the fuzzy evaluation:

Amax = 1/3 * (a1 + am + a2)

3. Findings and Results

3.1 What Elements Should be Included in the Mobile Learning Model for Adult Learners?

Based on the data analysis, the result shows that seven elements (usability, navigation, touch gesture, andragogy, scaffolding, content, and layout) are important to include in the mobile learning model for adult learners to improve the quality of learning through mobile technology.

3.2 What are the Threshold Values (d), Percentage Agreement and Fuzzy Score (A) of the FDM Based on the Consensus Reached by Experts?

The experts' consensus on the mobile learning components with threshold values below 0.2 is shown in Table 4. These findings indicate the acceptability of the first condition, which has a threshold value of (d) ≤ 0.2. The second requirement of the Fuzzy Delphi Method was likewise accepted, with more than 75% of experts agreeing. Because the collected data fulfilled both requirements for employing this technique to analyse data, the second round of Fuzzy Delphi was unnecessary. Moreover, all component defuzzification values were higher than the fuzzy score value (A) of 0.5. This shows that the experts accepted the elements.

Table 4
Experts' consensus on the model elements is based on the threshold values (d), percentage agreement and fuzzy score (A)

Expert	Usability	Layout	Navigation	Content	Touch Gesture	Andragogy	Scaffolding
1	0.134	0.107	0.173	0.112	0.122	0.092	0.081
2	0.134	0.199	0.173	0.234	0.183	0.234	0.224
3	0.171	0.107	0.132	0.071	0.122	0.132	0.183
4	0.220	0.199	0.132	0.112	0.183	0.224	0.081
5	0.134	0.199	0.173	0.377	0.143	0.173	0.224
6	0.110	0.107	0.132	0.071	0.122	0.092	0.183
7	0.110	0.412	0.336	0.071	0.143	0.143	0.122
8	0.183	0.107	0.173	0.193	0.265	0.132	0.081
9	0.147	0.260	0.132	0.071	0.224	0.102	0.081
10	0.196	0.199	0.173	0.234	0.183	0.224	0.224
Threshold value (d)	0.154	0.189	0.173	0.155	0.169	0.155	0.149
Percentage of Expert Consensus (%)	94%	85%	93%	90%	93%	93%	93%
Score Value A	0.712	0.670	0.693	0.647	0.673	0.653	0.654

3.2.1 What are the rankings of those elements based on the consensus reached by experts?

Table 5 shows the experts' consensus on the elements of the model. First, with a threshold score of (d) 0.2, the proposed elements satisfied the fundamental rule. In addition, the second rule, with an expert consensus of at least 75%, was also acceptable. Lastly, the defuzzification values of each component were all more than the fuzzy score value (A) of 0.5. The result shows that the experts accepted the elements. Table 5 lists the agreed-upon elements in order of priority. Overall, these elements have gained expert approval and fulfil the requirements.

Table 5
Expert consensus on the elements of the model

Elements	Triangular Numbers	Fuzzy	Defuzzification Value	Results	Rank
	Average Threshold (d) Value	The average percentage of Expert Consensus (%)	Average Fuzzy Score (A)		
Usability	0.154	94%	0.712	Accept	1
Layout	0.189	85%	0.670	Accept	4
Navigation	0.173	93%	0.693	Accept	2
Content	0.155	90%	0.647	Accept	7
Touch Gesture	0.169	93%	0.673	Accept	3
Andragogy	0.155	93%	0.653	Accept	6
Scaffolding	0.148	93%	0.654	Accept	5

4. Discussion

The determining elements in a mobile learning model are based on three conditions; threshold value, expert consensus, and fuzzy score. Each proposed element is accepted since each construct fulfilled all three requirements, as shown in Table 5. Based on the findings, the threshold value (d) and the consensus percentage of the seven elements (usability, navigation, touch gesture, andragogy, scaffolding, content, and layout) fulfilled the requirements of the FDM.

The proposed elements fulfilled the primary rules with the threshold score (d) ≤ 0.2. The second rule was also accepted where the percentage consensus of experts of more than 75% expert agreed. For the third rule, the average fuzzy score (A) for all elements is 0.5 and above. Results indicated the highest consensus of the experts is usability (94%), followed by navigation, a touch gesture, andragogy, and scaffolding, where these four elements' percentages are (93%), content (90%), and the last layout (85%). The finding shows that the seven (Figure 3) proposed elements are essential to be applied in the mobile learning design model for adult learners.

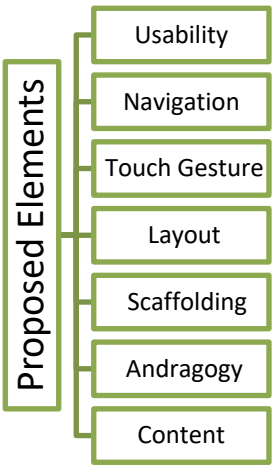

Fig. 3. Proposed elements for the model of mobile learning for adult learners

5. Conclusions

M-learning enables students to access learning materials anytime and from any location. Besides that, M-learning also can foster continuous learning among adult learners. Overall, this study results show that the proposed elements fulfilled the primary, second and third rules with the threshold score (d) ≤ 0.2, the percentage consensus of experts of more than 75% expert agreed and the average fuzzy score (A) for all elements is 0.5 and above. This study's findings indicated the expert's view on the main elements of a model for adult learners. The model design is based on an analysis of existing guidelines and models. Based on the consensus of expert opinion, seven elements (usability, navigation, touch gesture, andragogy, scaffolding, content, and layout) are important to be applied within the mobile learning model for adult learners to enhance their learning experience.

The limitation of this study is the number of respondents who participated was small. Therefore, it is recommended to extend this study by using more respondents to determine the generalized extent of these findings. For further study, these seven elements will be mapped into the mobile application to do the usability test.

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