ISSN 2090-3359 (Print)
ISSN 2090-3367 (Online)

Advances in Decision Sciences

Volume 27
Issue 2
June 2023

亞洲大學
ASIA UNIVERSITY

Published by Asia University, Taiwan

Impact of Factors on Students' E-Learning Outcomes: Evidence from Pedagogical Universities in Vietnam with Applications in Decision Sciences

Vu Thi Ngoc Tu*
Hanoi National University of Education, 136 Xuan Thuy Road, Hanoi 100000, Vietnam
***Corresponding author:** Email: Ngoctu304@yahoo.com.vn

Vu Thai Giang
Hanoi National University of Education, 136 Xuan Thuy Road, Hanoi 100000, Vietnam
Email: giangvt@hnue.edu.vn

Hoang Anh Phuoc
Hanoi National University of Education, 136 Xuan Thuy Road, Hanoi 100000, Vietnam
Email: phuocsp@gmail.com

Nguyen Thi Hai Thien
Hanoi National University of Education, 136 Xuan Thuy Road, Hanoi 100000, Vietnam
Email: nguyenhaithien.edu@gmail.com

Tran Quoc Thanh
Hanoi National University of Education, 136 Xuan Thuy Road, Hanoi 100000, Vietnam
Email: thanhtq@hnue.edu.vn

Nguyen Thi Hue
Hanoi National University of Education, 136 Xuan Thuy Road, Hanoi 100000, Vietnam
Email: huenguyentlgd@gmail.com

Mai Quoc Khanh
Hanoi National University of Education, 136 Xuan Thuy Road, Hanoi 100000, Vietnam
Email: khanhmq@hnue.edu.vn

Luong Thi Thanh Hai
National University of Art Education, 18/55 Tran Phu Road, Hanoi 100000, Vietnam
Email: luongthithanhhai@spnttw.edu.vn

Received: January 16, 2023; First Revision: March 5, 2023;

Last Revision: May 26, 2023; Accepted: June 21, 2023;

Published: June 30, 2023

Abstract

Purpose: In the modern era of technology, Decision Science plays a crucial role across various domains, including Education. As educational practices adapt to the challenges posed by the fourth industrial revolution and the Covid-19 pandemic, e-learning has emerged as a superior approach, as evident from numerous studies conducted across Europe and Asia, this study utilizes a widely recognized decision-making model to define the priority of the factors affecting the students' e-learning outcomes at Pedagogical Universities in Vietnam.

Design/methodology/approach: The fuzzy analytic hierarchy process (AHP) approach, one of the most widely used multi-criteria decision-making approaches, is applied in this study. The study points out the limitations of Chang's (1996) fuzzy AHP approach and conducts a more comparative analysis by using the approach proposed by Hue et al. (2022). To do so, this study collects the data via in-depth interviews with lecturers and managers at Pedagogical Universities in Vietnam.

Findings: The findings in this study demonstrate that the dimensions of both "lecturers" and "students" have the most significant impact on students' e-learning outcomes at Pedagogical Universities in Vietnam, followed by system and technology, as well as course design and content. Specifically, within the lecturer dimension, Information, and communication technology skills (L2) and easy language communication (L3) play crucial roles and exert the strongest influence on students' e-learning outcomes. Conversely, within the student dimension, the most influential factors are students' motivation (S2) and self-learning ability (S6). Informed by Decision Science, a set of recommendations can be suggested for pedagogical universities aiming to enhance students' e-learning outcomes: (i) strengthen training and development programs for both lecturers and students, focusing on technology-related skills and effective teaching and learning methods; (ii) implement policies that incentivize lecturers and teachers to adopt innovative and positive teaching methods; (iii) develop blended learning models, invest in suitable equipment, and establish policies that encourage the creation of digital teaching materials; (iv) establish a clear roadmap and strategy for investing in equipment and online teaching infrastructure; (v) provide students with techniques to maintain focus, knowledge on maintaining a healthy balance during online learning, and self-learning abilities; (vi) carefully select appropriate courses to maximize the effectiveness of online learning, with a focus on theoretical subjects that require less practical or in-class calculation; and (vii) meticulously choose software that meets the specific requirements of each course and aligns with the existing educational infrastructure.

Originality/value: This study compares Chang's (1996) and Hue et al.'s (2022) fuzzy AHP approaches to determine the critical factors impacting students' e-learning outcomes in pedagogical universities in Vietnam. Four dimensions were considered: lecturer; students; course design and content; and system and technology. As far as we know, this study is the first paper to obtain the above-mentioned results in the literature.

Keywords: Decision Science in education, Fuzzy AHP, Generalized fuzzy numbers, E-Learning, Pedagogical Universities

JEL classification: D81, I23

1. Introduction

In today's digital age, Decision Science plays a vital role in the field of education. Among the educational trends that have emerged in response to the fourth industrial revolution and the Covid-19 pandemic, e-learning has gained widespread adoption in educational institutions across the globe. E-learning is a method of learning and teaching using modern technology devices and involving an internet connection. Compared with traditional learning methods, e-learning is not limited in time and place and can convey a wide range of information through many convenient means, helping learners to acquire knowledge and skills more flexibly (Alhabeeb and Rowley, 2018). Furthermore, online learning offers the opportunity to share information, is a cost-effective solution, promotes interaction, and leverages technology integration to create an optimal learning environment (Naveed et al., 2020).

Several previous studies have demonstrated the benefits of the e-learning approach in enhancing student engagement and learning experience. These studies have indicated that e-learning positively influences students' perception of teaching methods and learning platforms (Huy et al., 2023). By emphasizing both learning and teaching, e-learning provides opportunities for increased student participation, enthusiasm, and ultimately, improved persistence and commitment (Ismail et al., 2018). Universities possess several characteristics that make them conducive to the implementation of e-learning, including students' proficiency in information technology, highly qualified lecturers, and convenient access to technology. Numerous studies have examined the factors that influence students' e-learning outcomes. These factors can be categorized into four dimensions: lecturers, students, course design and content, and system and technology. Various approaches, such as multivariate regression analysis, structural equation modeling, and hierarchical analysis methods, have been proposed and employed to identify the critical success factors of e-learning.

Recent studies have utilized the Unified Theory of Acceptance and Use of Technology (UTAUT2) model developed by Venkatesh et al. (2003) to assess the factors that impact the successful implementation of e-learning in higher education. However, it is crucial to recognize that implementing e-learning goes beyond online teaching (Huy et al., 2023; Abbasi et al., 2020; Naveed et al., 2020). Therefore, understanding the influence and role of students, lecturers, and systems and technology is crucial for ensuring the successful adoption of e-learning in higher education. An examination of the existing literature reveals a scarcity of comprehensive studies that systematically investigate the factors influencing the effectiveness of students' e-learning outcomes, encompassing aspects such as lecturers, students, course design and content, as well as system and technology (Sari and Nayir, 2020; Baber, 2020; Naveed et al., 2020; Das and Meredith, 2021). Furthermore, a lack of research explores the prioritization of these influencing factors regarding the effectiveness of students' e-learning activities, particularly within the context of pedagogical universities in Vietnam.

Currently, the fuzzy analytic hierarchy process (AHP) approach, initially proposed by Chang (1996), is one of the most widely techniques to solve multi-criteria decision-making problems. The fuzzy AHP is frequently utilized to determine factor impacts or criterion weights in uncertain information environments. Previous research has utilized fuzzy AHP to identify critical success factors in online learning. For example, Bhuasiri et al. (2012) employed the Delphi method and AHP approach to identify factors that influence the acceptance of e-learning systems in developing countries. Alqahtani and Rajkhan (2020) utilized AHP and

TOPSIS techniques to identify critical success factors for E-learning during COVID-19. Naveed et al. (2020) utilized both AHP and fuzzy AHP to examine factors from various dimensions of web-based e-learning systems. Other studies have also used fuzzy AHP, such as Kien et al. (2018) and Merhi (2021). Specifically, Kien et al. (2018) used AHP and fuzzy AHP to evaluate outsourcing services in East and Southeast Asia, while Merhi (2021) used AHP to assess the critical success factors affecting the implementation of data intelligence in the public sector. Nevertheless, some studies have criticized Chang's (1996) fuzzy AHP approach, which may lead to the irrational weighting of decision criteria and sub-criteria, resulting in incorrect decision-making (Wang et al., 2008; Hue et al., 2022). As a response, Hue et al. (2022) proposed a revised generalized fuzzy AHP approach that uses the centroid index to address Chang's (1996) limitations. Despite this, no research has applied Hue et al.'s (2022) approach to prioritize factors influencing students' e-learning outcomes, particularly in the context of pedagogical universities.

In Vietnam, there are 14 pedagogical universities and 52 universities with pedagogical training departments. The largest pedagogical universities in Vietnam include Hanoi National University of Education, Ho Chi Minh City University of Education, Hue University of Education, Danang University of Education, and Ho Chi Minh City University of Technology and Education. Pedagogical universities hold a particularly important position, as places to train the country's future teachers and lecturers. During the Covid epidemic period, universities in Vietnam in general and pedagogical universities, in particular, have adapted to promote online learning using teaching software such as "Zoom Cloud Meetings", "Microsoft Teams", and "Google Classroom". To enhance the quality of future online learning activities, it is essential to identify the factors that influence the e-learning outcomes of pedagogical students. Therefore, in this study, the shortcomings of Chang's (1996) fuzzy AHP approach are identified and compared with the approach proposed by Hue et al. (2022). Subsequently, both Chang's (1996) and Hue et al.'s (2022) fuzzy AHP approaches are utilized to prioritize the factors that influence students' e-learning outcomes within the context of pedagogical universities in Vietnam.

2. Literature review on the factors impacting students' online learning outcomes

2.1. Lecturers' dimension

The role of lecturers in determining the online learning outcomes of university students has been widely acknowledged (Abbasi et al., 2020). Lecturers are expected to facilitate learning by imparting knowledge, motivating students, and helping them solve problems while reducing academic dishonesty (Campbell and Campbell, 1997; Chirikov et al., 2020; Alqahtani and Rajkhan, 2020). In the context of online learning, the role of lecturers becomes even more crucial as they need to provide detailed explanations and documentation to help students avoid confusion and improve learning (Mishra et al., 2020). The attitudes and willingness of lecturers to support students also significantly impact the quality of students' learning (Pittenger and Doering, 2010; Naveed et al., 2020). However, some lecturers view online learning negatively (Shieh, 2009) and are hesitant to take online courses due to concerns about the format's quality of instruction and student interaction (Ward et al., 2010), which can impede the large-scale implementation of online courses by universities (Allen and Seaman, 2006). It has been suggested that timely feedback from lecturers is also an important factor that affects student learning outcomes (Naveed et al., 2020). Furthermore, the lecturers' knowledge of computer systems and e-learning software plays a significant role in determining the effectiveness of online teaching (Mukhtar et al., 2020; Alqahtani and Rajkhan, 2020).

2.2. Students’ dimension

Student-related factors are widely acknowledged to play a significant role in determining online learning outcomes for university students. Specifically, attributes such as proactivity, self-learning ability, and a strong sense of discipline have been identified as important prerequisites for achieving success in online learning environments (Pham et al., 2021). In addition, good interactions between students, lecturers, and classmates contribute to ensuring the effectiveness of online learning (Noesgaard and Ørngreen, 2015; Shih et al., 2018). Students' motivation and attitude to online learning, commitment to learning, and knowledge of computer systems also contribute to improving student learning outcomes (Naveed et al., 2020; Alqahtani and Rajkhan, 2020).

2.3. Course Design and Content Dimension

One of the critical determinants of the quality of students' online learning is the design and content dimension of the course. The content of e-learning includes “the structure, and the content of the chapters of the study material and additional references” (Akyüz et al., 2009). For countries and institutions with little experience in providing online courses, course structure plays an important role in helping to overcome difficulties in students’ transition to online learning (Abbasi et al., 2020; Baber, 2020). The course should have a simple, user-friendly interface; Clear, attractive course content will contribute to increasing students' concentration and initiative (Naveed et al., 2020). The course should also have good design and content, which is reflected in aspects such as “interactive learning activities”, “appropriate design”, “use of multimedia instruction”, and “easy-to-understand content” (Sun et al., 2008; Ozkan and Koseler, 2009; Fresen, 2011; Naveed et al., 2020).

2.4. System and technology dimension

The system and technology dimension includes the factors that determine the quality of information transmitted between lecturers and students. The quality of systems and technologies relates to websites or software through which faculty and students can easily upload or access teaching and learning materials for different courses (Chopra et al., 2009). Das and Meredith (2021) have suggested that “digital devices with available internet connectivity are the basic requirements for online education”. Innovative system design with appropriate technologies enables rapid use of devices (Malik, 2010). To enhance the quality of online learning, certain universities have provided laptops, smartphones, and Wi-Fi connections to both faculty and students in specific cases (Sari and Nayir, 2020). Naveed et al. (2020) synthesized the factors determining the quality of online learning technology and systems such as: “appropriate systems”, “ease of access”, “technical support for users”, “good internet speed”, “efficient technology infrastructure”, and “reliability”.

3. Methodology

3.1. Chang's fuzzy AHP

This section presents the fuzzy AHP approach proposed by Chang (1996), as follows:

Step 1: Determining the comparison matrix

$$\tilde{£} = (\tilde{\Phi}_{\chi\varphi})_{\varepsilon \times \varepsilon} = \begin{bmatrix} (1,1,1) & (\tilde{\upsilon}_{12}, \tilde{\rho}_{12}, \tilde{\lambda}_{12}) & \cdots & (\tilde{\upsilon}_{1\varepsilon}, \tilde{\rho}_{1\varepsilon}, \tilde{\lambda}_{1\varepsilon}) \\ (\tilde{\upsilon}_{21}, \tilde{\rho}_{21}, \tilde{\lambda}_{21}) & (1,1,1) & \cdots & (\tilde{\upsilon}_{2\varepsilon}, \tilde{\rho}_{2\varepsilon}, \tilde{\lambda}_{2\varepsilon}) \\ \vdots & \vdots & \vdots & \vdots \\ (\tilde{\upsilon}_{\varepsilon 1}, \tilde{\rho}_{\varepsilon 1}, \tilde{\lambda}_{\varepsilon 1}) & (\tilde{\upsilon}_{\varepsilon 2}, \tilde{\rho}_{\varepsilon 2}, \tilde{\lambda}_{\varepsilon 2}) & \cdots & (1,1,1) \end{bmatrix},$$

where $\tilde{\Phi}_{\chi\varphi} = (\tilde{\upsilon}_{\chi\varphi}, \tilde{\rho}_{\chi\varphi}, \tilde{\lambda}_{\chi\varphi})$, $\tilde{\Phi}^{-1}_{\chi\varphi} = (1/\tilde{\lambda}_{\chi\varphi}, 1/\tilde{\rho}_{\chi\varphi}, 1/\tilde{\upsilon}_{\chi\varphi})$ for $\chi, \varphi = 1, \ldots, \varepsilon$ when $\chi \neq \varphi$.

Step 2: Calculating the values of the fuzzy synthetic extents

The fuzzy synthetic extents (FSEs) of $\tilde{\Phi}_{\chi\varphi} = (\tilde{\upsilon}_{\chi\varphi}, \tilde{\rho}_{\chi\varphi}, \tilde{\lambda}_{\chi\varphi})$ is calculated by:

$$\hat{¥} = \left(\frac{\sum_{\nu=1}^{\varepsilon} \tilde{\upsilon}_{\chi\varphi}}{\sum_{\chi=1}^{\varepsilon} \sum_{\varphi=1}^{\varepsilon} \tilde{\lambda}_{\chi\varphi}}, \frac{\sum_{\nu=1}^{\varepsilon} \tilde{\rho}_{\chi\varphi}}{\sum_{\chi=1}^{\varepsilon} \sum_{\varphi=1}^{\varepsilon} \tilde{\rho}_{\chi\varphi}}, \frac{\sum_{\nu=1}^{\varepsilon} \tilde{\lambda}_{\chi\varphi}}{\sum_{\chi=1}^{\varepsilon} \sum_{\varphi=1}^{\varepsilon} \tilde{\upsilon}_{\chi\varphi}} \right), \ \chi, \varphi = 1, 2, \ldots \varepsilon. \quad (1)$$

Step 3: Determining the degree of possibility of fuzzy numbers

The degree of possibility of $\tilde{\Phi}_1 = (\tilde{\upsilon}_1, \tilde{\rho}_1, \tilde{\lambda}_1)$ and $\tilde{\Phi}_2 = (\tilde{\upsilon}_2, \tilde{\rho}_2, \tilde{\lambda}_2)$ can be defined as:

$$V(\tilde{\Phi}_1 \geq \tilde{\Phi}_2) = \sup_{x_1 \geq x_2} \left[\min(\mu_{\tilde{\Phi}_1}(x_1), \mu_{\tilde{\Phi}_2}(x_2)) \right]. \quad (2)$$

$$V(\tilde{\Phi}_1 \geq \tilde{\Phi}_2) = hgt(\tilde{\Phi}_1 \cap \tilde{\Phi}_2) = \begin{cases} 1 & \text{if } \tilde{\rho}_1 \geq \tilde{\rho}_2 \\ 0 & \text{if } \tilde{\upsilon}_1 \geq \tilde{\lambda}_2 \\ \dfrac{\tilde{\upsilon}_1 - \tilde{\lambda}_2}{(\tilde{\rho}_2 - \tilde{\lambda}_2) - (\tilde{\rho}_1 - \tilde{\lambda}_1)} & \text{otherwise} \end{cases}. \quad (3)$$

Then, $d(\hat{\Upsilon}_\alpha) = V(\breve{\Phi} \geq \breve{\Phi}_1, \breve{\Phi}_2, \ldots, \breve{\Phi}_{\varepsilon-1}) = \min V(\breve{\Phi} \geq \breve{\Phi}_{\varepsilon-1})$ for $\alpha = 1, 2, \ldots, \varepsilon - 1$. (4)

Step 4: Defining the weight vector:

The weight vector is represented by $W' = \left(d'(\hat{\Upsilon}_1), d'(\Upsilon_2), \ldots, d'(\hat{\Upsilon}_\varepsilon) \right)^T$, (5)

where $\hat{\Upsilon}_\alpha (\alpha = 1, 2, \ldots, \varepsilon)$ are ε elements .

The normalized weight vector is defined as:

$$\hat{\Omega} = \left(d(\breve{\Psi}_1), d(\breve{\Psi}_2), \ldots, d(\breve{\Psi}_{\varepsilon}) \right)^T \quad . \tag{6}$$

3.2. The revised generalized fuzzy AHP approach with centroid index

In this section, we begin by highlighting the shortcomings of Chang's approach, as demonstrated by Examples 1 and 2. Subsequently, we introduce Hue et al.'s generalized fuzzy AHP method, which incorporates the centroid index.

Example 1. Assuming that a company intends to establish a priority vector of criteria for selecting suppliers, four main factors have been identified for evaluating the suppliers including Price policy (C1), product quality (C2), on-time delivery (C3), and financial stability (C4). Table 1 presents the fuzzy comparison matrix for the four criteria evaluated by decision-makers. Using Chang's approach, the weight vector for the four criteria is calculated as W = (1, 0, 0, 0.28), indicating that C2 and C3 are given a weight of zero and thus excluded from the decision analysis process.

Table 1. The priority vector obtained through Chang's approach

Criteria	**C1**	**C2**	**C3**	**C4**	**Chang's approach**	
					FSEs	**Priority vector**
C1	(1.00, 1.00, 1.00)	(2.00, 3.00, 4.00)	(3.00, 4.00, 5.00)	(3.00, 4.00, 5.00)	(0.31, 0.53, 0.87)	1
C2	(0.25, 0.33, 0.50)	(1.00, 1.00, 1.00)	(1.00, 1.00, 1.00)	(0.33, 0.50, 1.00)	(0.09, 0.12, 0.20)	0
C3	(0.20, 0.25, 0.33)	(1.00, 1.00, 1.00)	(1.00, 1.00, 1.00)	(0.33, 0.50, 1.00)	(0.09, 0.12, 0.19)	0
C4	(0.20, 0.25, 0.33)	(1.00, 2.00, 3.00)	(1.00, 2.00, 3.00)	(1.00, 1.00, 1.00)	(0.11, 0.23, 0.42)	0.28

Example 2. Consider two fuzzy numbers, denoted by $\tilde{A}_1 = (4,5,12)$ and $\tilde{A}_2 = (1,5,6)$. Applying Hue et al.'s approach, we obtain the relative importance values of 0.63 and 0.37 for and $\tilde{A}_2$, respectively, which implies that $\tilde{A}_1 \succ \tilde{A}_2$. It is worth noting that Chang's approach yields a priority value that is deemed unreasonable and inconsistent with human intuition.

To overcome the shortcoming of Chang's (1996) fuzzy AHP approach, Hue et al. (2022) presented a revised generalized fuzzy AHP approach using the centroid index as the following:

Step 1: Determining the comparison matrix of GTrFNs

$$CM = (\tilde{f}_{uv})_{t \times t} = \begin{bmatrix} (1,1,1,1;1) & (\tilde{g}_{12}, \tilde{h}_{12}, \tilde{k}_{12}, \tilde{l}_{12}; \tilde{w}_{12}) & \cdots & (\tilde{g}_{1t}, \tilde{h}_{1t}, \tilde{k}_{1t}, \tilde{l}_{1t}; \tilde{w}_{1t}) \\ (\tilde{g}_{21}, \tilde{h}_{21}, \tilde{k}_{21}, \tilde{l}_{21}; \tilde{w}_{21}) & (1,1,1,1;1) & \cdots & (\tilde{g}_{2t}, \tilde{h}_{2t}, \tilde{k}_{2t}, \tilde{l}_{2t}; \tilde{w}_{2t}) \\ \vdots & \vdots & \vdots & \vdots \\ (\tilde{g}_{t1}, \tilde{h}_{t1}, \tilde{k}_{t1}, \tilde{l}_{t1}; \tilde{w}_{t1}) & (\tilde{g}_{t2}, \tilde{h}_{t2}, \tilde{k}_{t2}, \tilde{l}_{t2}; \tilde{w}_{t2}) & \cdots & (1,1,1,1;1) \end{bmatrix}, \tag{7}$$

where $\tilde{f}_{uv} = (\tilde{g}_{uv}, \tilde{h}_{uv}, \tilde{k}_{uv}, \tilde{l}_{uv}; \tilde{w}_{uv})$ and $\tilde{f}_{uv}^{-1} = (1/\tilde{l}_{uv}, 1/\tilde{k}_{uv}, 1/\tilde{h}_{uv}, 1/\tilde{g}_{uv}; \tilde{w}_{uv})$ for $u, v = 1, \ldots, t$ and $u \neq v$.

Step 2: Calculating the values of the FSEs

The values of FSEs can be defined as follows:

$$\tilde{T}_u = \left(\tilde{l}_u, \tilde{m}_u, \tilde{u}_u, \tilde{v}_u; \min(\tilde{w}_{uv})\right)$$

$$= \left(\begin{array}{l} \dfrac{\sum_{v=1}^{n} \tilde{l}_{uv}}{\sum_{v=1}^{n} \tilde{l}_{uv} + \sum_{k=1,k\neq u}^{n} \sum_{v=1}^{n} \tilde{v}_{kv}}, \dfrac{\sum_{v=1}^{n} \tilde{m}_{uv}}{\sum_{v=1}^{n} \tilde{m}_{uv} + \sum_{u=1}^{n} \sum_{v=1}^{n} \tilde{u}_{kv}}, \\ \dfrac{\sum_{j=1}^{n} \tilde{u}_{uv}}{\sum_{v=1}^{n} \tilde{u}_{uv} + \sum_{k=1,k\neq u}^{n} \sum_{v=1}^{n} \tilde{m}_{kv}}, \dfrac{\sum_{j=1}^{n} v_{uv}}{\sum_{v=1}^{n} \tilde{v}_{uv} + \sum_{k=1,k\neq u}^{n} \sum_{v=1}^{n} \tilde{l}_{kv}}; \min(\tilde{w}_{uv}) \end{array} \right), \quad (8)$$

where $u, v = 1, 2, ..., n$

Step 3: Defining the weight vector of GTrFNs

The weight vector of GTrFNs is determined as follows:

$$\tilde{w}_u = \frac{D(C_u, M)}{\sum_{u=1}^{n} D(C_u, M)} = \frac{\sqrt{(\bar{\tilde{x}}_{\tilde{T}_u} - x_0)^2 + (\bar{\tilde{y}}_{\tilde{T}_u} - \frac{w}{3} y_0)^2}}{\sum_{u=1}^{n} \sqrt{(\bar{\tilde{x}}_{\tilde{T}_u} - x_0)^2 + (\bar{\tilde{y}}_{\tilde{T}_u} - \frac{w}{3} y_0)^2}}, \quad u = 1, \dots, n, \quad (9)$$

where $M = (x_0, y_0), x_0 = \min(\tilde{g}_u), y_0 = \min(\tilde{w}_{uv}),$ is the minimum point, $C_u = (\bar{\tilde{x}}_{\tilde{T}_u}, \bar{\tilde{y}}_{\tilde{T}_u})$ is the centroid point.

4. Application

This section compares Chang's (1996) and Hue et al.'s (2022) fuzzy AHP approaches to determine the critical factors impacting students' e-learning outcomes in pedagogical universities in Vietnam. A committee of three experienced decision makers (D1, D2, and D3), who are lecturers and managers at pedagogical universities in Vietnam, evaluated the critical factors that impact students' e-learning outcomes. The factors and sub-factors used in the study are presented in Table 1.

Table 1. Dimensions and critical factors impacting students' e-learning outcomes

No.	Dimensions	Critical factors	References
1	**System and technology (S&T)**	Appropriate System (S&T1)	Chopra et al., 2019; Naveed et al., 2020; Sari and Nayir, 2020; Das and Meredith, 2021
		Ease of Access (S&T2)	
		Good Internet Speed (S&T3)	
		Efficient Technology Infrastructure (S&T4)	
		Reliability (S&T5)	
2	**Lecturers (L)**	Attitude towards E-Learning (L1)	Pittenger and Doering, 2010; Naveed et al., 2020
		Information and Communication Technology Skills (L2)	
		Easy Language Communication (L3)	
		Appropriate Timely Feedback (L4)	
3	**Students (S)**	Proactivity towards E-Learning (S1)	Noesgaard and Ørngreen, 2015; Shih et al., 2018;
		Students' Motivation (S2)	

No.	Dimensions	Critical factors	References
		Effectiveness of the Internet (S3)	Naveed et al., 2020; Alqahtani and Rajkhan, 2020; Pham et al, 2021
		Interaction with Lecturer and other Students (S4)	
		Sense of Compliance (S5)	
		Self-learning Ability (S6)	
4	**Course design and content (CD&C)**	Use of Multimedia Instruction (CD&C1)	Sun et al., 2008; Fresen, 2011; Naveed et al., 2020
		Appropriate Course Design Structure and Interface (CD&C2)	
		Attractive Course Content (CD&C3)	
		Interactive Learning Activity (CD&C4)	

This study utilizes Table 2 to present the linguistic values and triangular fuzzy numbers. The committee members used the data from Table 1 to determine the priority level of the dimensions and factors that impact students' e-learning outcomes at Pedagogical universities in Vietnam.

Table 2. Intensity scale for generalized fuzzy AHP pairwise comparison

Order	Linguistic values	TFNs
1	Equal importance	(1,1,1)
2	Importance	(2,3,4)
3	Strong importance	(4,5,6)
4	Very strong importance	(6,7,8)
5	Absolute importance	(8,9,9)

To rank the priorities of four dimensions and nineteen factors, the committee applied Chang’s (1996) and Hue et al.’s (2022) fuzzy AHP approach. The averaged fuzzy comparison matrix of dimensions and factors assessed by the committee is presented in Tables 3-7.

Table 3. Averaged fuzzy comparison matrix of four dimensions

Dimensions	S&T	L	S	CD&C
S&T	(1.00, 1.00, 1.00)	(0.19, 0.24, 0.33)	(0.47, 0.51, 0.58)	(1.08, 1.44, 1.83)
L	(3.33, 4.33, 5.33)	(1.00, 1.00, 1.00)	(2.00, 2.33, 2.67)	(4.00, 5.00, 5.67)
S	(2.33, 3.00, 3.67)	(0.72, 0.73, 0.75)	(1.00, 1.00, 1.00)	(3.42, 4.11, 4.50)
CD&C	(1.08, 1.44, 1.83)	(0.20, 0.26, 0.38)	(0.79, 1.15, 1.54)	(1.00, 1.00, 1.00)

Table 4. Averaged fuzzy comparison matrix of five factors in relation to “System and technology (S&T)”

S&T	S&T1	S&T2	S&T3	S&T4	S&T5
S&T1	(1.00, 1.00, 1.00)	(2.33, 3.00, 3.67)	(1.39, 2.07, 2.75)	(2.33, 3.00, 3.67)	(2.00, 3.00, 4.00)
S&T2	(0.47, 0.51, 0.58)	(1.00, 1.00, 1.00)	(0.79, 1.15, 1.54)	(2.67, 3.67, 4.67)	(1.06, 1.40, 1.75)
S&T3	(1.50, 1.89, 2.33)	(3.42, 4.11, 4.50)	(1.00, 1.00, 1.00)	(3.06, 3.40, 3.42)	(3.33, 3.67, 3.67)
S&T4	(0.47, 0.51, 0.58)	(0.22, 0.29, 0.42)	(1.70, 2.04, 2.38)	(1.00, 1.00, 1.00)	(1.08, 1.44, 1.83)
S&T5	(0.25, 0.33, 0.50)	(1.75, 2.11, 2.50)	(0.70, 0.70, 0.71)	(1.08, 1.44, 1.83)	(1.00, 1.00, 1.00)

Table 5. Averaged fuzzy comparison matrix of for factors in relation to “Lecturers - (L)”

L	L1	L2	L3	L4
L1	(1.00, 1.00, 1.00)	(0.81, 1.18, 1.58)	(1.06, 1.40, 1.75)	(1.39, 2.07, 2.75)
L2	(2.08, 2.78, 3.50)	(1.00, 1.00, 1.00)	(0.50, 0.56, 0.67)	(4.33, 5.00, 5.33)
L3	(1.75, 2.11, 2.50)	(1.67, 2.33, 3.00)	(1.00, 1.00, 1.00)	(3.42, 4.11, 4.50)
L4	(1.50, 1.89, 2.33)	(0.43, 0.44, 0.46)	(0.79, 1.15, 1.54)	(1.00, 1.00, 1.00)

Table 6. Averaged fuzzy comparison matrix of six factors in relation to “Students (S)”

S	S1	S2	S3	S4	S5	S6
S1	(1.00, 1.00, 1.00)	(0.19, 0.24, 0.33)	(1.75, 2.11, 2.50)	(3.33, 4.33, 5.33)	(1.67, 2.33, 3.00)	(0.25, 0.33, 0.50)
S2	(3.33, 4.33, 5.33)	(1.00, 1.00, 1.00)	(5.33, 6.33, 7.00)	(5.39, 6.07, 6.08)	(3.39, 4.07, 4.75)	(2.00, 2.33, 2.67)
S3	(1.06, 1.40, 4.33)	(0.15, 0.17, 0.21)	(1.00, 1.00, 1.00)	(1.08, 1.44, 1.83)	(0.50, 0.56, 0.67)	(0.20, 0.26, 0.38)
S4	(0.19, 0.24, 0.33)	(1.41, 1.74, 2.08)	(1.08, 1.44, 1.83)	(1.00, 1.00, 1.00)	(2.42, 2.78, 3.17)	(0.75, 1.08, 1.43)
S5	(0.50, 0.56, 0.67)	(1.43, 1.78, 2.14)	(1.67, 2.33, 3.00)	(1.04, 1.38, 1.72)	(1.00, 1.00, 1.00)	(1.46, 1.83, 2.22)
S6	(2.00, 3.00, 4.00)	(0.72, 0.73, 0.75)	(4.00, 5.00, 5.67)	(4.75, 5.44, 5.83)	(2.72, 3.40, 4.08)	(1.00, 1.00, 1.00)

Table 7. Averaged fuzzy comparison matrix of for factors in relation to “Course design and content (CD&C)”

CD&C	CD&C1	CD&C2	CD&C3	CD&C4
CD&C1	(1.00, 1.00, 1.00)	(0.50, 0.56, 0.67)	(0.22, 0.29, 0.42)	(1.67, 2.33, 3.00)
CD&C2	(1.67, 2.33, 3.00)	(1.00, 1.00, 1.00)	(0.50, 0.56, 0.67)	(3.33, 4.33, 5.33)
CD&C3	(2.67, 3.67, 4.67)	(1.67, 2.33, 3.00)	(1.00, 1.00, 1.00)	(5.33, 6.33, 7.33)
CD&C4	(0.50, 0.56, 0.67)	(0.21, 0.27, 0.39)	(0.14, 0.16, 0.19)	(1.00, 1.00, 1.00)

By using Chang's (1996) and Hue et al.'s (2022) approach and referring to Tables 3-7, the fuzzy synthetic extent values of dimensions and factors were calculated. Table 8 indicates that there was a slight difference in the results obtained using Chang's (1996) and Hue et al.'s (2022) approach.

Table 8. Fuzzy synthetic extent values of dimensions and factors

Dimensions	FSEs		Factors	FSEs	
	Chang's (1996) approach	Hue et al.'s (2022) approach		Chang's (1996) approach	Hue et al.'s (2022) approach
S&T	(0.08, 0.11, 0.16)	(0.09, 0.11, 0.15)	**S&T1**	(0.17, 0.27, 0.41)	(0.20, 0.27, 0.35)
			S&T2	(0.11, 0.17, 0.26)	(0.12, 0.17, 0.24)
			S&T3	(0.24, 0.31, 0.41)	(0.25, 0.31, 0.38)
			S&T4	(0.09, 0.12, 0.17)	(0.09, 0.12, 0.16)
			S&T5	(0.09, 0.13, 0.18)	(0.09, 0.13, 0.17)
L	(0.31, 0.44, 0.62)	(0.36, 0.44, 0.52)	**L1**	(0.13, 0.19, 0.30)	(0.14, 0.19, 0.27)
			L2	(0.23, 0.32, 0.44)	(0.25, 0.32, 0.40)
			L3	(0.23, 0.33, 0.46)	(0.25, 0.33, 0.41)
			L4	(0.11, 0.15, 0.22)	(0.11, 0.15, 0.21)
S	(0.23, 0.31, 0.42)	(0.24, 0.31, 0.38)	**S1**	(0.09, 0.14, 0.21)	(0.10, 0.14, 0.19)
			S2	(0.23, 0.32, 0.43)	(0.24, 0.32, 0.39)
			S3	(0.04, 0.06, 0.14)	(0.05, 0.06, 0.13)
			S4	(0.08, 0.11, 0.16)	(0.08, 0.11, 0.15)
			S5	(0.08, 0.12, 0.17)	(0.08, 0.12, 0.16)
			S6	(0.17, 0.25, 0.35)	(0.18, 0.25, 0.31)
CD&C	(0.09, 0.13, 0.20)	(0.10, 0.13, 0.19)	**CD&C1**	(0.10, 0.15, 0.23)	(0.11, 0.15, 0.21)
			CD&C2	(0.20, 0.30, 0.45)	(0.22, 0.30, 0.39)
			CD&C3	(0.32, 0.48, 0.71)	(0.38, 0.48, 0.58)
			CD&C4	(0.06, 0.07, 0.10)	(0.06, 0.07, 0.10)

Using Chang's and Hue et al.'s approach, the weight vectors of the dimensions and factors impacting the students' e-learning outcomes are shown in Table 9. The result indicates that Chang's (1996) approach gave zero weights to some dimensions and factors. Hue et al.'s (2022) approach can overcome the shortcomings of Chang's (1996) approach. Table 9 also shows that "lecturers" and "students" are the most important dimensions impacting students' e-learning outcomes at Pedagogical Universities in Vietnam. Specifically, in terms of the lecturer dimension, Information and Communication Technology (ICT) skills (L2) and Easy Language Communication (L3) play crucial roles and have the strongest impact on students' e-learning outcomes. On the other hand, for the student dimension, the strongest influencing factors are Students' Motivation (S2) and Self-learning ability (S6). The reality at pedagogical universities in Vietnam indicates that the proportion of lecturers with Ph.D. degrees is still relatively low (around 40% in 2019-2020). Moreover, many lecturers lack genuine interest in teaching online due to the additional time required for lesson preparation and limitations in technological capabilities. Additionally, lecturers' expertise and professionalism vary across fields of study and between universities in different regions. There are limitations in the abilities of lecturers, particularly in foreign languages, information technology, and innovative teaching methods. The absence of leading experts and highly skilled lecturers is a notable issue. Lecturers at pedagogical universities receive training and professional development in pedagogical knowledge, teaching experience, and skills. However, sufficient training in online teaching methods and information technology skills must be provided. It is worth emphasizing that the deficiency in information technology skills directly hampers creativity in instructional design and innovation in teaching methods for lecturers.

To enhance students' e-learning outcomes, pedagogical universities should implement several measures shortly. Firstly, they should strengthen training and development programs for lecturers and students, focusing on technology-related skills and effective teaching and learning methods. Regular training sessions should be conducted to improve lecturers' proficiency in utilizing online platforms and tools, including inviting experts to share their knowledge and conducting workshops. In addition, pedagogical universities should introduce policies that incentivize lecturers and teachers to adopt innovative and positive teaching methods. Organizing competitions for outstanding lesson plans or innovative teaching approaches can motivate lecturers and promote optimal teaching methods. Providing regular guidance and support to lecturers in their teaching activities is also essential. To stay up-to-date with the latest trends and approaches in educational science, pedagogical universities should organize seminars, training courses, and conferences. These platforms will facilitate knowledge sharing and enable lecturers to remain informed about advancements in e-learning.

Furthermore, to promote e-learning, pedagogical universities must develop blended learning models, invest in suitable equipment, and establish policies that encourage the creation of digital teaching materials. Specifically, they should invest in the technical infrastructure of classrooms, provide additional equipment such as headphones and microphones, and allocate dedicated technical support staff. This will not only facilitate effective coordination and management of students during classes but also expand the integration of information technology throughout the entire training process. Considering the limited financial resources, pedagogical universities need a clear roadmap and strategy for investing in equipment and online teaching infrastructure. Establishing a dedicated technical support team to assist lecturers and students in resolving technical issues during the learning process is crucial. Detailed guidelines on organizing online classes and specific training tailored to each lecturer's needs should be provided. It is also important to develop specific plans for different subjects. Regular monitoring and supervision of online teaching activities should be implemented to promptly identify and address any issues that may arise.

However, based on the specific characteristics of each region, pedagogical universities must be flexible in selecting the most suitable form of organizing classes. Additionally, it is necessary to investigate and assess students' capacity to meet online learning requirements, including their access to learning equipment. Providing students with techniques for maintaining focus, knowledge on maintaining a healthy balance during online learning, and self-learning abilities is crucial. Furthermore, pedagogical universities should carefully select appropriate courses to maximize the effectiveness of online learning, with a focus on theoretical subjects that require less practical or in-class calculation. There are numerous software tools available to support online teaching. Therefore, pedagogical universities must meticulously choose software that fulfills the specific requirements of each course and aligns with their existing educational infrastructure. Each software has its advantages and disadvantages that should be considered to make the most appropriate choice. To ensure high effectiveness in online teaching, pedagogical universities should provide training for both students and lecturers to familiarize them with the software before officially commencing the teaching program.

Lecturers, in addition to the knowledge provided through training programs by pedagogical universities, must also acquire information technology application skills and become familiar with software tools. In areas with limited network conditions, lecturers must find effective ways to deliver assignments and transmit knowledge to students. To create an engaging classroom environment, lecturers should establish a comfortable atmosphere and encourage student participation in lesson development. Lecturers should be delivered friendly and meticulously, avoiding creating pressure or diminishing students' interest in learning.

The findings of this study align with those of previous research indicating that both lecturers and students have significant impacts on students' e-learning outcomes (Abbasi et al., 2020; Pham et al., 2021). Notably, in response to the Covid pandemic, pedagogical universities in Vietnam have provided training courses to help lecturers and students become familiar with online learning software.

Table 9. Weight vector of dimensions and factors impacting students' e-learning outcomes

Dimensions	**Weight scores**		**Factors**	**Weight scores**	
	Chang's (1996) approach	**Hue et al.'s (2022) approach**		**Chang's (1996) approach**	**Hue et al.'s (2022) approach**
S&T	**0.00**	0.12	**S&T1**	0.41	0.27
			S&T2	0.08	0.18
			S&T3	0.51	0.31
			S&T4	**0.00**	0.12
			S&T5	**0.00**	0.13
L	0.69	0.44	**L1**	0.15	0.20
			L2	0.42	**0.32**
			L3	0.43	**0.33**
			L4	**0.00**	0.16
S	0.31	0.31	**S1**	**0.00**	0.14
			S2	1.00	**0.32**
			S3	**0.00**	0.08
			S4	**0.00**	0.11
			S5	**0.00**	0.12
			S6	**0.00**	**0.25**
CD&C	**0.00**	0.14	**CD&C1**	**0.00**	0.16
			CD&C2	0.29	0.30
			CD&C3	0.71	0.48
			CD&C4	**0.00**	0.08

5. Conclusion

As technology continues to advance, e-learning has become increasingly important in facilitating information sharing, enhancing interaction, and creating conducive learning environments. To explore the issue. there have been some studies examining the factors that affect students' online learning outcomes. However, it seems that there is no study evaluating the impact of the factors that affect students' online learning outcomes at pedagogical universities in Vietnam, which is where future teachers of the country are trained. To bridge the gap in the literature, this study employed the fuzzy AHP approach, which is a widely adopted method for multi-criteria decision-making to extend the issue. To do so, the research overcomes the limitations of Chang's (1996) fuzzy AHP approach and applies a more comparative analysis by using the approach proposed by Hue et al. (2022) to examine the issue further. Moreover, an application in the real case of pedagogical universities in Vietnam was undertaken. By using this approach, this study considered 04 dimensions and 19 factors including system and technology (05 factors), lecturers (04 factors), students (06 factors), course design, and content (04 factors), and obtain the results that indicated "lecturers" and "students" are the most important dimensions impacting students' e-learning outcomes at Pedagogical Universities in Vietnam.

From the standpoint of Decision Science, the research further illustrates that e-learning has been demonstrated to be an effective instructional approach during the era of rapid advancements in science, technology, and digital transformation. Moreover, drawing from Decision Science principles, a range of recommendations have been put forward for pedagogical universities, including the following: (i) strengthen training and development programs for lecturers and students, focusing on technology-related skills and effective teaching and learning methods; (ii) implement policies encouraging lecturers and teachers to adopt innovative and positive teaching methods; (iii) develop blended learning models, invest in suitable equipment, and establish policies that promote the creation of digital teaching materials; (iv) establish a clear roadmap and strategy for investing in equipment and online teaching infrastructure; (v) provide students with techniques to maintain focus, knowledge on achieving a healthy balance during online learning, and self-learning abilities; (vi) thoughtfully select appropriate courses that maximize the effectiveness of online learning, emphasizing theoretical subjects that require less practical or in-class calculation; and (vii) carefully choose software that meets the specific requirements of each course and aligns with the existing educational infrastructure. This study also recommended that lecturers acquire information technology application skills and familiarize themselves with software tools. They should also find effective methods for delivering assignments and transmitting knowledge to students. Creating an engaging classroom environment involves establishing a comfortable atmosphere and encouraging student participation in lesson development. Lecturers should provide instruction in a friendly and meticulous manner, avoiding unnecessary pressure or diminishing students' interest in learning. This study also showed that the results obtained by using Hue et al.'s (2022) approach are more consistent than those obtained by using Chang's (1996) approach. Though the scope of this study is confined to pedagogy universities, future research could broaden the scope to encompass other types of universities. Furthermore, the AHP method is utilized in this study to evaluate the factors influencing students' online learning outcomes. Alternatively, other studies could use more advanced statistical analysis methods to investigate the impact of these factors further.

Acknowledgments

This research is funded by a ministerial project under grant number B2021- SPH - 07.

References

Alhabeeb A. and Rowley J (2018). E-learning critical success factors: Comparing perspectives from academic staff and students. *Computers & Education*, 127, 1-12. https://doi.org/10.1016/j.compedu.2018.08.007

Abbasi S., Ayoob T., Malik A., and Memon S. I (2020). Perceptions of students regarding E-learning during Covid-19 at a private medical college. *Pakistan Journal of Medical Sciences*, 36:S57. https://doi.org/10.12669/pjms.36.COVID19-S4.2766

Alqahtani A. Y., and Rajkhan A. A. (2020). E-Learning Critical Success Factors during the COVID-19 Pandemic: A Comprehensive Analysis of E-Learning Managerial Perspectives. *Education Sciences*, 10(9), 216. https://doi.org/10.3390/educsci10090216

Allen I. E., and Seaman J. *Growing by Degrees: Online Education in the United States, 2005*. Wellesley, MA: Sloan Consortium (NJ1), 2006.

Akyüz H. İ., Aky¨uz, S. S. H. I., and Samsa, S. (2009). The effects of blended learning environment on the critical thinking skills of students. *Procedia - Social and Behavioral Sciences*, 1(1), 1744-1748. https://doi.org/10.1016/j.sbspro.2009.01.308

Baber H. (2020). Determinants of students' perceived learning outcome and satisfaction in online learning during the pandemic of COVID-19. *Journal of Education and E-Learning Research*, 7(3), 285-292. https:// 10.20448/journal.509.2020.73.285.292

Bhuasiri W, Xaymoungkhoun O, Zo H, Rho J. J., Ciganek A. P. (2012). Critical success factors for e-learning in developing countries: A comparative analysis between ICT experts and faculty. *Computers & Education*, 58, 843-855.

Campbell T. A., and Campbell D. E. (1997). Faculty/student mentor program: effects on academic performance and retention. *Research in Higher Education*, 38, 727-742. https://doi.org/10.1023/A:1024911904627

Chang D. Y (1996). Applications of the extent analysis method on fuzzy AHP. *European Journal of Operational Research*, 3, 649-655. https://doi.org/10.1016/0377-2217(95)00300-2

Chirikov I., Shmeleva E., and Loyalka P. (2020). The role of faculty in reducing academic dishonesty among engineering students. *Studies in Higher Education*, 45, 2464-2480. https://doi.org/10.1080/03075079.2019.1616169

Chopra G., Madan P., Jaisingh P., and Bhaskar P. (2019). Effectiveness of e-learning portal from students' perspective: A structural equation model (SEM) approach. *Interactive Technology and Smart Education*, 16(2), 94-116. https://doi.org/10.1108/ITSE-05-2018-0027

Das R., and Meredith D. P. (2021). Factors affecting effective online teaching transition in Asian universities during COVID-19. *Journal of University Teaching & Learning Practice*, 18(8), 1-16. https://doi.org/10.53761/ 1.18.8.8

Chen S. H. (1985). Operations on fuzzy numbers with function principle. *Tamkang Journal of Mathematics*, 6, 13-25.

Fresen J. W. (2011). Factors influencing lecturer uptake of e-learning. The Journal of Teaching English with Technology, 11(1), 81-97. https://eric.ed.gov/?id=EJ1145653

Hsieh C. H., and Chen S.H. Similarity of generalized fuzzy numbers with graded mean integration representation. Proc. 8th Int. fuzzy Syst. Association World Congress, Taipei, Taiwan, Republic of China, 1999, 2, pp. 551-555.

Hue T. T., Tuan N. A., Van L. H., Lien L. T., Huong D. D., Anh L. T., Huy N. X., and Dat, L. Q. (2022). Prioritization of Factors Impacting Lecturer Research Productivity Using an Improved Fuzzy Analytic Hierarchy Process Approach. *Sustainability*, 14, 6134. https://doi.org/10.3390/su14106134

Huy, N. X., Huyen, N. T. T., Huy, V. N., Ba, N. T., & Dat, L. Q. (2023). Factors influencing the effectiveness of blended learning activities: A case study of Vietnam National University, Hanoi. Multidisciplinary Science Journal, 5(in Progress), 2023044-2023044.

Ismail AO, Mahmood AK, Abdelmaboud A (2018) Factors influencing academic performance of students in blended and traditional domains. International Journal of Emerging Technologies in Learning 13(02):170-187.

Kien, P. V., Wong, W. K., Moslehpour, M., & Musyoki, D. (2018). Simultaneous Adaptation of AHP and Fuzzy AHP to Evaluate Outsourcing Services in East and Southeast Asia. Journal of Testing and Evaluation, 48(2) https://doi. org/10.1520/JTE20170420. ISSN, 0090-3973.

Malik M. W. (2010). Factor Affecting Learner's Satisfaction Towards E-Learning: A Conceptual Framework. *OIDA International Journal on Sustainable Development*, 2(3), 77-82. https://ssrn.com/abstract=1711989

Mishra L., Gupta T., and Shree A. (2020). Online teaching-learning in higher education during lockdown period of COVID-19 pandemic. *International Journal of Educational Research Open*, 1:100012. https://doi.org/10.1016/j.ijedro.2020.100012

Merhi M. I. (2021). Evaluating the critical success factors of data intelligence implementation in the public sector using analytical hierarchy process. Technological Forecasting & Social Change 173 (2021)121180.

Mukhtar K., Javed K., Arooj M., and Sethi A. (2020). Advantages, limitations and recommendations for online learning during the COVID-19 pandemic era. *Pakistan Journal of Medical Sciences*, 36:S27. http://doi: 10.12669/pjms.36.COVID19-S4.2785

Naveed Q. N., Qureshi M. R. N., Tairan N., Mohammad A., Shaikhid A., Alsayedid A. O., Shah A., and Alotaibi F. M (2020). Evaluating critical success factors in implementing E-learning system using multicriteria decision-making. *PLoS ONE*, 15(5): e0231465. https://doi.org/10.1371/journal.pone.0231465

Noesgaard S. S., and Ørngreen R. (2015). The effectiveness of E-learning: an explorative and integrative review of the definitions, methodologies and factors that promote e-learning effectiveness. *Electronic Journal of E-Learning*, 13(4), 278-290. https://files.eric.ed.gov/fulltext/EJ1062121.pdf

Ozkan S. and Koseler R. (2009). Multi-dimensional students' evaluation of e-learning systems in the higher education context: An empirical investigation. *Computers & Education*, 53(4), 1285-1296. https://doi.org/10.1016/j.compedu.2009.06.011

Pittenger A., and Doering A. (2010). Influence of motivational design on completion rates in online self-study pharmacy-content courses. *Distance Education*, 31, 275-293. https://doi.org/10.1080/01587919.2010.513953

Pham T. T. T., Le H. A., and Do D. T. (2021). The Factors Affecting Students' Online Learning Outcomes during the COVID-19 Pandemic: A Bayesian Exploratory Factor Analysis. *Education Research International*, Article ID 2669098, 13 pages. https://doi.org/10.1155/2021/2669098

Shieh D. (2009). These lectures are gone in 60 seconds. *The Chronicle of Higher Education*, 26, 1-13. https://doi: 10.1016/j.ijindorg.2013.12.001

Sari T., and Nayir F. (2020). Challenges in Distance Education During the (Covid-19) Pandemic Period. *Qualitative Research in Education*, 9(3), 328-360. https://doi.org/10.17583/qre.2020.5872

Shih T. K., Gunarathne W. K. T. M., Ochirbat A., and Su H.-M. (2018). Grouping peers based on complementary degrees and social relationships using genetic algorithm. *ACM Transactions on Internet Technology*, 19(1), 1-29. https://doi.org/10.1145/3193180

Sun P. C., Tsai R. J., Finger G., Chen Y. Y., and Yeh D. (2008). What drives a successful e-Learning? An empirical investigation of the critical factors influencing learner satisfaction. *Computers & Education*, 50(4), 1183-1202. https://doi.org/10.1016/j.compedu.2006.11.007

Venkatesh V, Morris MG, Davis GB, Davis FD (2003) User acceptance of information technology: Toward a unified view. MIS Quarterly 27(3):425-78.

Ward M. E., Peters G., and Shelley K. (2010). Student and faculty perceptions of the quality of online learning experiences. *The International Review of Research in Open and Distributed Learning*, 11, 57-77. http://doi: 10.19173/irrodl.v11i3.867

Wang Y. M., Luo Y., and Hua Z. S (2008). On the extent analysis method for fuzzy AHP and its applications. *European Journal of Operational Research*, 186, 735-747. https://doi.org/10.1016/j.ejor.2007.01.050