Listening to the Voice of Customers: Assessing the PetraVerse Learning Management System

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***Abstract*—This study evaluates the PetraVerse Learning Management System (LMS), developed by Petra Christian University, as a gamified solution addressing the challenges in online and hybrid learning. PetraVerse integrates immersive digital modules with game-like elements, such as skill cards, interactive factions, and rewards, creating a highly engaging educational experience for students. By leveraging gamification, the platform transforms learning into an interactive process that motivates students, enhances soft skill development, and fosters collaboration. Using a Fuzzy Quality Function Deployment (FQFD) approach, the study collected and analyzed feedback from students and professionals to identify key technical and user-centered requirements, including user interface design, internet speed, and gamification features. Findings indicate that PetraVerse surpasses traditional platforms in user satisfaction and technological performance, positioning it as a dynamic alternative to conventional learning systems. Although challenges such as internet access remain, the study demonstrates PetraVerse's potential to redefine online education through gamification, offering a more immersive and motivational learning environment.**

***Keywords*—gamification, Learning Management System (LMS), Fuzzy Quality Function Deployment (FQFD), hybrid learning**

I. Introduction

Online and hybrid learning environments pose challenges for educational institutions in maintaining quality and engagement in a fully virtual setting [1, 2]. Platforms such as Coursera, Google Classroom, and YouTube have provided solutions [3], yet they often fall short of creating an engaging, interactive experience that keeps students motivated. Research shows that online learning environments can sometimes reduce student motivation and increase monotony [4, 5].

In response to the growing demand for effective online learning options, Petra Christian University is harnessing the power of PetraVerse to provide engaging and effective online learning opportunities. PetraVerse is not solely a digital learning management system but a combination of gamification and immersive digital learning modules employing novel visual learning media, allowing students to learn while playing games. This unique approach is made possible through PetraVerse's integration with Learning Management System (LMS) gamification, which includes a skill card function to measure soft skill development, interactive factions for collaboration, and rewards for evaluation [6, 7]. PetraVerse can be accessed at www.PetraVerse.id [8]. Gamification combines aesthetics, cognitive skills, and game elements to engage, motivate, enhance learning, and solve diverse problems [7]. Structural gamification, one of the two main categories, uses game elements to motivate students without changing content. Landers [9] explains how game elements are used to enhance learning, namely action language, assessment, challenge, control, story, environment, human interaction, immersion, and goals. These game elements play a crucial role in this form of gamification. Utilizing a reward system, this form of gamification engages users in the learning process and motivates them through content [10]. With proper implementation, PetraVerse has the potential to transform the educational experience, making it a viable alternative to offline learning [11].

While PetraVerse offers numerous benefits, challenges related to internet connectivity and tool, or device constraints may arise. This study therefore aims to enhance PetraVerse's performance. However, assessing the effectiveness of such a system requires a comprehensive analysis framework that incorporates both quantitative and qualitative user feedback, particularly for technological and user experience improvements. Common methods for assessing system effectiveness include the Analytic Hierarchy Process (AHP) [12, 13], the Delphi method [14], and Quality Function Deployment (QFD) [15]. The AHP is a system analysis decision-making approach, particularly useful when multiple criteria need to be evaluated, breaking down a decision problem into a hierarchy and assigning weights to criteria based on pairwise comparisons [13]. Previous studies frequently employed the AHP to determine the weights of customer requirements in QFD. While pairwise comparisons of qualities facilitate thorough assessment, discrepancies frequently emerge among decision-makers, particularly when confronted with numerous options, complicating the resolution of Multi-Criteria Decision Making (MCDM) issues. Rezaei [16] established the Best–Worst Method (BWM), which minimizes the amount of pairwise comparisons by creating a novel pairwise comparison framework. The Delphi method is also often used in system analysis to gather expert opinions iteratively, particularly useful for consensus-building and long-term forecasting [17, 18]. Threat-Oriented Person Screening Integrated System (TOPSIS) is a widely utilized and effective method in MCDM that systematically, rationally, and precisely ranks diverse possibilities. In contrast to conventional multivariate statistical analysis techniques employed for evaluation issues, the TOPSIS method offers the benefits of intuitive analytical concepts, straightforward computations, and minimal sample requirements. Recently, it has been effectively utilized to resolve numerous MCDM issues [19, 20]. One problem associated with the TOPSIS technique is the necessity for external attribute weights.

QFD is a method for capturing consumer requirements and

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transforming them into products or services [15]. It emphasizes the importance of listening to consumer requirements and desires before determining the product features or services that will satisfy those demands [21]. In education, QFD has been used to improve bibliometric analysis and literature review [15], curriculum reviews [22], curriculum redesign [23], and more. This paper investigates the use of fuzzy QFD (FQFD) to improve the PetraVerse learning management system.

Unlike standard QFD, FQFD incorporates fuzzy logic, enabling flexible handling of uncertainties and subjective inputs [24]. FQFD is particularly effective for capturing varied and often confusing user input, such as the levels of significance students assign to platform aspects such as interface design or loading speed. FQFD outperforms other approaches. While AHP facilitates the prioritization of items, it may struggle with unclear or ambiguous data due to its need for precise numerical input. FQFD, by using linguistic variables such as "high importance" and "medium importance," makes it easier to discuss doubt and uncertainty and capture the vague nature of human judgment in system assessments, such as PetraVerse. Furthermore, the Delphi technique must incorporate the mathematical rigor of FQFD, particularly in addressing the complexity of balancing numerous technological and user needs. Integrating customer-driven priorities and fuzzy logic in FQFD offers a more resilient and flexible framework for assessing PetraVerse, particularly in identifying and prioritizing features that enhance both user enjoyment and technical performance.

This paper's originality resides in utilizing the Fuzzy-Quality Function Deployment (F-QFD) methodology to assess and improve the PetraVerse Learning Management System (LMS). The paper combines fuzzy logic with Quality Function Deployment (QFD) to address subjective and ambiguous user inputs, offering an enhanced approach for analyzing user-centered requirements. Notable new elements comprise. This research employs F-QFD inside the educational technology sector to assess a gamified LMS such as PetraVerse. In contrast to conventional QFD, which may encounter difficulties with ambiguous or subjective data, F-QFD enables the analysis to effectively capture nuanced user priorities and satisfaction levels with enhanced flexibility. The research demonstrates that Fuzzy-QFD can accommodate users' diverse and frequently contradictory demands (e.g., students and educators) within a Learning Management System (LMS). This adaptability facilitates a comprehensive evaluation of interface design, loading speed, and interactive content, highlighting their influence on student engagement and technical performance. The paper's innovation is in employing Fuzzy-QFD as a methodological enhancement to tackle challenges in user-centered design, particularly in gamified educational platforms, promoting PetraVerse as a progressive alternative to traditional LMS solutions.

II. Literature Review

Current Learning Management Systems (LMS) trends are shifting toward personalized, interactive, and data-driven educational environments that engage students beyond conventional course delivery methods. These innovations underscore adaptability, user involvement, and immediate feedback, with gamification, Artificial Intelligence (AI), and immersive technology leading the way. Significant LMS trends are relevant to the PetraVerse platform, along with its benefits and strengths within the current LMS landscape. Gamification for engagement remains a central trend in LMS design, with studies showing its effectiveness in increasing student engagement, motivation, and retention [7]. The integration of AI in LMS allows real-time adaptability and customization based on user behavior and preferences [25]. LMS platforms are shifting toward immersive learning through immersive and hybrid learning experiences, such as Virtual Reality (VR), Augmented Reality (AR), and Extended Reality (XR), enabling students to participate in realistic simulations and virtual labs that deepen comprehension and practical skills [26]. LMS platforms increasingly rely on learning analytics to track user progress, predict outcomes, and inform instructional decisions. Platforms with data analytics allow instructors to gain insights into student performance and make data-driven curriculum improvements [27].

Considering these trends, the PetraVerse platform demonstrates unique strengths meeting or extending current LMS advancements. PetraVerse is a cutting-edge Learning Management System (LMS) developed using the Visual Novel Gamification method [28], equipped with immersive technology and digital modules. Immersive technology [29] was employed to develop the platform for field education. PetraVerse enables students at Petra Christian University to gain knowledge as if playing a game. This is made possible through PetraVerse's integration with the learning Management Gamification System (LMS), which includes a Skill Card feature to evaluate soft skills development, factions for interaction and collaboration, and educational games as part of the assessment process, accompanied by rewards. PetraVerse is expected to reduce costs and time, offering more learning benefits in an asynchronous system accessible at any time and from any location. The platform can also generate digital modules that appeal to students of the millennial generation.

A. Quality Function Deployment (QFD)

QFD is a systematic approach to ensure product design aligns closely with customer expectations, delivering the product in a desirable and valuable manner. It begins with actively listening to consumer feedback and preferences, using them as directives and recommendations for developers [30].

QFD employs multiple matrices, typically four, to explicitly identify connections between firm activities and customer satisfaction. These matrices are derived from the "what-how" matrix, often termed the House of Quality (HOQ) [31]. QFD is an iterative procedure executed by a multifunctional team [24], with the HoQ structure depicted in Fig. 1.

Key components of HoQ are: First, determine WHATs. Consumer Attributes (CA) or "WHATs" (area (A) in Fig. 1) refer to the desired advantages of a product or service, as expressed by the consumer. Prioritizing WHATs requires balancing efforts to meet customer-value-added needs. Priorities are typically seen in the (B) section of Fig. 1. Then, determined HOWs. In the HOQ, engineering qualities are called "HOWs" and measurable criteria. Multidisciplinary teams [32] identify HOWs and place them on the matrix diagram's (C) region (Fig. 1). Third, prepare the relationship matrix. A team determines Which WHATs affect Which HOWs and How Much. Next, develop the correlation matrix. The roof matrix (E) in Fig. 1 shows the physical links between technical needs—last, Action plan. The area (F) weights of the HOWs are placed at the base of the quality matrix These weights are a key HOQ output and are determined by

$$WH_i = VH_{i1} \times IW_1 + \cdots + VH_{in} \times IW_n \quad (1)$$

where: WH_i is the weight of HOW $- i$; VH_{i1} is the correlation value of HOW $- i$ with WHAT $- n$; IW_n represents the importance or priority of WHAT $- n$ [33–35].

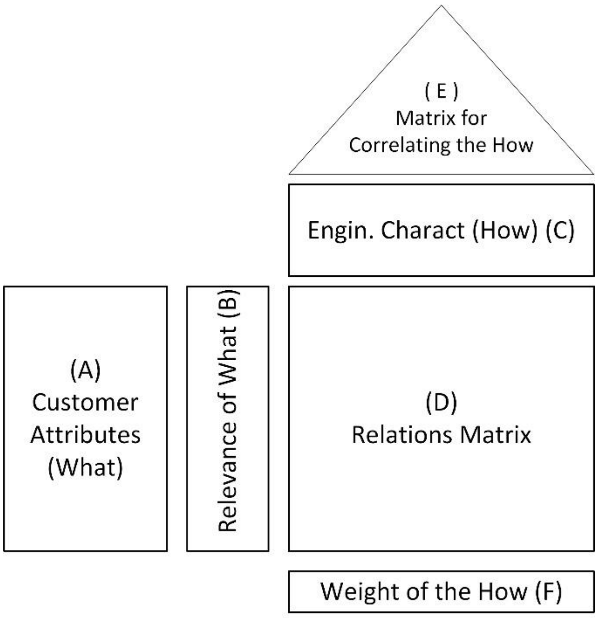

Fig. 1. House of quality [33].

B. Fuzzy-Logic

Decision-makers sometimes face uncertainties, questions, and concerns, which probability theory helps to address, embracing the notion that an inaccuracy, whatever form, is controlled by random law. However, for objective decision-making, various ambiguities and inaccuracies require specific instruments. Fuzzy logic can assist in accurately handling these uncertainties [36]. Logic traditionally divides into binary categories, such as yes/no or true/false, but real-life issues and how individuals think about and solve problems are not two-sided. Bivalent logic is based on classical sets, while fuzzy logic is based on a fuzzy set—a collection of objects without a clear boundary between the objects in or outside the set. The term behind this idea is "membership", where each item in a set has a value that indicates how much it is a part of the set. This value is between 0 and 1, with 0 being the lowest membership level and 1 being the highest, while all values in between exhibit different levels of "partial" membership.

There are numerous varieties of fuzzy numbers, each of which may be more appropriate for analyzing a specific ambiguous structure than others; the current analysis employs triangular fuzzy numbers, commonly employed for quantifying linguistic data (Fig. 2). Triangular fitness functions are often used in literature because they are simple to manage computationally.

Definition 1. Triangular Fuzzy Number

A fuzzy number $\tilde{A} = (\alpha, \beta, \gamma)$ is called triangular fuzzy number if its membership function is given by

$$\mu_{\tilde{A}}(x) = \begin{cases} 0, & x < \alpha \\ \frac{x-\alpha}{\beta-\alpha}, & \alpha \le x \le \beta \\ \frac{\gamma-x}{\gamma-\beta}, & \beta \le x \le \gamma \\ 0, & x > \gamma \end{cases} \quad (2)$$

Following Ref. [33], let $U = \{VL, L, M, H, VH\}$ represents linguistic set used to express opinions on a group of attributes (VL = very low, L = low, M = medium, H = high, VH= very high). The linguistic variables of U can be measured using triangular fuzzy numbers in the following manner: $VL \to (0,1,2)$; $L \to (2,3,4)$; $M \to (4,5,6)$; $H \to (6,7,8)$; $VH \to (8,9,10)$.

Definition 2: Fuzzy Operators [37]

For two triangular fuzzy number $\tilde{A} = (\alpha_1, \alpha_2, \alpha_3)$ and $\tilde{B} = (\beta_1, \beta_2, \beta_3)$ where α_1 and β_1 are the lower bounds; α_2 and β_2 are the peak values; α_3 and β_3 are the upper bounds.

Fuzzy addition $\tilde{C} = \tilde{A} + \tilde{B}$ is defined as:

$$\tilde{C} = (\alpha_1 + \beta_1, \alpha_2 + \beta_2, \alpha_3 + \beta_3) \quad (3)$$

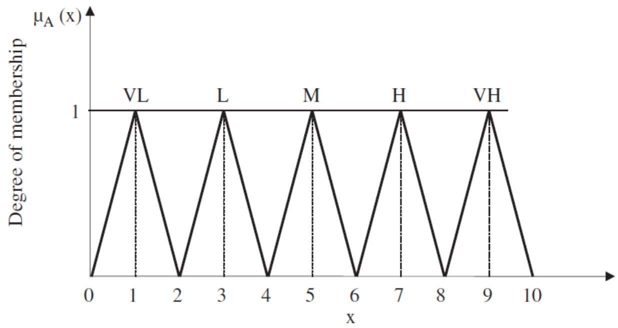

Fig. 2. Linguistic scale for relative importance [33].

Fuzzy multiplication $\tilde{C} = \tilde{A} \times \tilde{B}$ is defined as:

$$\tilde{C} = (\alpha_1 \cdot \beta_1,\ \alpha_2 \cdot \beta_2,\ \alpha_3 \cdot \beta_3) \quad (4)$$

Multiplying two triangular fuzzy numbers directly is straightforward in this way, but in practice, it is sometimes necessary to check the positivity of the intervals to avoid incorrect results, as multiplication can affect the order of intervals.

Fuzzy correlation

The correlation might be computed by normalizing and comparing degrees of similarity between fuzzy numbers.

Fuzzy similarity measure $S(\tilde{A}, \tilde{B})$ is defined as

$$S(\tilde{A}, \tilde{B}) = \frac{1 - distance\ (\tilde{A}, \tilde{B})}{1 + distance\ (\tilde{A}, \tilde{B})} \quad (5)$$

$$distance\ (\tilde{A}, \tilde{B}) = \sqrt{\frac{(\alpha_1-\beta_1)^2 + (\alpha_2-\beta_2)^2 + (\alpha_3-\beta_3)^2}{3}} \quad (6)$$

The result $0 \le S(\tilde{A}, \tilde{B}) \le 1$, providing a fuzzy correlation score based on the similarity between the two fuzzy numbers.

C. Fuzzy-QFD

Researchers initially investigated the integration of fuzzy logic into the QFD architecture to mitigate the inherent fuzziness of customer needs and technical specifications. Fuzzy QFD has been applied across sectors, such as software development, service industries, and manufacturing [25, 33]. Each sector offers unique opportunities and challenges for utilizing fuzzy logic to improve QFD processes.

Fuzzy QFD employs fuzzy linguistic variables to articulate Customer Requirements (CR), facilitating adaptability and subjective interpretation. Fuzzy membership functions define fuzzy relationships between Technical Requirements (TR) correlating with each CR. A fuzzy relationships matrix is then constructed and filled with fuzzy membership values representing the strength of the relationship between each CR and TR. Finally, CR can be prioritized according to their significance to consumer satisfaction using the House of Quality (HOQ) matrix [38].

III. Materials and Methods

The research started with a Focus Group Discussion (FGD) with 11 respondents. These 11 respondents, for the design of the PetraVerse LMS through fuzzy QFD, were considered adequate, combining diverse perspectives and relevant expertise. Eight students were from diverse fields—engineering, design, informatics, languages, communication, management, and education—and three were professionals (LMS developers, experienced lecturers, and PetraVerse managers), forming a strong foundation for developing an interactive and flexible LMS. In QFD design, input quality takes precedence over quantity. Feedback from experienced users is valuable in identifying the real needs and expectations of users, critical for creating the right product [39]. Effective QFD design prioritizes the relevance and depth of insights from user and designer perspectives, making it more than solely a number but a valuable guide toward an on-demand solution [40, 41]. Zhai *et al.* [42] show that subjective linguistic assessments can be effectively processed with a smaller respondent pool. Yu and Kwak [43] propose a structured approach using Fuzzy QFD for service development in the banking industry, demonstrating that a limited number of respondents can provide valuable insights.

This FGD activity is divided into two phases. The initial phase involves identifying student requirements concerning the Learning Management System (LMS) that can satisfy their learning needs. A notable benefit of LMSs is their ability to enhance interaction between students, instructors, and peers, with engagement playing a vital role in determining the effectiveness and fulfillment of online learning experiences. Engagement tools, including quizzes, gamification, and social interaction features, have demonstrated the potential to enhance student motivation and participation [44]. User system experience is also essential for determining student and instructor LMS acceptance and contentment. Systems that feature intuitive navigation, explicit interfaces, and seamless functionality tend to exhibit a higher likelihood of success [45]. Therefore, Customer Requirements (CRs) and Technical Requirements (TRs) of LMSs should be identified for effective use in learning.

The expectations and needs of users, such as students and faculty, from a learning management system are fundamental to understanding Customer Requirements (CRs). Recognizing and ranking these CRs is crucial for developing a user-focused system. Those CRs include the following. (1) Usability, which frequently constitutes the paramount criterion in LMS design. Studies indicate that an intuitive interface greatly influences student happiness and educational results [46]. (2) Clarity and accessibility of content. Well-structured materials enhance students' ability to retain and utilize knowledge, underscoring the significance of content clarity and navigational simplicity [47]. (3) Interactive and engagement. Using gamification features in LMS, such as PetraVerse, aligns with recent research indicating that interactive components enhance user engagement and motivation. Hamari *et al.* [48] observed that gamified learning environments diminish monotony and enhance user engagement by using components such as points, badges, and interactive features. (4) Technical performance parameters, such as loading speed and consistent access, are crucial for ensuring a seamless user experience in systems significantly reliant on real-time interaction and multimedia. Obonya and Kadlečík [49] emphasize the significance of technical performance in LMS success, especially in environments with substantial user demand for interactive material. (5) CRs, such as personalization and adjustable learning paths, align with adaptive learning trends, where students receive individualized content and activities based on their performance and preferences. Brusilovsky and Millán [50] indicate that tailored content delivery, informed by user progress and preferences, can improve learning results.

Technical Requirements (TRs) are system-specific attributes needed to meet defined customer needs, covering technological elements in LMS design that enhance usability, functionality, and user engagement. The TRs include the following. (1) Scalable infrastructure. Scalability is essential for systems such as PetraVerse that integrate multimedia and interactive functionalities. Research conducted by Veluvali and Surisetti [51] demonstrates that LMSs are capable of accommodating escalating loads and user demands exhibit greater resilience and efficacy, particularly as institutions expand. Technical requirements such as server scalability and bandwidth optimization ensure the robustness required to sustain performance. (2) Gamification systems and engagement tools. TRs, such as point-based incentives and interactive faction tools, require clearly defined back-end architectures to facilitate seamless user interactions and to preserve the learning experience flow [52]. (3) Data management and analytics. Collecting and examining user data can yield significant insights into learning behaviors and system interaction, allowing learning management systems to adjust to changing user requirements [53]. (4) Security and privacy. LMS platforms managing sensitive data must prioritize data security and user privacy to establish user confidence.

The final step in the initial phase is determining comparable Learning Media (LM) that serve as references to enhance the described designs. The second stage evaluates each student's relative importance, indicating priority and quantifying the correlation matrix between technical needs and customer requirements. FGD data were subsequently analyzed using the House of Quality framework, as shown in Fig. 3. The initial FGD phase involves the identification of Parts A, B, and F, while the second phase involves the identification of Parts C and D of the HoQ. Other HoQ components are calculated using triangular fuzzy logic.

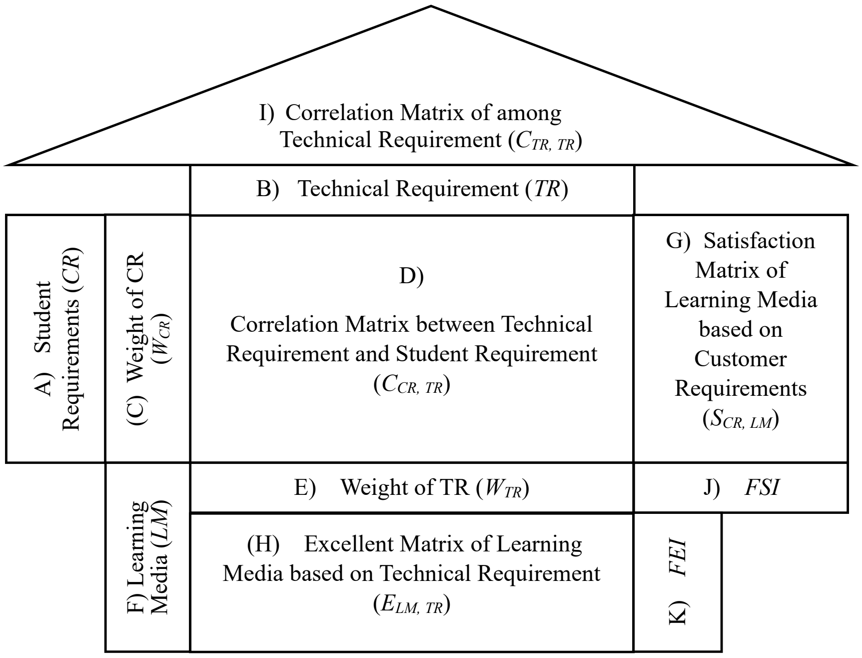

Fig. 3. The fuzzy-QFD house of quality.

IV. Result and Discussion

A. Elements of the Initial Phase in the FGD

Part A of the HoQ identified student requirements as follows: (CR1) availability of chat rooms; (CR2) the materials delivered are easy to understand; (CR3) providing customer service; (CR4) clear audio quality; (CR5) attractive visuals; (CR6) higher loading speed of the website/ application; (CR7) ease-of-use (user-friendly); and (CR8) attractive user interface.

The technical requirements (Part B) are identified as follows: (TR1) internet speed: 20 Mbps; (TR2) provides multiple learning modules for different majors; (TR3) clear UI/UX positioning; (TR4) Daily Quest: daily missions that must be accomplished to obtain points; (TR5) gamification system points may be redeemed for digital assets such as avatars and backdrops; (TR6) the availability of practice questions and answer keys; (TR7) the material is explained via new features, comics, and VR modules; and (TR8) provides a database for measuring students' soft skills.

The comparable learning media (Part F) that may be used as references according to the discussion are (LM1) PetraVerse, (LM2) YouTube, (LM3) Google Classroom, (LM4) Cloud Lentera, (LM5) Quizziz, and (LM6) Kahoot..

B. The Weights

Experts and students determine the weight of importance (Part C) or Customer Requirement (WCR), calculated using the average operator, formulated as follows:

$$W_{CR} = \{w_i, \text{where } i = 1, \cdots, k\},$$

$$w_i = \frac{1}{n} \otimes (w_{i1} \oplus w_{i2} \oplus \cdots \oplus w_{in}) \quad (7)$$

where k is the number of customer requirements and n is the number of experts and students, namely the respondents (in this study, $k = 8$ requirements and $n = 11$ people). Each element in the W_{CR} vector is a triangular fuzzy number defined as a triplet $w_i = (w_{i\alpha}, w_{i\beta}, w_{i\gamma})$. The average of importance weights is obtained based on the perceptions expressed by each customer, as shown in Table 1.

Table 1. The average weight of customer requirements

Customer Requirements	w_i		
	α	β	γ
CR1	4.0	5.0	6.0
CR2	8.0	9.0	10.0
CR3	6.9	7.9	8.9
CR4	4.9	5.9	6.9
CR5	7.6	8.6	9.6
CR6	4.9	5.9	6.9
CR7	6.2	7.2	8.2
CR8	6.0	7.0	8.0

It is evident that CR2—the clarity of the given materials—has high significance in meeting customer expectations, followed by CR5, visually appealing graphics, and CR3, delivering excellent customer service. Next, in Part D, each participant was asked to articulate their viewpoint, using one of the five linguistic variables, concerning the association between each Technical Requirement (TR) and Customer Requirement (CR). Table 2 displays the opinions offered by all participants. Triangular fuzzy numbers are employed to quantify the linguistic factors. Similar to the last scenario, the fuzzy number generated for each client is expressed by the following equation

$$C_{CR,TR} = \{c_{ij}, \text{where } i = 1, \cdots, k,\ \ j = 1, \cdots, m\},$$

$$c_{ij} = \frac{1}{n} \otimes (c_{ij1} \oplus c_{ij2} \oplus \cdots \oplus c_{ijn}) \quad (8)$$

where k is the number of CR, m is the number of TR, and n is the number of participants (in this study , $k = 8, m = 8$, and $n = 11$). The matrix $C_{CR,TR}$ is the correlation between CR and TR. The entries c_{ij} in the matrix indicate the combined correlation scores between the i-th CR and the j-th TR. The triplet, $c_{ij} = (c_{ij\alpha}, c_{ij\beta}, c_{ij\gamma})$ determines that the elements of c_{ij} are triangular fuzzy numbers. Table 2 exhibits the correlation between the TR and CR.

In Part E, we need to determine each TR's weight (Y_{TR}) so that the priority of technical requirements for each Learning Media (LM) can be deduced. The technical requirement weight (Y_{TR}) is the average aggregate weighted correlation score c_{ij} with the aggregate customer requirement weight w_i, calculated using the equation:

$$Y_{TR} = \{y_j, \text{where } j = 1, \cdots, m\},$$

$$y_j = \frac{1}{k} \otimes [(c_{j1} \otimes w_1) \oplus (c_{j2} \otimes w_2) \oplus \cdots \oplus (c_{jk} \otimes w_k)] \quad (9)$$

where k, m is the convention. For every y_j in the vector, Y_{TR} represents weight for each TR. Y_j is a triangular fuzzy number defined as a triplet $Y_j = (Y_{j\alpha}, Y_{j\beta}, Y_{j\gamma})$. Table 3 shows the weight for each Technical Requirement (TR). It is shown that TR3—Clear UI/UX positioning has the highest requirement followed by TR 7 and TR 1.

Next, we need to calculate the E_{LM} superiority level matrix for each technical requirement TR (Part G). Therefore, each respondent was asked to indicate their preference for one of five linguistic factors concerning the excellence of each learning media (LM) based on the technical requirement (TR). Table 4 shows the opinions offered by all respondents

$$E_{LM,TR} = \{e_{hj}, \text{where } h = 1, \cdots, v;\ j = 1, \cdots, m\},$$

$$e_{hj} = \frac{1}{n} \otimes (e_{hj1} \oplus e_{hj2} \oplus \cdots \oplus e_{hjn}) \quad (10)$$

$$S_{CR,LM} = \{s_{ih}, \text{where } i = 1, \cdots, k,\ \ h = 1, \cdots, v\},$$

$$s_{ih} = \frac{1}{n} \otimes (c_{ih1} \oplus c_{ih2} \oplus \cdots \oplus c_{ihn}) \quad (11)$$

where k is the number of CR, v is the number of LM, and n is the number of respondents. $S_{CR,LM}$ is the score correlation matrix between CR and LM. The elements s_{ih} represents score correlation aggregate between the-i CR and the-h LM. The s_{ih} is a triangular fuzzy number which is represented by a triplet $s_{ih} = (s_{ih\alpha}, s_{ih\beta}, s_{ih\gamma})$. Table 5 presents the satisfaction level of each learning media based on the customer requirements.

Table 2. Correlation between TR and CR

CRi	$c_{CRi,TR1}$			$c_{CRi,TR2}$			$c_{CRi,TR3}$			$c_{CRi,TR4}$			$c_{CRi,TR5}$			$c_{CRi,TR6}$			$c_{CRi,TR7}$			$c_{CRi,TR8}$		
	α	β	γ	α	β	γ	α	β	γ	α	β	γ	α	β	γ	α	β	γ	α	β	γ	α	β	γ
CR1	2.9	3.9	4.9	2.2	3.2	4.2	3.3	4.3	5.3	1.1	2.1	3.1	0.7	1.7	2.7	2.9	3.9	4.9	1.1	2.1	3.1	2.9	3.9	4.9
CR2	2.7	3.7	4.7	5.1	6.1	7.1	5.6	6.6	7.6	2.7	3.7	4.7	1.8	2.8	3.8	5.3	6.3	7.3	5.1	6.1	7.1	4.7	5.7	6.7
CR3	4.0	5.0	6.0	2.7	3.7	4.7	3.1	4.1	5.1	1.1	2.1	3.1	1.8	2.8	3.8	2.2	3.2	4.2	1.8	2.8	3.8	3.1	4.1	5.1
CR4	7.1	8.1	9.1	3.8	4.8	5.8	5.1	6.1	7.1	1.8	2.8	3.8	1.3	2.3	3.3	2.2	3.2	4.2	5.8	6.8	7.8	2.2	3.2	4.2
CR5	5.1	6.1	7.1	4.9	5.9	6.9	4.4	5.4	6.4	4.4	5.4	6.4	4.7	5.7	6.7	3.6	4.6	5.6	7.1	8.1	9.1	4.2	5.2	6.2
CR6	8.0	9.0	10.0	6.7	7.7	8.7	7.8	8.8	9.8	5.8	6.8	7.8	5.3	6.3	7.3	6.2	7.2	8.2	7.1	8.1	9.1	5.1	6.1	7.1
CR7	4.9	5.9	6.9	5.8	6.8	7.8	7.6	8.6	9.6	5.1	6.1	7.1	5.3	6.3	7.3	6.7	7.7	8.7	6.9	7.9	8.9	6.2	7.2	8.2
CR8	5.1	6.1	7.1	5.6	6.6	7.6	7.3	8.3	9.3	5.6	6.6	7.6	6.0	7.0	8.0	4.7	5.7	6.7	6.0	7.0	8.0	4.9	5.9	6.9

Table 3. The weight of each Technical Requirement (TR)

y_{TR1}			y_{TR2}			y_{TR3}			y_{TR4}			y_{TR5}			y_{TR6}			y_{TR7}			y_{TR8}		
α	β	γ	α	β	γ	α	β	γ	α	β	γ	α	β	γ	α	β	γ	α	β	γ	α	β	γ
20.3	28.3	37.6	19.2	26.9	36.0	23.0	31.4	41.1	14.6	21.6	29.9	14.3	21.2	29.4	17.8	25.3	34.1	21.5	29.6	39.0	17.3	24.8	33.6

Table 4. Superiority weight matrix for each learning media based on the technical requirement

Learning Media	$E_{LMh,TR1}$			$E_{LMh,TR2}$			$E_{LMh,TR3}$			$E_{LMh,TR4}$			$E_{LMh,TR5}$			$E_{LMh,TR6}$			$E_{LMh,TR7}$			$E_{LMh,TR8}$		
	α	β	γ	α	β	γ	α	β	γ	α	β	γ	α	β	γ	α	β	γ	α	β	γ	α	β	γ
LM1	6.4	7.4	8.4	5.8	6.8	7.8	4.9	5.9	6.9	6.0	7.0	8.0	6.0	7.0	8.0	6.4	7.4	8.4	7.1	8.1	9.1	6.4	7.4	8.4
LM2	7.3	8.3	9.3	6.9	7.9	8.9	7.1	8.1	9.1	0.4	1.4	2.4	0.9	1.9	2.9	2.9	3.9	4.9	3.8	4.8	5.8	0.7	1.7	2.7
LM3	5.8	6.8	7.8	6.0	7.0	8.0	5.8	6.8	7.8	1.3	2.3	3.3	0.7	1.7	2.7	4.9	5.9	6.9	0.2	1.2	2.2	3.6	4.6	5.6
LM4	5.6	6.6	7.6	7.1	8.1	9.1	5.6	6.6	7.6	2.0	3.0	4.0	1.3	2.3	3.3	5.3	6.3	7.3	0.9	1.9	2.9	3.6	4.6	5.6
LM5	6.9	7.9	8.9	6.4	7.4	8.4	6.2	7.2	8.2	3.6	4.6	5.6	4.2	5.2	6.2	6.2	7.2	8.2	1.3	2.3	3.3	4.9	5.9	6.9
LM6	7.1	8.1	9.1	5.6	6.6	7.6	6.0	7.0	8.0	3.1	4.1	5.1	3.8	4.8	5.8	5.6	6.6	7.6	1.3	2.3	3.3	4.7	5.7	6.7

Table 5. Satisfaction level of each learning media based on the customer requirements

Customer Requirements	$S_{Cri,LM1}$			$S_{Cri,LM2}$			$S_{Cri,LM3}$			$S_{Cri,LM4}$			$S_{Cri,LM5}$			$S_{Cri,LM6}$		
	α	β	γ	α	β	γ	α	β	γ	α	β	γ	α	β	γ	α	β	γ
CR1	3.1	4.1	5.1	2.0	3.0	4.0	5.1	6.1	7.1	4.2	5.2	6.2	2.0	3.0	4.0	2.9	3.9	4.9
CR2	5.1	6.1	7.1	4.0	5.0	6.0	4.4	5.4	6.4	4.2	5.2	6.2	3.3	4.3	5.3	4.0	5.0	6.0
CR3	4.2	5.2	6.2	3.1	4.1	5.1	2.0	3.0	4.0	3.3	4.3	5.3	2.9	3.9	4.9	3.6	4.6	5.6
CR4	6.9	7.9	8.9	6.9	7.9	8.9	3.8	4.8	5.8	4.0	5.0	6.0	4.9	5.9	6.9	4.7	5.7	6.7
CR5	7.1	8.1	9.1	5.3	6.3	7.3	3.6	4.6	5.6	4.0	5.0	6.0	4.4	5.4	6.4	4.9	5.9	6.9
CR6	3.1	4.1	5.1	6.9	7.9	8.9	6.2	7.2	8.2	3.6	4.6	5.6	5.3	6.3	7.3	5.1	6.1	7.1
CR7	4.0	5.0	6.0	7.1	8.1	9.1	5.6	6.6	7.6	4.9	5.9	6.9	5.6	6.6	7.6	4.9	5.9	6.9
CR8	5.8	6.8	7.8	5.8	6.8	7.8	4.4	5.4	6.4	4.2	5.2	6.2	5.6	6.6	7.6	5.1	6.1	7.1

where v is the number of LM, m is the number of TR, and n is the number of respondents (in this study, $v = 6$, $m = 8$, and $n = 11$). $E_{LM,TR}$ is the correlation score matrix between LM and TR, and the elements e_{hj} represent the score correlation aggregate between the v-LM and the j-TR. The element e_{hj} is a fuzzy triangular number, which is represented by a triplet

$e_{hj} = (e_{hj\alpha}, e_{hj\beta}, e_{hj\gamma})$.

In Part H, we need to calculate the satisfaction level matrix of each LM based on each customer requirement. The triangular fuzzy number of the level of satisfaction with each learning media is assessed based on customer requirements formulated in the following equation

We need to calculate the Fuzzy Satisfaction Index (FSI) of the LMS rating based on the degree of satisfaction with all student requirements (Part I). The learning media (X_{LM}) ranking based on the degree of customer satisfaction is the average of the aggregate weighted correlation score with the aggregate weight of technical requirements Y_j is expressed as follows

$$X_{MP} = \{x_h, \text{where } h = 1, \cdots, v\ \};$$

$$x_h = \frac{1}{k} \otimes [(s_{i1} \otimes w_i) \oplus (s_{i2} \otimes w_i) \oplus \cdots \oplus (s_{iv} \otimes w_i)] \quad (12)$$

where k and m is the convention. For every w_j element of vector W_{TR} represents the weight of each technical requirement (TR). x_h is a triangular number which is defined as a triplet $x_h = (x_{h\alpha}, x_{h\beta}, x_{h\gamma})$—see Table 6. Then we can define the FSI of each learning media as

$$FSI_h = \frac{(x_{h\alpha} + 4x_{h\beta} + x_{h\gamma})}{4} \quad (13)$$

In Table 7, respondents expressed the highest level of satisfaction with YouTube as a learning tool, followed by PetraVerse and Kahoot. Furthermore, it is necessary to quantify the correlation between technical requirements and assess their interdependencies, which will support the evaluation of suggested or enhanced LM designs. A triangular fuzzy number is derived to quantify the degree of the correlation between technical needs using the following equation:

$$T_{TR,TR} = \{t_{jg}, \text{where } j = 1, \cdots, m-1; g = j-1, \cdots, m\},$$

$$t_{jg} = \frac{1}{n} \otimes (c_{jg1} \oplus c_{jg2} \oplus \cdots \oplus c_{jgn}) \quad (14)$$

where m is the number of TR and n is the customer number (in this study $m = 8$, and $n = 11$). $C_{TR,TR}$ is the score correlation matrix between TR_j and TR_g, $j \neq g$, where t_{jg} is the element of $T_{TR,TR}$ which represents the correlation aggregate between TR_j and TR_g. The element of t_{jg} is a triangular fuzzy number which is defined as a triplet $t_{jg} = (t_{jg\alpha}, t_{jg\beta}, t_{jg\gamma})$. Table 8 presents the correlation among technical requirements, while Table 9 represents the number of correlations among the technical requirements.

Fig. 4 exhibits that TR1, tthe internet speed, correlates with all other technical requirements, except for TR2 and TR8. The requirement to provide multiple learning media modules for different majors (TR2) correlates with TR3 and TR6–TR8. The gamification systems point (TR5) negatively correlated with TR8.

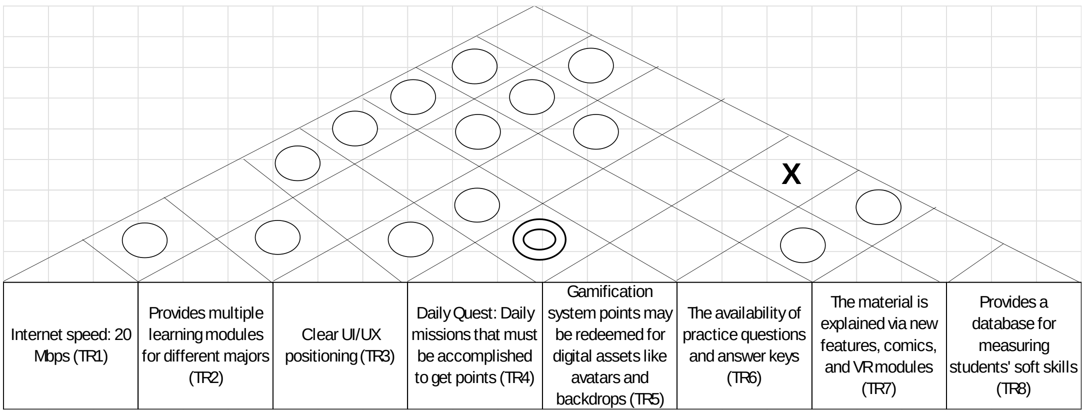

Fig. 4. The HoQ roof: The correlation strength among technical requirements.

Table 6. The weight of learning media satisfaction based on the customer requirement

Petraverse			Youtube			Google Classroom			Cloud Lantera			Quizziz			Kahoot		
X_{LM1}			X_{LM2}			X_{LM3}			X_{LM4}			X_{LM5}			S_{LM6}		
α	β	γ	α	β	γ	α	β	γ	α	β	γ	α	β	γ	α	β	γ
19.6	27.5	36.8	21.4	29.5	38.9	17.8	25.4	34.3	16.3	23.6	32.3	17.6	25.1	33.9	17.9	25.5	34.4

Table 7. Learning media rank based on the Fuzzy Satisfaction Index (FSI)

FSI for each LM	FSI_{LM1}	FSI_{LM2}	FSI_{LM3}	FSI_{LM4}	FSI_{LM5}	FSI_{LM6}
Score	27,88	29,83	25,75	23,97	25,42	25,84
Rank	2	1	4	6	5	3

Table 8. Correlation among the Technical Requirement (TR)

	$t_{TR1,TR}$							$t_{TR2,TR}$						$t_{TR3,TR}$					$t_{TR4,TR}$				$t_{TR5,TR}$			$t_{TR6,TR}$		$t_{TR7,TR}$
	TR2	TR3	TR4	TR5	TR6	TR7	TR8	TR3	TR4	TR5	TR6	TR7	TR8	TR4	TR5	TR6	TR7	TR8	TR5	TR6	TR7	TR8	TR6	TR7	TR8	TR7	TR8	TR8
α	5.8	4.2	5.1	5.6	5.3	6.2	4.7	5.3	4.7	4.2	6.9	6.4	6.0	5.6	5.6	4.9	6.0	4.7	7.1	4.2	4.7	4.2	3.1	4.2	2.7	5.3	5.8	4.2
β	6.8	5.2	6.1	6.6	6.3	7.2	5.7	6.3	5.7	5.2	7.9	7.4	7.0	6.6	6.6	5.9	7.0	5.7	8.1	5.2	5.7	5.2	4.1	5.2	3.7	6.3	6.8	5.2
γ	7.8	6.2	7.1	7.6	7.3	8.2	6.7	7.3	6.7	6.2	8.9	8.4	8.0	7.6	7.6	6.9	8.0	6.7	9.1	6.2	6.7	6.2	5.1	6.2	4.7	7.3	7.8	6.2
The correlation strength	+	**0**	+	+	+	+	**0**	+	**0**	**0**	+	+	+	+	+	**0**	+	**0**	++	**0**	**0**	**0**	**0**	**0**	-	+	+	**0**

Table 9. Number of correlations $T_{TR,TR}$

Technical Requirement	TR1	TR2	TR3	TR4	TR5	TR6	TR7	TR8
Number of correlations	5	5	4	3, has a strong correlation (++) with TR5	4: has a negative correlation (-) with TR8 and a strong correlation (++) with TR4	4	4	3: has a negative correlation (-) with TR5

The last stage involves computing the Fuzzy Technical Index (FTI) to determine the ranking of the LM based on the level of excellence assessed by all technical requirements. The learning media ranking (Z_{LM}) based on technical requirement excellence is the average aggregate weighted correlation score, e_{hj}, with the aggregate weight of technical requirement y_j formulated by the following equation

$$Z_{MP} = \{z_h, \text{where } h = 1, \cdots, v\ \},$$

$$z_h = \frac{1}{m} \otimes \left[(e_{j1} \otimes y_1) \oplus (e_{j2} \otimes y_2) \oplus \cdots \oplus (e_{jk} \otimes y_k)\right] \quad (15)$$

where k and m is the convention. W_j in vector W_{TR} represents the weight of every technical requirement (TR). z_h is a triangular fuzzy number which is defined as a triplet $z_h = (z_{h\alpha}, z_{h\beta}, z_{h\gamma})$. Then, we can define FTI as:

$$FTI_h = \frac{(z_{h\alpha} + 4z_{h\beta} + z_{h\gamma})}{4} \quad (16)$$

Table. 10. The level of excellence' weight for each learning media based on the technical requirements

Learning Media	$Z_{LMh} = z_h$			FTI	Rating
	α	β	γ		
Petraverse	113.0	186.3	285.2	193	1
Youtube	76.0	131.9	210.6	138	4
Google Classsroom	68.5	122.1	198.2	128	6
Cloud Lantera	75.2	131.6	211.1	137	5
Quizziz	92.9	157.1	245.8	163	2
Kahoot	87.2	148.9	234.6	155	3

Upon considering all criteria, this study concludes that PetraVerse is the most effective learning medium, followed by Quizziz and Kahoot.

C. Discussion

Several key areas have been identified to improve PetraVerse and better meet customer requirements. First, CR2—clarity of delivered materials—requires attention. Simplifying complex topics and providing clear explanations through relatable examples will enhance user experience. More structured content such as infographics and flowcharts will also improve material comprehension. CR5—visual appeal—can be addressed by refining aesthetic design, focusing on modern, colorful, and engaging visuals, particularly in avatars, gamified backgrounds, and interactive elements. Enhancing customer service (CR3) is also crucial. Integrating AI-based chatbots or human support, available 24/7, and offering a comprehensive FAQ section will provide the necessary assistance to users. Furthermore, to address CR7 and CR8, the platform must improve usability by simplifying navigation and minimizing the steps required to perform actions, ensuring that desktop and mobile versions are optimized for ease of use. CR6—loading speed—can be enhanced by optimizing backend infrastructure, reducing load times, and ensuring that interactive elements such as gamified features do not compromise performance. Addressing CR4—audio quality—requires ensuring that all audio content, such as VR modules and voiceovers, maintains clear, high-quality sound, achieved using top-tier equipment and compression techniques.

For technical requirements, TR7—engaging features—necessitates expanding interactive content such as VR modules, comics, and gamified learning paths, updated regularly based on feedback to maintain engagement. Gamification systems (TR4 and TR5) can be enhanced by offering daily quests and redeemable points, ensuring new quests and rewards are introduced frequently to keep users motivated. Additionally, interactive scenarios and quizzes that track progress will integrate tools to measure soft skills (TR8), such as communication and teamwork. Regular feedback collection from users will ensure ongoing improvements in all areas. By addressing these elements, PetraVerse can meet the requirements outlined and ensure a superior learning experience for students. The adaptive framework of PetraVerse, conforms to constructivist learning theory [54] and the platform's immersive modules align with the notion of experience learning [55]. Understanding the challenges of extending the PetraVerse platform to diverse educational environments is critical in preparing for its more comprehensive application and effect. The platform's success at Petra Christian University is a promising model for inspiring positive change in other schools. However, this growth is not without obstacles. First, regarding technological infrastructure and internet accessibility**,** rural and undeveloped educational institutions may have limited internet bandwidth or obsolete gear. PetraVerse requires reliable, high-speed internet and sufficient device processing power for immersive digital modules and gamification. The platform's usefulness may be reduced if low-bandwidth versions are produced for places with insufficient technical infrastructure. (2) Regarding teacher training and support**,** PetraVerse adoption across institutions requires extensive teacher training. Teachers must understand the platform's technical features and how to use gamification and interactive learning. (3) Regarding costs and licensing, though PetraVerse has helped Petra Christian University, other schools, especially those with low funds, may need more money to implement such an advanced platform. (4) Educational cultures may react differently to gamified learning. Gamification may be too entertaining or non-academic for some institutions, which favor conventional learning approaches. To avoid student and teacher opposition, we may need gradual integration or hybrid solutions to integrate PetraVerse's game-based learning approach with traditional teaching methods. (5) As PetraVerse extends to additional institutions, systems that capture student data for progress monitoring or tailored learning will raise data privacy and security problems.

Early identification and resolution of these challenges will streamline the deployment and scalability of PetraVerse across diverse educational settings. Recognizing these potential obstacles underscores the need for adaptable solutions., including delivering alternative platform versions tailored to different technical skills and educational objectives, as well as providing the flexibility and resilience needed for successful implementation.

V. Conclusion

This study evaluates the efficacy of the PetraVerse Learning Management System (LMS), a gamified platform created by Petra Christian University. The PetraVerse platform integrates gamification techniques and immersive digital modules, enhancing the dynamic and captivating nature of the learning experience.

The study emphasizes that PetraVerse, with its student-centric approach, provides an alternative to conventional learning by integrating gaming with education, beneficially facilitating student motivation. However, internet access and limitations in computer capabilities continue to pose significant barriers. The present work employs a Quality Function Deployment (QFD) methodology to enhance the platform by collecting input from professionals and students, making them feel valued in the process.

Based on its unique blend of gamification (containing elements such as skill cards and incentives) and asynchronous learning, the research highlights PetraVerse as a notable breakthrough. According to the fuzzy QFD analysis, the most essential technological requirements for the system are a straightforward User Interface (UI) design, the ability to test soft skills, and fast broadband.

The research findings validate PetraVerse as a highly efficient learning tool, surpassing other platforms such as YouTube, Kahoot, and Google Classroom in both user satisfaction and technical proficiency. The findings also demonstrate that PetraVerse closely aligns with current LMS trends and educational theories, highlighting its strengths in gamification, adaptability, immersive learning, and data-driven personalization. PetraVerse's adaptive framework, augmented by fuzzy QFD, further aligns with constructivist learning theory by tailoring learning trajectories according to detailed input. Additionally, the platform's immersive modules correspond with experiential learning theory, providing practical virtual simulations that enhance comprehension, particularly beneficial in skill-oriented education. Finally, its data analytics functionalities offer real-time feedback and facilitate formative evaluation, supporting targeted interventions to enhance outcomes, consistent with contemporary research on learning analytics.

Despite the limitations, the research demonstrates how PetraVerse's interactive methodology can overcome these obstacles and augment the prospects of online education, instilling a sense of hope in the readers. In addition, educational institutions facing similar struggles with online and hybrid learning environments could adopt this model to foster higher levels of student engagement and retention. The system's flexibility, integrating tools for soft skill development, collaboration, and gamified assessments, makes it adaptable for various academic disciplines and educational levels.

Institutions with limited resources or regions with connectivity issues may find PetraVerse's asynchronous learning features particularly valuable, as it allows learning to take place at any time and in any location. Additionally, other universities might adapt this model to align with their specific needs, using its gamification principles to motivate students and enhance the learning experience.

Furthermore, as online learning continues to evolve globally following the pandemic, PetraVerse's approach could inspire new trends in educational technology by incorporating entertainment and learning to meet modern educational demands.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

I Nyoman Sutapa completed the fuzzy-QFD computations, Siana Halim authored the research paper and reviewed the literature, and Felecia organized data collection and focus group discussion. All authors had approved the final version.

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