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Evaluating impact of digitalization on higher education quality

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ABSTRACT

This research employs the spherical fuzzy analytic hierarchy process (SFAHP) to prioritize key factors shaping the higher education quality in Ho Chi Minh City, Vietnam within the context of increasing digitalization. Through a structured hierarchy encompassing criteria such as accessibility of digital resources, adaptability and innovation, pedagogical integration, student engagement, and technological infrastructure, a novel decision-making approach was applied in this study to evaluate the relative importance of these facets, using in-depth expert interviews. The findings underscore pedagogical integration and student engagement as pivotal, indicating the essential role of innovative teaching methodologies integrated with technology. Additionally, accessibility of digital resources emerges as critical, emphasizing the imperative of equitable access to technological tools for diverse student demographics. Lower-ranked criteria such as adaptability and innovation and technological infrastructure, though deemed less critical, are foundational for fostering an agile, innovative, and technology-empowered educational ecosystem. The implications drawn from these findings provide a strategic direction for policymakers and educational stakeholders, aiming to enhance the quality, accessibility, and relevance of higher education in Vietnam's dynamic digital landscape. This framework could be expanded to different educational contexts to effectively integrate technology in learning environments.

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1. INTRODUCTION

The convergence of digital technology and education has heralded a transformative era in the higher education landscape, especially after COVID-19 [1], [2]. Online education quality continues to be a barrier to the evolution of digitalization in education, even as institutions work to adapt and change [3]. Because digital technologies are so dynamic and transformational in educational contexts, evaluating and grading the effects of digitalization on educational quality has become critical [4]. With the speed at which technology is changing curriculum delivery, student engagement, and pedagogical approaches, it is imperative to have a thorough ranking system in place to identify the subtle effects of different digital components [5].

Previous research on the impact of digitalization on higher education quality has yielded invaluable insights into various dimensions of this nexus. Studies have explored diverse aspects, including the effectiveness of online learning platforms [6], the role of digital tools in enhancing student engagement [7], and the accessibility of education through technology [8]. Several research endeavors have focused on the perceptions and experiences of students and educators regarding the integration of digital resources into the

learning environment [9]. While these studies contribute significantly to understanding the surface-level effects of digitalization on higher education, its impact on the quality of online education remains pertinent issue. A discernible research gap persists in the absence of a comprehensive and systematic methodology to rank and prioritize these impacts on higher education online quality. However, current research does not have a consistent framework to measure the effect of various digital features on quality in online education. In view of this fact, it becomes important to formulate a structured approach termed as the spherical fuzzy multi-criteria decision making (SFMCDM) to evaluate and rank these elements systematically. This would fill the gap from which a more systematic comparison of how digitalization influences higher education could be established, and not solely individual qualitative findings.

This research provides a structured framework to evaluate and prioritize the diverse impacts of digitalization. Understanding its effects on technological infrastructure, digital resource accessibility, pedagogical integration, student engagement, and innovation is crucial for guiding strategic decisions by educational institutions and policymakers [10]–[12]. This study aims to bridge the gap between theory and practice, offering a SFAHP methodology to quantify and rank the evolving impact of digitalization on higher education quality.

In this context, the spherical fuzzy analytic hierarchy process (SFAHP) provides a useful framework for assessing and prioritizing digitalization impacts in their inherent multidimensionality. This advanced multi-criteria decision making (MCDM) tool breaks down complex problems into manageable hierarchies, enabling systematic comparisons and precise prioritization. In the context of assessing higher education quality, SFAHP offers a systematic methodology to assess the impact of digital elements on education outcomes that can be used in evaluating quality higher educations.

This paper explores the application of SFAHP in assessing the impact of digitalization on higher education quality. It aims to identify and prioritize key criteria such as technological infrastructure, digital resource accessibility, pedagogical integration, student engagement, and innovation. The study outlines the steps in applying the SFAHP methodology, including hierarchy construction, fuzzy comparisons, weight derivation, and result synthesis. This structured approach aims to guide educational institutions and policymakers in making informed decisions about digitalization strategies to enhance educational quality.

In the subsequent sections, this paper will expound upon the theoretical underpinnings of digitalization in the context of higher education and its impact on higher education quality, present a research methodology focusing on SFAHP, delineate its application via empirical findings, and discuss the implications and potential strategies associated with the results of ranking the impact of digitalization on higher education quality. Finally, the paper provides research conclusions and certain policy implications.

2. LITERATURE REVIEW

The distinctions among terms such as digitization, digitalization, and digital transformation can be perplexing, particularly when employed interchangeably, yet each denotes a specific concept. While digitization involves the conversion of analog entities into digital formats, digitalization and digital transformation are related concepts but differ in scope and depth within the realm of education [13], [14]. Digitalization refers to the adoption and incorporation of digital technologies, tools, and resources within existing processes and systems. In education, it involves the integration of digital tools like learning management systems, online resources, and digital classrooms to enhance specific aspects of teaching, learning, and administrative functions [14]. Digitalization often focuses on automating tasks, improving efficiency, and providing access to digital resources, but may not necessarily change the fundamental approaches to education. On the other hand, digital transformation signifies a fundamental shift in educational paradigm [15]. It involves a holistic and fundamental rethinking of educational models, pedagogical approaches, and administrative systems by leveraging digital technologies. Digital transformation in education goes beyond mere adoption; it encompasses a cultural shift, redefining teaching methods, curriculum design, assessment strategies, and the entire learning experience [16]. It aims to create a more agile, adaptive, and innovative educational environment, often challenging traditional educational structures. Further, digitalization is about incorporating digital tools into existing practices, while digital transformation involves a broader and deeper reimagining of education itself through the pervasive use of digital technologies to create new, more effective educational approaches.

In the context of higher education in developing countries, digitalization is a buffet for digital transformation [17]. The integration of digitalization into education is increasingly prominent, as highlighted by Sysoieva [18]. Scholars emphasize the educational system's role in swiftly transitioning society into a digital age, one that necessitates diverse tools, environments, and readiness for novel employment opportunities. This transformation is not solely for the younger generation, but also aims to prepare individuals of varying ages, including middle-aged and older populations, for the evolving landscape of work. Digitalization encompasses the integration and utilization of digital technologies, tools, and methodologies to enhance teaching, learning, administrative processes, and overall educational experiences [19]. It encompasses the use of digital resources such as online platforms, learning management systems, multimedia content, virtual classrooms, data analytics,

and AI-driven tools to enhance the educational ecosystem. Assessing digitalization in higher education requires evaluating technological infrastructure, resource accessibility, pedagogical integration, student engagement, adaptability, and innovation.

Utilizing information technology is crucial for enhancing educational quality and advancing the digitalization-driven educational revolution. Digital transformation is thus a key factor in the strategic development of educational institutions, as supported by various scholars [20]–[22]. The surge of digital change mirrors a potent force, akin to a sweeping tsunami, reshaping numerous business practices and redefining the educational landscape at a national level [23]. Rather than restricting its use, educators harness technology to empower students, fostering enriched sensory experiences and expanding digital engagements, ultimately fostering deeper learning processes.

The criteria for digitalization in higher education constitute a diverse array of components that collectively establish the standard and efficiency of technology integration within educational environments. These criteria span technological infrastructure, emphasizing the necessity for robust systems and networks to support digital tools and platforms [24]. The technological infrastructure criterion serves as the backbone for the quality of online education in higher education settings, exerting a profound impact on the overall online learning experience [25], [26]. A robust infrastructure is essential for seamless access to digital platforms and resources in online education [27]. Adequate bandwidth, network stability, and hardware are crucial for smooth interactions between students, educators, and learning materials. Effective infrastructure not only supports resource accessibility but also ensures reliable content delivery, minimizing disruptions and enhancing learning. It also enables advanced features like multimedia, interactive tools, and real-time collaboration, enriching the online learning experience. Thus, technological infrastructure is a key factor in shaping the quality and effectiveness of online education.

Accessibility of digital resources is a crucial criterion for ensuring equitable availability for all students, regardless of their location, socioeconomic status, or abilities. It fosters an inclusive online learning environment and enhances student engagement and satisfaction [28]. Easy access to digital resources supports diverse learning experiences and accommodates various learning styles, promoting personalized education. Studies also show that improved accessibility boosts retention rates and academic performance in online higher education [29]. Prioritizing accessibility in digital resources significantly enhances the quality and effectiveness of online education.

In order to enhance learning, the technology should be seamlessly integrated with teaching which is called pedagogical integration. Zhang *et al*. [30] examined the impact of interactive video in e-learning, comparing it with non-interactive video, no video, and traditional classroom settings. Their findings highlighted that interactivity significantly enhances the educational value of video content [30]. Educational simulation-based medical training enhanced learners' performance compared with non-simulation educational formats. Non-interactive video in e-learning did not improve learning outcomes or satisfaction among learners. Effective pedagogical integration of technology is linked to increased student engagement, higher academic achievement, and improved critical thinking in online learning. Blau *et al*. [31] emphasized that well-designed pedagogical strategies enhance digital literacy and collaborative learning, promoting peer-to-peer interaction and knowledge sharing. Their findings highlight the importance of communication and collaboration in fostering student ownership of learning, with teamwork progressing from sharing to cooperation and collaboration.

Student engagement is crucial for fostering collaboration and active learning through digital platforms, enhancing the quality of online higher education [32]. Wong [33] found that active learning via digital tools boosts student motivation and comprehension, while Blakey and Major [34] showed that interactive experiences increase participation and improve academic performance. Active engagement also fosters a sense of community, encouraging collaboration and knowledge sharing, thereby enhancing the overall quality of online education [35].

Adaptability and innovation highlight the evolving nature of digital tools, emphasizing their ability to cater to diverse learning styles and support innovative educational practices [36]. Alamri *et al*. [37] found that adaptive digital tools tailored to individual learning needs significantly enhance outcomes in online education. Innovations like games and augmented reality further boost engagement and knowledge retention [38]. Collins and Halverson [39] noted that adaptable tools allow educators to quickly integrate new technologies, creating a dynamic learning environment. Thus, adaptability and innovation are crucial for enhancing online education by meeting diverse needs and fostering innovative teaching. Together, criteria such as technological infrastructure, accessibility of digital resources, pedagogical integration, student engagement, adaptability, and innovation form a comprehensive framework for evaluating the impact of digitalization on online higher education, emphasizing meaningful technology integration to improve the educational experience.

3. METHOD

The analytic hierarchy process (AHP) is a widely used tool for complex decision making, particularly in scenarios involving multiple criteria [40]–[42]. Its effectiveness is evident across various domains, including economics, technology, and education [43], [44]. AHP excels at integrating insights from

diverse experts and balancing qualitative and quantitative data within a structured framework. It uses pairwise comparisons to quantify qualitative aspects, making it ideal for handling uncertainty in educational assessments. In the SFAHP approach, AHP is combined with spherical fuzzy sets to address ambiguity in expert evaluations, enhancing objectivity by reducing subjective bias. This study leverages SFAHP to systematically rank and prioritize criteria, clarifying the complex factors affecting the impact of digitalization on online higher education quality. Experts' interviews have been comprehensively analyzed based on the SFAHP approach. The deep knowledge and experience in areas of higher education, digital pedagogy and technological integration are criteria for selecting experts. The SFAHP approach is separated into several steps, which are described in this section [45]–[52].

- Step 1. Construct a hierarchical structure of five criteria including accessibility of digital resources, adaptability and innovation, pedagogical integration, student engagement, and technological infrastructure.
- Step 2. Create pairwise comparisons using spherical fuzzy judgment matrices from nine education experts based on language terms in Table 1.

Table 1's score indices (I) are computed using (1) and (2):

$$I = \sqrt{\left|100 \times \left[\left(\omega_{\tilde{A}_{SF}} - \psi_{\tilde{A}_{SF}}\right)^2 - \left(\xi_{\tilde{A}_{SF}} - \psi_{\tilde{A}_{SF}}\right)^2\right]\right|} \quad (1)$$

for AMI, VHI, HI, SMI, and EI:

$$I^{-1} = \frac{1}{\sqrt{\left|100 \times \left[\left(\omega_{\tilde{A}_{SF}} - \psi_{\tilde{A}_{SF}}\right)^2 - \left(\xi_{\tilde{A}_{SF}} - \psi_{\tilde{A}_{SF}}\right)^2\right]\right|}} \quad (2)$$

for EI, SLI, LI, VLI, and ALI where, $\omega_{\tilde{A}_{SF}}$, $\xi_{\tilde{A}_{SF}}$, and $\psi_{\tilde{A}_{SF}}$ represent membership, non-membership, and hesitancy degrees, respectively, of spherical fuzzy set $\tilde{A}_{SF}$.

- Step 3. Verify the consistency ratio (CR) of each pairwise comparison matrix. The CR has a 10% threshold.
- Step 4. Determine the spherical fuzzy weights of higher education quality components amidst the era of digitalization and defuzzify their weights using (3) and (4):

$$W_w = \left\{\left[1 - \prod_{j=1}^{n}\left(1 - \alpha_{\tilde{A}_{SF_{ij}}}^2\right)^{w_j}\right]^{1/2}, \prod_{j=1}^{n} \beta_{\tilde{A}_{S_{ij}}}^{w_j}, \left[\prod_{j=1}^{n}\left(1 - \alpha_{\tilde{A}_{SF_{ij}}}^2\right)^{w_j} - \prod_{j=1}^{n}\left(1 - \alpha_{\tilde{A}_{SF_{ij}}}^2 - \chi_{\tilde{A}_{SF_{ij}}}^2\right)^{w_j}\right]^{1/2}\right\} \quad (3)$$

$$SF(\tilde{w}_j^{SF}) = \sqrt{\left|100 \times \left[\left(3\alpha_{\tilde{A}_{SF}} - \frac{\chi_{\tilde{A}_{SF}}}{2}\right)^2 - \left(\frac{\beta_{\tilde{A}_S}}{2} - \chi_{\tilde{A}_{SF}}\right)^2\right]\right|} \quad (4)$$

Table 1. Linguistic measures of importance used for pairwise comparisons [53]–[57]

Education experts	(ω, ξ, ψ)	Score index
Absolutely more importance (AMI)	(0.9, 0.1, 0.0)	9
Very high importance (VHI)	(0.8, 0.2, 0.1)	7
High importance (HI)	(0.7, 0.3, 0.2)	5
Slightly more importance (SMI)	(0.6, 0.4, 0.3)	3
Equal importance (EI)	(0.5, 0.4, 0.4)	1
Slightly low importance (SLI)	(0.4, 0.6, 0.3)	1/3
Low importance (LI)	(0.3, 0.7, 0.2)	1/5
Very low importance (VLI)	(0.2, 0.8, 0.1)	1/7
Absolutely low importance (ALI)	(0.1, 0.9, 0.0)	1/9

4. RESULTS AND DISCUSSION

The prioritization of key factors impacting the higher education quality in Vietnam's digitalization context has been determined after analyzing experts' interviews. Unlike previous studies in which the importance of specific criteria in enhancing the quality of online higher education in Vietnam has not been thoroughly addressed, this paper provides empirical insights into these critical factors. The resulting weights for the dimensions in the hierarchical SFAHP model based on pairwise comparisons are in Table 2. The "criteria" column outlines the various factors considered in the decision-making process. The "priority weight" column represents its

relative importance within the decision hierarchy. The "rank" column enumerates the order of importance, with "1" denoting the most crucial criterion and subsequent numbers indicating decreasing levels of significance.

Table 2. The priority of multifaceted dimensions of digitalization in higher education

Criteria	Priority weight	Rank
Accessibility of digital resources (C1)	0.203	3
Adaptability and innovation (C2)	0.184	4
Pedagogical integration (C3)	0.236	1
Student engagement (C4)	0.212	2
Technological infrastructure (C5)	0.165	5

The SFAHP analysis yielded prioritized criteria indicating their relative importance within the decision framework. Among the identified criteria, pedagogical integration emerges as the most pivotal, securing the top rank with a priority of 23.6%. This is followed by student engagement, holding the second position with a priority of 21.2%. The hierarchy continues with accessibility of digital resources occupying the third spot at 20.3%, emphasizing its significant albeit relatively lower importance in comparison to the preceding criteria. Adaptability and innovation, accounting for 18.4%, and technological infrastructure, with 16.5%, round up the hierarchy, indicating their comparatively lesser influence on the decision process. Overall, these results provide a clear hierarchy of criteria, offering valuable insights to aid in decision making by highlighting the varying degrees of importance among the factors considered. The findings have integrated the experts' views into highlighting the factors' weights which converts to strategic decision-making processes in education. The disclosure of non-obvious insights into the prioritizatio of factors in the rapidly developed digital context is the key innovative aspect of this study.

The ranking of various factors in digitalization's impact on higher education online quality, including pedagogical integration, student engagement, accessibility of digital resources, adaptability and innovation, technological infrastructure in Vietnamese universities, was a central focus of this research. The SFAHP analysis underscores pedagogical integration as the top-ranked criterion, aligning with findings from various studies emphasizing its paramount importance in educational settings. The experts' perspectives have been carefully analyzed to ensure that the priorities accurately reflect the Vietnamese context. Within the landscape of higher education's online domain in Vietnam and the adoption of digitalization, this result holds profound implications. It suggests that effectively intertwining teaching methodologies with technology could serve as a pivotal key to enhancing the quality of online education in Vietnam. Emphasizing a cohesive relationship between teaching approaches and technology might offer an opportunity to optimize the online learning experience, fostering holistic advancements in higher education amidst the era of digital transformation [58], [59]. This insight could guide strategies aimed at elevating the standards of online education, accentuating the significance of integrating effective pedagogical practices with technological advancements to shape a more robust educational landscape in Vietnam. Integrating pedagogical approaches into higher education in Vietnam involves a strategic fusion of teaching methodologies with digital tools to elevate the quality of online learning. This initiative encompasses several key facets. Firstly, curriculum development must align with innovative teaching strategies that leverage technology to create engaging online experiences. Equipping educators with training in digital pedagogy is vital, enabling them to proficiently use educational technologies and interactive methods. Creating collaborative online platforms, implementing technology-enabled assessment tools, and fostering continuous improvement mechanisms are essential for enhancing learning outcomes. Moreover, ensuring equitable access to digital resources among students from diverse backgrounds is imperative. By embracing pedagogical integration, Vietnam can not only support the effectiveness of online education, but also equip learners with crucial skills of the digital era, fostering a more competitive and adaptable educational landscape.

Student engagement, the second-ranked criterion, bears substantial relevance within Vietnam's higher education landscape, particularly in the sphere of online learning [60], [61]. Enhancing student engagement is pivotal as it directly influences learning outcomes and the overall educational experience [33]. Strategies tailored for Vietnam could encompass various approaches to bolster engagement in online education. Creating interactive digital platforms incorporating multimedia tools, forums, and collaborative spaces fosters active participation and peer interaction. Moreover, personalized learning experiences, adaptive systems, and innovative teaching methods like gamification and project-based learning cater to diverse learning preferences, fostering deeper engagement. Building a sense of community among online learners through collaborative activities and effective communication channels further amplifies engagement levels. By prioritizing student engagement in online education, Vietnam can nurture a more dynamic and fulfilling learning environment, propelling academic achievement and student satisfaction within the digital realm.

The third-ranked criterion, accessibility of digital resources, holds the main significance in Vietnam's higher education, particularly within the realm of online learning [60], [62]. It highlights the vital need for ensuring the availability and ease of access to essential technological tools and educational materials. Elevating accessibility involves strategies aimed at providing equitable access to digital resources for all students, irrespective of their geographical location or socioeconomic background. This encompasses initiatives such as developing robust technological infrastructure across urban and rural areas, establishing centralized repositories of educational materials, and designing user-friendly online platforms accessible on diverse devices. Additionally, providing training and technical support for students and educators and adhering to accessibility standards further enhances the accessibility of digital resources. Prioritizing accessibility in Vietnam's higher education landscape not only fosters educational equity, but also empowers a wider spectrum of learners to actively engage in online education, contributing to a more inclusive and enriched learning environment across the country.

The criteria of adaptability and innovation, as well as technological infrastructure, though ranked lower in the hierarchy, remain integral in shaping the landscape of higher education in Vietnam, especially in the context of digitalization. Adaptability and innovation criterion emphasizes the capacity of educational institutions to evolve and innovate in response to changing educational landscapes. In the Vietnamese context, fostering adaptability and innovation involves cultivating a culture that embraces emerging trends, pedagogical methodologies, and technological advancements. Encouraging educators to experiment with new teaching methods, integrating emerging technologies, and adapting swiftly to evolving learning needs could significantly impact the quality of education. In terms of technological infrastructure, while it is ranked lower, the criterion of technological infrastructure outlines the foundational support required for effective digital education. Vietnam's investment in robust technological infrastructure, including internet accessibility and digital devices, plays a fundamental role in bridging the digital divide. Strengthening this infrastructure across all regions ensures equitable access to online education, empowering students and educators to fully engage in digital learning experiences [63], [64]. Both adaptability and innovation, along with technological infrastructure, are fundamental components underpinning the successful implementation of online education in Vietnam. While they might hold lower priority in the hierarchy, they form the backbone of an adaptable, innovative, and technologically empowered educational ecosystem, enabling sustainable advancements in higher education. Emphasizing these criteria in educational policies and institutional strategies can significantly contribute to the holistic development of Vietnam's higher education landscape in the digital age.

In summary, the superiory of pedagogical integration to technological infrastructure is innovative. This finding challenges the traditional notion of prioritizing infrastructure in digital education. Instead, the focus should position towards teaching methodologies, which are the core of successful online learning outcomes. Moreover, the interconnection of pedagogy and technology is emphasized. Such integration is the driver for quality enhancement. Therefore, the investment into either pedagogy or technology separately could not reach the expected outcomes. Finally, student engagement with digital resources, which has not been thoroughly emphasized in prior studies, is proven to significantly influence online learning success.

5. CONCLUSION

SFAHP rankings provide a clear understanding of the key elements influencing Vietnam's higher education in the digital age. Pedagogical integration and student engagement emerged as top priorities, highlighting the importance of innovative teaching methodologies paired with technology for effective online education. The focus on digital resource accessibility underscores the need for equitable access across diverse student demographics. Although adaptability, innovation, and technological infrastructure rank lower, their role in fostering a flexible and innovative educational ecosystem remains essential.

Strategic emphasis on pedagogical integration should encourage collaboration between educators and technologists to develop technology-driven teaching methods. Student engagement policies must prioritize interactive and personalized learning experiences, community building, and inclusivity. Enhancing digital accessibility, especially in underserved areas, requires investments in robust infrastructure to bridge the digital divide. Promoting adaptability and innovation within institutions calls for policies supporting experimentation with emerging technologies and continuous learning among educators. Investing in technological infrastructure is critical for ensuring reliable access to digital resources. Additionally, professional development in digital pedagogy is essential to empower educators to integrate technology effectively into their teaching. While this study offers valuable insights, its reliance on expert evaluations may not fully capture the perspectives of other stakeholders. Future research should consider broader viewpoints and explore how digital pedagogy innovation might influence the prioritization of these factors to optimize online education.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflict of interest.

DATA AVAILABILITY

Derived data supporting the findings of this study are available from the corresponding author, [PTN], upon request where appropriate.

REFERENCES

[1] A. Marks and M. Al-Ali, "Digital transformation in higher education: a framework for maturity assessment," in *COVID-19 Challenges to University Information Technology Governance*, Cham: Springer International Publishing, 2022, pp. 61–81, doi: 10.1007/978-3-031-13351-0_3.

[2] E. Martyakova and E. Gorchakova, "Quality education and digitalization of the economy," in *Lecture Notes in Mechanical Engineering*, pp. 212–21, 2019, doi: 10.1007/978-3-030-18180-2_17.

[3] V. J. García-Morales, A. Garrido-Moreno, and R. Martín-Rojas, "The Transformation of higher education after the COVID disruption: emerging challenges in an online learning scenario," *Frontiers in Psychology*, vol. 12, Feb. 2021, doi: 10.3389/fpsyg.2021.616059.

[4] A. Djakona, R. Lavrov, L. Anisimova, O. Koval, M. Polkhovska, and S. Shumaieva, "Digital technologies and rankings as tools of the competitiveness in the educational services market," *IJCSNS International Journal of Computer Science and Network Security*, vol. 21, no. 11, 2021, doi: 10.22937/IJCSNS.2021.21.11.7.

[5] T. Volery and D. Lord, "Critical success factors in online education," *International Journal of Educational Management*, vol. 14, no. 5, pp. 216–223, Sep. 2000, doi: 10.1108/09513540010344731.

[6] R. S. Al-Maroof *et al.*, "The effectiveness of online platforms after the pandemic: will face-to-face classes affect students' perception of their behavioural intention (BIU) to use online platforms?" *Informatics*, vol. 8, no. 4, 2021, doi: 10.3390/informatics8040083.

[7] S. Gopinathan, A. H. Kaur, S. Veeraya, and M. Raman, "The role of digital collaboration in student engagement towards enhancing student participation during COVID-19," *Sustainability (Switzerland)*, vol. 14, no. 11, p. 6844, Jun. 2022, doi: 10.3390/su14116844.

[8] J. Martín-Gutiérrez, C. E. Mora, B. Añorbe-Díaz, and A. González-Marrero, "Virtual technologies trends in education," *Eurasia Journal of Mathematics, Science and Technology Education*, vol. 13, no. 2, 2017, doi: 10.12973/eurasia.2017.00626a.

[9] K. Xie, M. J. Nelson, S. L. Cheng, and Z. Jiang, "Examining changes in teachers' perceptions of external and internal barriers in their integration of educational digital resources in K-12 classrooms," *Journal of Research on Technology in Education*, vol. 55, no. 2, pp. 281–306, Mar. 2023, doi: 10.1080/15391523.2021.1951404.

[10] P. Ingavelez-Guerra, V. E. Robles-Bykbaev, A. Perez-Munoz, J. Hilera-Gonzalez, and S. Oton-Tortosa, "Automatic adaptation of open educational resources: an approach from a multilevel methodology based on students' preferences, educational special needs, artificial intelligence and accessibility metadata," *IEEE Access*, vol. 10, pp. 9703–9716, 2022, doi: 10.1109/ACCESS.2021.3139537.

[11] A. N. Diep, C. Zhu, K. Struyven, and Y. Blieck, "Who or what contributes to student satisfaction in different blended learning modalities?" *British Journal of Educational Technology*, vol. 48, no. 2, pp. 473–489, Mar. 2017, doi: 10.1111/bjet.12431.

[12] C. Rapanta, L. Botturi, P. Goodyear, L. Guàrdia, and M. Koole, "Balancing technology, pedagogy and the new normal: post-pandemic challenges for higher education," *Postdigital Science and Education*, vol. 3, no. 3, 2021, doi: 10.1007/s42438-021-00249-1.

[13] C. Mahlow and A. Hediger, "digital transformation in higher education-buzzword or opportunity?" *eLearn*, vol. 2019, no. 5, 2019, doi: 10.1145/3329488/3331171.

[14] L. Gorina, M. Gordova, I. Khristoforova, L. Sundeeva, and W. Strielkowski, "Sustainable education and digitalization through the prism of the COVID-19 pandemic," *Sustainability (Switzerland)*, vol. 15, no. 8, p. 6846, Apr. 2023, doi: 10.3390/su15086846.

[15] J. M. Balkin and J. Sonnevend, "The digital transformation of education," in *Education and Social Media: Toward a Digital Future*, pp. 9–24, 2016, doi: 10.7551/mitpress/9780262034470.003.0002.

[16] A. Marks, M. AL-Ali, and K. Rietsema, "Learning management systems: a shift toward learning and academic analytics," *International Journal of Emerging Technologies in Learning*, vol. 11, no. 4, pp. 77–82, Apr. 2016, doi: 10.3991/ijet.v11i04.5419.

[17] V. Davydenko, A. Kuznetsova, and N. Chichik, "Impact of digitalization trends on the development of the Russian system of advanced training and methodological support for teachers," in *ACM International Conference Proceeding Series*, Mar. 2021, pp. 1–7, doi: 10.1145/3487757.3490929.

[18] S. Sysoieva, "Digitalization of education: pedagogcial priorities," *Education: Modern Discourses*, vol. 4, pp. 14–22, 2021.

[19] J. T. Schmidt and M. Tang, "Digitalization in education: challenges, trends and transformative potential," in *Führen und Managen in der digitalen Transformation*, Wiesbaden: Springer Fachmedien Wiesbaden, 2020, pp. 287–312, doi: 10.1007/978-3-658-28670-5_16.
[20] J. P. Marcolini, "Curricula for sustainability in higher education," *Journal of Ethnic and Cultural Studies*, vol. 4, no. 2, 2017.
[21] Z. Öztürkler, "Evaluation of technology strategies as quality strategy of higher education institutions," *Eurasia Journal of Mathematics, Science and Technology Education*, vol. 13, no. 7, pp. 4021–4033, Jun. 2017, doi: 10.12973/eurasia.2017.00770a.
[22] B. L. Adams, "The far reaching impact of transformative curriculum: a narrative critical ethnographic case study," *Journal of Curriculum Studies Research*, vol. 1, no. 1, pp. 17–32, Dec. 2019, doi: 10.46303/jcsr.01.01.2.
[23] W. F. Crittenden, I. K. Biel, and W. A. Lovely, "Embracing digitalization: student learning and new technologies," *Journal of Marketing Education*, vol. 41, no. 1, pp. 5–14, 2019, doi: 10.1177/0273475318820895.
[24] P. Landri, *Digital governance of education: technology, standards and europeanization of education*. *Bloomsbury Publishing*, pp. 1–172, 2018.
[25] W. Ali, "Online and remote learning in higher education institutes: a necessity in light of COVID-19 pandemic," *Higher Education Studies*, vol. 10, no. 3, p. 16, May 2020, doi: 10.5539/hes.v10n3p16.
[26] D. G. Giday and E. Perumal, "Students' perception of attending online learning sessions post-pandemic," *Social Sciences and Humanities Open*, vol. 9, p. 100755, 2024, doi: 10.1016/j.ssaho.2023.100755.
[27] W. Bank, "Remote learning and COVID-19: the use of educational technologies at scale across an education system as a result of massive school closings in response to the COVID-19 pandemic to enable distance education and online learning," *Remote Learning and COVID-19*, no. March 16, pp. 1–12, 2020.
[28] S. Z. Salas-Pilco, Y. Yang, and Z. Zhang, "Student engagement in online learning in Latin American higher education during the COVID-19 pandemic: a systematic review," *British Journal of Educational Technology*, vol. 53, no. 3, 2022, doi: 10.1111/bjet.13190.
[29] J. Field and E. Kurantowicz, "Retention and access in higher education: implications for policy and practice," *Student Voices on Inequalities in European Higher Education: Challenges for Theory, Policy and Practice in a Time of Change*, pp. 163–168, 2014, doi: 10.4324/9780203526088.
[30] D. Zhang, L. Zhou, R. O. Briggs, and J. F. Nunamaker, "Instructional video in e-learning: assessing the impact of interactive video on learning effectiveness," *Information and Management*, vol. 43, no. 1, pp. 15–27, Jan. 2006, doi: 10.1016/j.im.2005.01.004.
[31] I. Blau, T. Shamir-Inbal, and O. Avdiel, "How does the pedagogical design of a technology-enhanced collaborative academic course promote digital literacies, self-regulation, and perceived learning of students?" *Internet and Higher Education*, vol. 45, p. 100722, Apr. 2020, doi: 10.1016/j.iheduc.2019.100722.
[32] M. Habib, "Digital transformation strategy for developing higher education in conflict-affected societies," *Social Sciences and Humanities Open*, vol. 8, no. 1, p. 100627, 2023, doi: 10.1016/j.ssaho.2023.100627.
[33] L. Wong, "Student engagement with online resources and its impact on learning outcomes," *Journal of Information Technology Education: Innovations in Practice*, vol. 12, pp. 129–146, 2013, doi: 10.28945/1829.
[34] C. H. Blakey and C. H. Major, "Student perceptions of engagement in online courses: an exploratory study," *Online Journal of Distance Learning Administration*, vol. 22, no. 4, pp. 1–11, 2022.
[35] M. Pinto and C. Leite, "Digital technologies in support of students learning in higher education: literature review," *Digital Education Review*, no. 37, pp. 343–360, 2020, doi: 10.1344/DER.2020.37.343-360.
[36] M. Osmani, N. M. Hindi, and V. Weerakkody, "Developing employability skills in information system graduates: Traditional vs. innovative teaching methods," in *Research Anthology on Developing Critical Thinking Skills in Students*, IGI Global, pp. 1331–1344, 2020, doi: 10.4018/978-1-7998-3022-1.ch069.
[37] H. Alamri, V. Lowell, W. Watson, and S. L. Watson, "Using personalized learning as an instructional approach to motivate learners in online higher education: Learner self-determination and intrinsic motivation," *Journal of Research on Technology in Education*, vol. 52, no. 3, pp. 322–352, Jul. 2020, doi: 10.1080/15391523.2020.1728449.
[38] G. Lampropoulos, E. Keramopoulos, K. Diamantaras, and G. Evangelidis, "Augmented reality and gamification in education: a systematic literature review of research, applications, and empirical studies," *Applied Sciences (Switzerland)*, vol. 12, no. 13, p. 6809, Jul. 2022, doi: 10.3390/app12136809.
[39] A. Collins and R. Halverson, *Rethinking education in the age of technology: the digital revolution and schooling in America*. New York, 2018.
[40] P. V. Nguyen, P. T. Nguyen, Q. L. H. T. T. Nguyen, and V. D. B. Huynh, "Calculating weights of social capital index using analytic hierarchy process," *International Journal of Economics and Financial Issues*, vol. 6, no. 3, pp. 1189–1193, 2016.
[41] M. Tavana, M. Soltanifar, and F. J. Santos-Arteaga, "Analytical hierarchy process: revolution and evolution," *Annals of Operations Research*, vol. 326, no. 2, pp. 879–907, Jul. 2023, doi: 10.1007/s10479-021-04432-2.
[42] O. S. Vaidya and S. Kumar, "Analytic hierarchy process: an overview of applications," *European Journal of Operational Research*, vol. 169, no. 1, pp. 1–29, Feb. 2006, doi: 10.1016/j.ejor.2004.04.028.
[43] T. Saaty and L. Vargas, "Models, methods, concepts & applications of the analytic hierarchy process," *Springer Science & Business Media*, vol. 175, 2012, doi: 10.1007/978-1-4614-3597-6.
[44] V. Podvezko, "Application of AHP technique," *Journal of Business Economics and Management*, vol. 10, no. 2, pp. 181–189, 2009, doi: 10.3846/1611-1699.2009.10.181-189.
[45] F. K. Gündoğdu and C. Kahraman, "A novel spherical fuzzy QFD method and its application to the linear delta robot technology development," *Engineering Applications of Artificial Intelligence*, vol. 87, 2020, doi: 10.1016/j.engappai.2019.103348.
[46] I. U. Sari and C. Kahraman, "Intuitionistic fuzzy z-numbers BT - intelligent and fuzzy techniques: smart and innovative solutions", *Cham: Springer International Publishing*, vol. 1197, 2021, doi: 10.1007/978-3-030-51156-2.
[47] S. Moslem, "A novel parsimonious spherical fuzzy analytic hierarchy process for sustainable urban transport solutions," *Engineering Applications of Artificial Intelligence*, vol. 128, p. 107447, Feb. 2024, doi: 10.1016/j.engappai.2023.107447.
[48] G. Candan and M. C. Toklu, "Sustainable industrialization performance evaluation of European Union countries: an integrated spherical fuzzy analytic hierarchy process and grey relational analysis approach," *International Journal of Sustainable Development and World Ecology*, vol. 29, no. 5, pp. 387–400, Jul. 2022, doi: 10.1080/13504509.2022.2027293.
[49] O. Dogan, "Process mining technology selection with spherical fuzzy AHP and sensitivity analysis," *Expert Systems with Applications*, vol. 178, p. 114999, Sep. 2021, doi: 10.1016/j.eswa.2021.114999.
[50] J. Ortega, S. Moslem, and D. Esztergár-Kiss, "An integrated approach of the AHP and spherical fuzzy sets for analyzing a park-and-ride facility location problem example by heterogeneous experts," *IEEE Access*, vol. 11, 2023, doi: 10.1109/ACCESS.2023.3281865.
[51] K. Shahzad *et al.*, "Analysis of obstacles to adoption of solar energy in emerging economies using spherical fuzzy AHP decision support system: A case of Pakistan," *Energy Reports*, vol. 10, pp. 381–395, Nov. 2023, doi: 10.1016/j.egyr.2023.06.015.
[52] P. H. Nguyen, L. A. T. Nguyen, H. A. T. Pham, and M. A. T. Pham, "Breaking ground in ESG assessment: integrated DEA and MCDM framework with spherical fuzzy sets for Vietnam's wire and cable sector," *Journal of Open Innovation: Technology, Market, and Complexity*, vol. 9, no. 3, p. 100136, Sep. 2023, doi: 10.1016/j.joitmc.2023.100136.

[53] F. K. Gündoğdu and C. Kahraman, "A novel spherical fuzzy analytic hierarchy process and its renewable energy application," *Soft Computing*, vol. 24, no. 6, pp. 4607–4621, Mar. 2020, doi: 10.1007/s00500-019-04222-w.
[54] C. Kahraman and F. K. Gündogdu, "Decision making with spherical fuzzy sets," *Cham: Springer International Publishing*, vol. 392, 2021, doi: 10.1007/978-3-030-45461-6.
[55] F. K. Gündoğdu and C. Kahraman, "Spherical fuzzy analytic hierarchy process (AHP) and its application to industrial robot selection," in *Intelligent and Fuzzy Techniques in Big Data Analytics and Decision Making: Proceedings of the INFUS 2019 Conference*, vol. 1029, 2019, pp. 23–25, doi: 10.1007/978-3-030-23756-1_117.
[56] C. T. Lorio *et al.*, "Optimal treatment technology selection for acid mine drainage via spherical fuzzy analytic hierarchy process," *Minerals Engineering*, vol. 202, 2023, doi: 10.1016/j.mineng.2023.108260.
[57] S. Tepe, "Coding program selection using spherical fuzzy analytic hierarchy and pythagorean fuzzy analytic hierarchy processes," *Academic Platform Journal of Engineering and Smart Systems*, vol. 11, no. 1, pp. 11–18, Jan. 2023, doi: 10.21541/apjess.1143964.
[58] C. González, "The relationship between approaches to teaching, approaches to e-teaching and perceptions of the teaching situation in relation to e-learning among higher education teachers," *Instructional Science*, vol. 40, no. 6, 2012, doi: 10.1007/s11251-011-9198-x.
[59] G. Kurt, D. Atay, and H. A. Öztürk, "Student engagement in K12 online education during the pandemic: the case of Turkey," *Journal of Research on Technology in Education*, vol. 54, no. sup1, pp. S31-S47, 2022, doi: 10.1080/15391523.2021.1920518.
[60] L. T. Pham and T. K. T. Dau, "Online learning readiness and online learning system success in Vietnamese higher education," *International Journal of Information and Learning Technology*, vol. 39, no. 2, pp. 147–165, 2022, doi: 10.1108/IJILT-03-2021-0044.
[61] G. T. T. Trinh, "Examining the impacts of out-of-class student engagement on student competencies in the context of business students in Vietnam–evidence from universities in Hanoi," *Journal of Applied Research in Higher Education*, vol. 16, no. 2, pp. 446-468, 2024, doi: 10.1108/JARHE-09-2022-0297.
[62] S. Alphonce and K. Mwantimwa, "Students' use of digital learning resources: diversity, motivations and challenges," *Information and Learning Science*, vol. 120, no. 11–12, pp. 758–772, Nov. 2019, doi: 10.1108/ILS-06-2019-0048.
[63] A. Lahiya and S. Mokodenseho, "Examining the relationship between technological infrastructure and the quality of online education programs," *West Science Interdisciplinary Studies*, vol. 1, no. 02, pp. 74–83, 2023, doi: 10.1007/s11528-024-01005-5.
[64] J. A. Machusky and K. G. Herbert-Berger, "Understanding online learning infrastructure in U.S. K-12 schools: a review of challenges and emerging trends," *International Journal of Educational Research*, vol. 114, 2022, doi: 10.1016/j.ijer.2022.101993.

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