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Article

Navigating online learning challenges and educational infrastructure in times of crisis: Insights and solutions among Thai engineering students utilizing a mixed-methods analysis

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Abstract: The rapid shift to online learning during COVID-19 posed challenges for students. This investigation explored these hurdles and suggested effective solutions using mixed methods. By combining a literature review, interviews, surveys, and the analytic hierarchy process (AHP), the study identified five key challenges: lack of practical experience, disruptions in learning environments, condensed assessments, technology and financial constraints, and health and mental well-being concerns. Notably, it found differences in priorities among students across academic years. Freshmen struggled with the absence of hands-on courses, sophomores with workload demands, and upperclassmen with mental health challenges. The research also discussed preferred strategies for resolution, emphasizing independent learning methods, managing distractions, and adjusting assessments. By providing tailored insights, this study aimed to enhance online learning. Governments and universities should support practical work, prioritize student well-being, improve digital infrastructure, adapt assessments, foster innovation, and ensure resilience.

Keywords: online learning; student challenges; engineering education; Thai undergraduate engineering students; analytic hierarchy process; COVID-19

1. Introduction

The global outbreak of the COVID-19 pandemic necessitated unprecedented measures in higher education, prompting a rapid transition from traditional face-to-face instruction to online learning modalities. This abrupt shift posed significant challenges for students, educators, and institutions worldwide, particularly in disciplines traditionally reliant on hands-on experiences, such as engineering education (Hora et al., 2016). Moreover, amidst this transition, Thai undergraduate engineering students encountered unique obstacles, compounded by pre-existing educational inequalities and limited access to technology within the country's developing context (UNESCO, 2020).

Acknowledging the Ministry of Higher Education, Science, Research, and Innovation's mandate for universities to adopt online learning in 2020, it was evident that the swift transition lacked adequate preparation, resulting in a myriad of challenges for both students and educators. Consequently, to address these challenges effectively, there was a critical need for research that delved into the specific experiences of Thai undergraduate engineering students and proposed tailored solutions to optimize the online learning milieu.

Hence, this study aims to investigate the challenges encountered by Thai undergraduate engineering students during the transition to online learning amidst the COVID-19 pandemic. The study aimed to identify the varying priorities and concerns of undergraduate engineering students across different academic years regarding online learning challenges. It also sought to explore students' perspectives on potential solutions and strategies to address these challenges. Additionally, the study prioritized the identified challenges and proposed solutions using the analytic hierarchy process (AHP) technique, considering the relative importance assigned by students from different academic years.

Understanding the nuanced challenges faced by Thai undergraduate engineering students in adapting to online learning was crucial for informing targeted interventions and policy decisions. This study aimed to provide actionable insights by exploring student perspectives and priorities, enhancing the effectiveness and inclusivity of online learning practices within the Thai higher education context. The utilization of the AHP technique ensured systematic prioritization of proposed solutions to address the most pressing challenges identified by students.

2. Literature review

2.1. Global challenges in online learning

The rapid transition to online learning during the COVID-19 pandemic exposed and exacerbated several challenges inherent in this educational modality. Technological and infrastructural disparities became evident as unequal access to reliable internet connections, devices, and software hindered student participation, particularly in developing countries and among marginalized populations (Dhawan, 2020; Selwyn, 2004). This digital divide not only limited access but also created frustration and decreased motivation for those without adequate resources or digital literacy skills (Coman et al., 2020).

The shift to online learning also necessitated significant pedagogical adaptations. Online environments often struggled to replicate the social dynamics and interactions of traditional classrooms, leading to decreased student engagement and motivation (Ali, 2020). Thus, effective online learning required more than simply transferring traditional teaching methods to a virtual platform. Course design, assessments, and instructor-student interactions had to be intentionally adapted to the online format to ensure effectiveness (Sangrà et al., 2012).

Furthermore, academic integrity emerged as a major concern in online environments. The potential for both intentional and unintentional academic misconduct increased, challenging the ability to uphold learning integrity through reliable assessments (Harmon and Lambrinos, 2008). In addition to academic challenges, the prolonged nature of online learning negatively impacted students' mental well-being. Increased feelings of isolation, blurred boundaries between study and personal life, and heightened stress and anxiety became prevalent issues (Aristovnik et al., 2020).

2.2. International experiences and lessons learned

The challenges of online learning were not unique to any single country. Studies conducted across the globe revealed both common themes and variations in how these challenges manifested and were addressed. Research with Albanian university students (Xhelili et al., 2021) highlighted issues with internet connectivity, limited access to technology, and unfamiliarity with online learning modalities, leading to calls for increased teacher support. In Sri Lanka, IT students (Akuratiya and Meddage, 2020) primarily lamented the reduced interaction with professors and peers, along with technical difficulties hindering active participation. Malaysian studies (Al-Kumaim et al., 2021; Razami and Ibrahim, 2021) pointed to excessive workloads, unfamiliarity with online platforms, and health-related issues like stress and anxiety. A study in Jordan (Malkawi and Mohailan, 2022) focused on the impact of e-learning systems on student performance, emphasizing the importance of system readiness and diverse teaching methodologies. In Indonesia, research by Hasniati (2022) revealed that online learning faced significant obstacles due to deficiencies in physical infrastructure, internet accessibility, and technological proficiency. Maqableh and Alia (2021) identified technological hurdles, mental health concerns, and time management issues among undergraduate students during the COVID-19 lockdown, offering recommendations to enhance online learning environments.

In the United Arab Emirates, Mushtaha et al. (2022) examined the transition to online learning at the University of Sharjah, finding that while online learning offered flexibility, it also presented challenges related to mental health, socialization, and academic performance, particularly for engineering students and faculty. The study recommended a hybrid learning model that combines face-to-face and online elements.

In Nordic countries, Gumaelius et al. (2024) explored how engineering education adapted to digital transformation. Interviews with 20 university teachers revealed that valuing digital knowledge, generational differences, and universities' role in innovation were key factors. The study emphasized the need for reevaluating the purpose of digitalization, providing ongoing teacher training, and enhancing educational development in the digital age at universities.

In the United States, Asgari et al. (2021) investigated the challenges of transitioning to online engineering education at California State University, Long Beach. Surveys of faculty and students revealed issues such as logistical/technical problems, learning hurdles, and concerns about privacy/security. Recommendations included providing equipment/training, improving communication, and adopting effective assessment methods to enhance online engineering education.

Popescu et al. (2022) explored the shift to online learning in engineering education at the University of Craiova, Romania. They found challenges such as limited equipment access, reduced practical skills development, decreased motivation, and communication difficulties. Their solution involved a hybrid learning model, integrating online simulations, virtual labs, and increased interaction in online classes. Kapilan et al. (2021) found success in implementing virtual laboratories for mechanical engineering students in India, demonstrating the potential of innovative approaches to address the lack of hands-on experience. Buzatu et al. (2020) found that students were uncertain about the quality of online education compared to onsite settings, highlighting the importance of a smooth transition to online learning.

These international experiences emphasized the necessity of comprehensive approaches addressing technological, pedagogical, and social-emotional aspects of online learning. Successful implementation of virtual laboratories and innovative teaching methods in some contexts indicated that with careful planning and adaptation, online learning could be a viable and effective mode of education, even in disciplines like engineering that traditionally relied on in-person instruction.

2.3. Online learning in Thailand

In the Thai context, research has highlighted specific challenges faced by university students. Aroonsrimarakot et al. (2023) identified technological limitations, inadequate teaching methods, distractions, and decreased motivation as major obstacles. Wattanakasiwich et al. (2021) advocated for student-centered learning environments in Thai higher education to mitigate these challenges, while Muangmee et al. (2021) explored factors influencing the adoption of e-learning tools. Farsawang and Songkram (2023) examined determinants impacting Thai university students' inclinations towards online learning, suggesting tailored courses, flexibility, and refined assessment techniques.

Despite these efforts, specific challenges persisted in engineering education. Practical experience and hands-on learning were critical components of engineering programs, which were difficult to replicate in an online environment. This gap underscored the need for innovative solutions, such as virtual labs and simulation tools, to provide practical experience remotely.

2.4. AHP technique in educational decision-making

The analytic hierarchy process (AHP) was a multi-criteria decision-making tool widely used for prioritizing complex issues with multiple factors at play (Saaty, 1980). The AHP allowed decision-makers to structure complex problems by decomposing them into a hierarchy of criteria, sub-criteria, and alternatives (Saaty, 1980). Pairwise comparisons were then conducted to determine the relative importance of each element within the hierarchy. It was important to acknowledge limitations associated with the AHP technique. The reliance on subjective judgments during pairwise comparisons could introduce bias (Ishizaka and Siraj, 2018). Additionally, the AHP might have struggled to capture the full complexity of educational decision-making, which often involved qualitative and non-quantifiable factors alongside quantitative data (Roy, 2010).

Mohammed et al. (2018) conducted an evaluation of e-learning methodologies, utilizing the analytic hierarchy process (AHP) to assess five key e-learning evaluation criteria. They subsequently evaluated the performance of e-learning approaches across five reporting methods within each criterion, determining overall effectiveness using the TOPSIS technique. Results from public universities in Malaysia highlighted strategic readiness as the foremost consideration for e-learning implementation, emphasizing its pivotal role in enhancing the educational process. In a similar vein, Ding et al. (2023) employed the analytic hierarchy process (AHP) to assess online teaching quality, specifically in instrument analysis courses at universities. Their use of AHP aimed to enhance assessment methodologies' accuracy and efficiency in this domain, contributing to a more comprehensive understanding of online teaching effectiveness.

Likewise, Zhang (2023) utilized AHP methodology to develop a multi-criteria evaluation index system for assessing online teaching quality in English language training within an online college setting. By employing AHP, Zhang aimed to create a robust evaluation framework capable of capturing diverse aspects of online teaching quality, thereby facilitating informed decision-making processes within the educational context.

While Kebritchi et al. (2017) undertook a thorough review of literature concerning challenges in delivering online courses within higher education, their analysis predates the COVID-19 pandemic. Given the distinctive nature of this current research environment, it is essential to note that no prioritization of these challenges has been established. This current study bears resemblance to the investigation conducted by Aroonsrimarakot et al. (2023), which aimed to discern issues and remedies from the standpoint of higher education students. However, Aroonsrimarakot et al.'s (2023) research did not specifically target engineering education and did not employ prioritization through the analytic hierarchy process (AHP) technique.

2.5. Identification of research gaps and research questions

The reviewed literature, while highlighting the multifaceted challenges of online learning globally and within Thailand, revealed several key gaps that this study aimed to address. While existing research explored the broader landscape of online learning challenges (Aroonsrimarakot et al., 2023; Coman et al., 2020; Dhawan, 2020; Selwyn, 2004), there remained a paucity of research specifically focused on the experiences of engineering students in Thailand. This was a critical oversight, given the unique demands and characteristics of engineering education, such as the reliance on hands-on laboratories, specialized software, and practical application of knowledge.

Furthermore, existing studies in the Thai context (Farsawang and Songkram, 2023; Muangmee et al., 2021; Wattanakasiwich et al., 2021) did not sufficiently explore the nuanced differences in priorities and challenges faced by students at different academic levels. It was likely that freshmen, sophomores, and upperclassmen encountered distinct obstacles and required tailored support. Finally, while several studies offered potential solutions and recommendations (Kapilan et al., 2021; Malkawi and Mohailan, 2022), there was a need for more targeted interventions that considered the specific context of Thai engineering education and the diverse needs of students across academic years.

To address this gap, this study aimed to specifically focus on the experiences of Thai engineering students in online learning. By combining qualitative and quantitative methods, including interviews and the analytic hierarchy process (AHP), this research sought to identify and prioritize the unique challenges faced by these students. The AHP was selected over other prioritization techniques due to its suitability for handling complex decision-making processes involving multiple criteria. AHP is particularly effective in educational research where subjective judgments and multiple factors must be considered. It allows for both qualitative and quantitative data to be systematically compared, ensuring a thorough analysis of the challenges and solutions in online learning. Furthermore, AHP provides a structured framework for pairwise comparisons, making it easier to quantify the relative importance of various challenges and solutions. This method also includes a consistency check (using the consistency ratio) to ensure the reliability of the comparisons, enhancing the validity of the results.

To achieve this objective, this study investigated the following research questions:

(1) What were the primary challenges faced by Thai engineering students in online learning during times of crisis?

(2) How did these challenges differ across academic years (freshman, sophomore, upperclassman)?

(3) What were the most effective strategies for addressing these challenges from the perspectives of students, educators, and institutions?

By employing AHP to answer these questions, this study aimed to provide valuable insights that could inform the development of tailored interventions to enhance the online learning experience and educational infrastructure for Thai engineering students. This research had the potential to contribute not only to the academic discourse on online learning but also to the well-being and success of engineering students in Thailand during times of crisis.

3. Research methodology

The research commenced with delineating the research problem and objectives, followed by a thorough review of pertinent literature. Subsequently, a comprehensive mixed-methods approach was adopted, elaborating on the process for defining the population and sample. Additionally, challenges and guidelines for addressing learning issues were compiled. The inquiry design integrated the application of the analytic hierarchy process (AHP) technique to categorize and sequence solutions to learning problems. The ensuing sections featured an in-depth discussion of the results, culminating in a comprehensive summary of the research findings. **Figure 1** visually encapsulated the sequential steps of the research methodology.

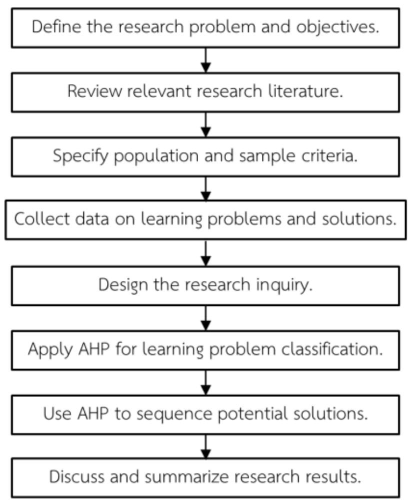


Figure 1. Flowchart of research methodology.

3.1. Exploring the scope of population and sample selection

The researchers selected a sample group of students exclusively from the Faculty of Engineering, spanning years 1 to 4, at a university in Bangkok. The Taro Yamane formula (Yamane, 1973) was used to determine the minimum sample size needed to achieve a 5% margin of error (Cirella and Russo, 2020; Yamane, 1973). This formula considered the population size (N) and the desired margin of error (e). In this study, with a population of 489 engineering students, a margin of error of 5%, and a 95% confidence level, the formula yielded a minimum sample size (n) of 221.

$$n = \frac{N}{1 + N(e^2)} = \frac{489}{1 + 489(0.05^2)} = 220.1 \approx 221$$

A stratified random sampling approach was employed to further enhance representativeness. This method ensured that each academic year (year 1 to year 4) was represented in the same proportion. More populated year classes were heavily sampled, while years with a smaller population had fewer samples drawn. The minimum sample size for each academic year was calculated based on their proportion within the total population, as detailed in **Table 1**.

Table 1. Distribution of sample size by academic year.

Academic level	Population size (people)	Sample size (people)
1	121	55
2	134	60
3	93	42
4	141	64
Total	489	221

3.2. Exploring online learning issues and solutions via open-ended questionnaires

The execution of individual interviews with a cohort of students involved employing open-ended questions to systematically extract insights regarding challenges and potential solutions. This iterative process persisted until thematic saturation was attained, resulting in a comprehensive sample size of 52 participants. The primary inquiries during these interviews were formulated as follows:

(1) In the face of the rapid transition to online learning prompted by the COVID-19 outbreak, what challenges did you encounter while adapting to this mode of study?
(2) Could you provide detailed insights into the strategies you employed to effectively address and resolve the challenges that arose during the transition to online learning?
(3) From your perspective, did you perceive overarching solutions that could efficaciously alleviate the challenges associated with online learning?

It is noteworthy that the use of open-ended questions facilitated an unrestrained expression of students' opinions, resulting in a diverse and comprehensive array of in-depth information.

The obtained results were systematically compared with findings from previous research to ensure a comprehensive examination of challenges associated with online learning. Subsequently, an exhaustive review was conducted to identify and compile all pertinent issues within the domain of online learning. The researchers meticulously analyzed and categorized the identified problem statements, subsequently formulating guidelines for addressing them.

Within the scope of this research, issues common to both conventional and online learning environments were excluded. Furthermore, the researchers judiciously omitted sensitive topics, including political matters and student-personnel relationships within the university, to maintain a focus on relevant aspects and circumvent potential discord within the university community. This strategic approach aimed to foster positive relationships and reduce extraneous factors that were not germane to the research objectives.

After collecting data, a thorough analysis was conducted to categorize challenges and solutions in online learning during the COVID-19 situation. The results were summarized in **Tables 2** and **3**, showcasing the identified challenges and proposed solutions, respectively.

Table 2. Perspectives on issues in online learning.

Type of issues or problems	Definition of issues
Students skipping practical workshops or labs pose challenges. (Issue 'A')	The absence of students' participation in workshops and labs, relying solely on video-based learning, resulted in a deficiency of practical skills.
Issues due to an adverse environment and disruptive individuals. (Issue 'B')	The study environment was compromised, as family members disrupted due to a lack of understanding of online learning, and dorm mates also caused disturbances. External noises such as construction, traffic, and chatter further impacted concentration levels.
Short assessment periods and excessive workloads. (Issue 'C')	The reduced exam time, coupled with the same or increased exam content, hampered students' ability to complete assessments on time. The excessive workload of homework and reports overwhelmed students.
Equipment malfunctions, internet disruptions, budget constraints, and incomplete university public relations. (Issue 'D')	Unreliable internet signals and disruptions in students' devices and internet connections occurred when submitting exams via platforms like Google Forms, Microsoft Teams, and Google Classroom. Limited study equipment and inadequate publicity of various assistance services by the university were notable issues. Living expenses, including dormitory rent despite non-occupancy, and increased electricity costs rose.
Health and mental challenges, impeding activities, causing physical deterioration and heightened stress. (Issue 'E')	Students experienced a decline in both physical and mental well-being, including pain in various body parts, nearsightedness, depression, stress, and pressure. Insufficient sleep and irregular eating patterns contributed to the challenges, highlighting the comprehensive impact on students' health.

Note: The uppercase letters (Issue A, B, C, D, and E) simply denote specific issue types, without indicating a hierarchy of importance. For example, Issue A does not signify greater significance than Issue B.

Table 3. Exploring perspectives on solutions for online learning issues.

Type of solution	Definition of guidelines
Students should seek additional knowledge outside of class time, supplementing classroom instruction. (Solution 'V')	Students should have sought additional sources of knowledge from books or the internet and should have asked their classmates or teachers when they had questions about a part of the content they didn't understand. Teachers should have adjusted their teaching styles appropriately, such as applying university technology to improve the online learning system. Universities should have been lenient and flexible in allowing students to enter the university to study practical subjects.
Students should organize the environment and addressed agreements with residents, including disturbances and internet use. (Solution 'W')	There should have been a discussion and agreement between students and their families or dorm mates regarding the changing teaching format and study time, aiming for mutual understanding. Students should have arranged the room used for online study to create a better environment, such as finding a suitable place to study.

Table 3. (*Continued*).

Type of solution	Definition of guidelines
Teachers should align assessment formats and workloads in accordance with modern examination regulations. (Solution 'X')	Teachers should have given an appropriate amount of work each week, recognizing that not all subjects provide assignments simultaneously. Teachers should have adjusted the format for assessing learning appropriately, such as assigning exams to be completed at home, allowing collaborative discussions among students, and implementing various evaluation methods within a set timeframe. Universities or professors should have maintained up-to-date examination rules, including measures like prohibiting cell phones, allowing only one computer, and requiring cameras to show students' faces.
The government, private sector, and universities should provide internet equipment and reduced educational costs. (Solution 'Y')	The government and universities should have provided assistance by lending equipment used in studying, granting special privileges for increased access to online learning, including support for internet connectivity, and reduced costs for educational equipment. The government and universities should have extended assistance in covering essential educational expenses, such as reducing tuition fees, and addressing costs associated with electricity and dormitory accommodations.
Activities to relieve physical and mental stress should be implemented. (Solution 'Z')	Students could have relieved stress by engaging in activities they enjoy, such as watching movies, listening to music, playing games, and reading books. To alleviate physical fatigue, students were encouraged to incorporate activities like stretching, exercising, and taking breaks to rest their eyes. Connecting with friends through social media was a positive way for students to engage socially. Engaging in conversations and activities with their families was beneficial for students.

3.3. Designing closed-ended questionnaires

From literature review and open-ended interviews, data sorting revealed five problem categories and corresponding solutions. Utilizing the AHP method, these findings were structured into an analytical hierarchy, as depicted in **Figure 2**.

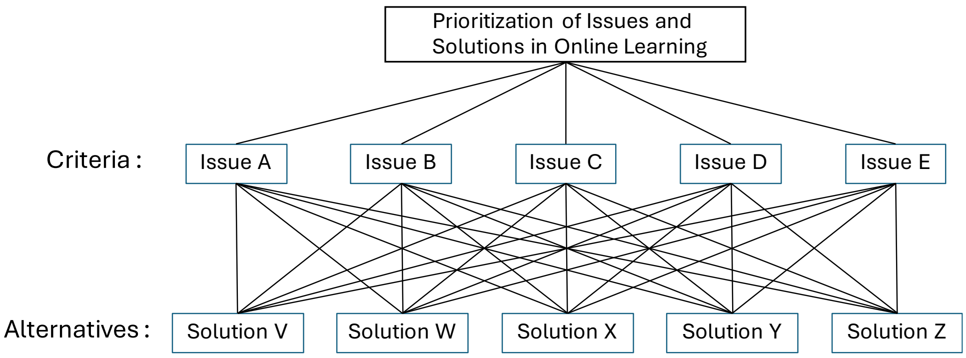


Figure 2. Analytical hierarchy structure chart.

The researchers conducted interviews utilizing closed-ended questionnaires, structured into two parts. Part 1 captured general information about the survey participants, while Part 2 focused on gathering insights from respondents regarding their evaluation of problems and solutions in online learning. The latter segment can be further categorized into two distinct forms of evaluation.

(1) An assessment form requiring respondents to assign scores, facilitating a comparative analysis of the significance of online learning issues through the AHP technique.

(2) An evaluation form prompting respondents to assign scores, enabling a comparative assessment of the importance of solutions to online learning issues using the AHP technique.

Intensity levels in the questionnaire were utilized to assess the weight of significance associated with online learning challenges and solutions during the COVID-19 situation. The results were presented in **Table 4**.

Table 4. Significance of pairwise comparison (Kou et al., 2013).

Intensity of importance	Meaning
1	Equally important
3	Slightly important compared to other criteria
5	Moderately important compared to other criteria
7	Very important compared to other criteria
9	Extremely important compared to other criteria

3.4. Exploring the university curriculum

The researchers gathered curriculum and educational plan data from bachelor's programs in the Faculty of Engineering. Coupled with questionnaire results, the findings indicated a notable focus on practical subjects in the faculty, as detailed in **Table 5**.

Table 5. Proportion of theoretical and practical coursework.

Academic level	Number of theoretical subjects	Number of practical subjects	Number of subjects studied both theory and practice	Total
1	9 (52.94%)	5 (29.41%)	3 (17.65%)	17
2	11 (73.33%)	2 (13.33%)	2 (13.33%)	15
3	11 (57.89%)	3 (15.79%)	5 (26.32%)	19
4	11 (73.33%)	2 (13.33%)	2 (13.33%)	15
Total	42 (63.64%)	12 (18.18%)	12 (18.18%)	66

4. Analysis and research findings

In the context of the analytic hierarchy process (AHP), the notations hold the following meanings:

i: The row index in matrices or vectors, denoting the i-th criterion or alternative.

j: The column index in matrices or vectors, denoting the j-th criterion or alternative.

a_{ij}: the element at the i-th row and j-th column of the pairwise comparison matrix, indicating the relative importance of criterion i over j.

A_{norm}: the normalized matrix derived from pairwise comparison matrix, essential for calculating weight vectors.

W: The weight vector illustrating the relative importance of criteria or alternatives.

CR: The Consistency Ratio, a metric gauging the reliability of judgments made during pairwise comparisons.

RI: The random consistency index.

$\lambda_{\max}$: The largest eigenvalue of A_{norm}.

S: The amalgamation matrix for each alternative, obtained through pairwise comparisons, portraying how well each alternative fares concerning the established criteria.

V_i: The overall score for each alternative, calculated by multiplying the weight vector W with each row of the synthesis matrix S and summing the products. The alternative with the highest V_i is considered the preferred choice.

4.1. Utilizing AHP technique for weighted analysis of problem and solution importance

The responses from all 221 participants were utilized to determine the weight assigned to each respondent's problem. This section provided an illustrative calculation example featuring a first-year student. The demonstration involved a single sample and followed these main steps:

(1) Pairwise comparison: A critical aspect of the decision-making process involved creating a matrix for pairwise comparisons as show in **Table 6**, which was extracted from a questionnaire completed by a first-year student. Numerical values from **Table 4**, were assigned to problems to determine their relative importance of one criterion over another. The principle of reciprocity was upheld, ensuring that each comparison (a_{ij}) corresponds inversely to a_{ji}.

Table 6. Exemplary pairwise comparison matrix for online learning issues by a first-year student.

Issues	A	B	C	D	E
A	1.00	3.00	3.00	9.00	5.00
B	0.33	1.00	0.33	5.00	3.00
C	0.33	3.00	1.00	9.00	7.00
D	0.11	0.20	0.11	1.00	0.33
E	0.20	0.33	0.14	3.00	1.00
Sum	1.9778	7.5333	4.5873	27.0000	16.3333

(2) Derivation of weight vectors: The pairwise comparison matrix in **Table 6** underwent normalization by adjusting each element relative to the sum of its respective column. This process resulted in a normalized matrix (A_{norm}), as shown in **Table 7**.

Table 7. Normalized pairwise matrix for a first-year student only.

Issues	A	B	C	D	E
A	0.5056	0.3982	0.6540	0.3333	0.3061
B	0.1685	0.1327	0.0727	0.1852	0.1837
C	0.1685	0.3982	0.2180	0.3333	0.4286
D	0.0562	0.0265	0.0242	0.0370	0.0204
E	0.1011	0.0442	0.0311	0.1111	0.0612
Sum	1.0000	1.0000	1.0000	1.0000	1.0000

(3) Calculation of priority vectors: The weight vector (W) was then computed by averaging the rows of normalized matrix (A_{norm}), as show in **Table 8**.

(4) Judgment consistency: Judgment consistency was assessed by calculating the consistency ratio (CR) using the following formula:

$$\text{CR} = \frac{\lambda_{\max} - n}{\text{RI}}$$

Table 8. Priority vector of the problem for a first-year student.

Issues	A	B	C	D	E	Priority vector*
A	0.5056	0.3982	0.6540	0.3333	0.3061	0.4395
B	0.1685	0.1327	0.0727	0.1852	0.1837	0.1486
C	0.1685	0.3982	0.2180	0.3333	0.4286	0.3093
D	0.0562	0.0265	0.0242	0.0370	0.0204	0.0329
E	0.1011	0.0442	0.0311	0.1111	0.0612	0.0698
Sum	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

*Note: The priority vector was derived through eigen vector estimation.

To assess the consistency of the pairwise comparisons, the consistency ratio (CR) for each matrix was calculated. A CR of 0.10 or less is generally considered acceptable. It was noted that from a sample of 221 people, the CR value for each person was calculated. It was found that the values met the criteria. If the CR value exceeded 1.0, the researchers reviewed the pairwise comparisons by consulting the student again about any discrepancies in the questionnaire. Alternatively, the researchers discarded that questionnaire and enlisted additional students to meet the required sample size.

(5) Computation of synthesis matrix: This student compared each solution against each issue using the same pairwise comparison process. As an example, **Table 9** illustrates the pairwise comparison of decision solutions influencing Issue 'A'. The normalized pairwise comparison matrix was created, as show in **Table 10**, to ensure that the values in the matrix accurately represented the relative importance or preference of criteria or alternatives in a consistent manner.

Table 9. Exemplary pairwise comparison matrix for solutions affecting Issue 'A' by a first-year student.

Solution	V	W	X	Y	Z
V	1.00	3.00	1.00	7.00	5.00
W	0.33	1.00	0.33	5.00	3.00
X	1.00	3.00	1.00	9.00	7.00
Y	0.14	0.20	0.14	1.00	0.33
Z	0.20	0.33	0.20	3.00	1.00
Sum	2.68	7.53	2.68	23.00	14.33

Table 10. Normalized pairwise matrix of solution weights affecting Issue 'A' by a first-year student.

Solutions	V	W	X	Y	Z	Solution weights
V	0.3737	0.3982	0.3737	0.3043	0.3488	0.3597
W	0.1246	0.1327	0.1246	0.2174	0.2093	0.1617
X	0.3737	0.3982	0.3737	0.3043	0.3488	0.3597
Y	0.0534	0.0265	0.0534	0.0435	0.0233	0.0400
Z	0.0747	0.0442	0.0747	0.1304	0.0698	0.0788
Sum	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

(6) Final ranking determination: The final ranking was determined by multiplying the weight vector (W) with each row of the synthesis matrix (S). Summing the products for each solution revealed the solution with the highest score (V_i) as the preferred choice, as shown in **Table 11**.

Table 11. Synthesis matrix to determine the final ranking.

Weight vector of issues		0.4395	0.1486	0.3093	0.0329	0.0698	Overall score	Rank
Issues		A	B	C	D	E		
Solutions	V	0.3597	0.4871	0.4468	0.5049	0.5295	0.4222	1
	W	0.1617	0.1438	0.1848	0.1274	0.1226	0.1623	3
	X	0.3597	0.2344	0.2500	0.2586	0.2054	0.2931	2
	Y	0.0400	0.0408	0.0390	0.0546	0.0546	0.0413	5
	Z	0.0788	0.0940	0.0794	0.0546	0.0879	0.0811	4

4.2. Weighted results of online learning issues and solutions

From the sample group, a total of 221 students spanning years 1 through 4 completed questionnaires. These responses were employed to compute the importance weights of both issues and solutions using the analytic hierarchy process (AHP) technique across all 221 instances. Significant statistical descriptions of the weight scores were obtained, categorized by year level, as detailed in **Table 12**.

Table 12. Summary statistics for issue and solution weights across every academic level.

Academic level	Summary statistics	Issues					Solutions				
		A	B	C	D	E	V	W	X	Y	Z
First-year (*n* = 55 people)	Min	0.0907	0.0291	0.0394	0.0305	0.0340	0.0579	0.0350	0.1083	0.0413	0.0362
	Max	0.6137	0.3058	0.5350	0.3654	0.5358	0.5272	0.2356	0.4377	0.5779	0.4139
	X bar	0.4391	0.0581	0.2210	0.0883	0.1936	0.3258	0.0867	0.3072	0.1408	0.1395
	S.D.	0.1219	0.0514	0.0888	0.0754	0.1338	0.0958	0.0485	0.0653	0.0777	0.0601
Second-year (*n* = 60 people)	Min	0.0447	0.0339	0.0307	0.0295	0.0357	0.0420	0.0369	0.1794	0.0326	0.0362
	Max	0.5086	0.5251	0.5474	0.3942	06294	0.4222	0.4662	0.4787	0.5779	0.5011
	X bar	0.2159	0.1219	0.3235	0.0992	0.2395	0.1849	0.1418	0.3276	0.1534	0.1923
	S.D.	0.1402	0.1247	0.1517	0.0949	0.1625	0.1142	0.1019	0.0942	0.0989	0.0951

Table 12. (*Continued*).

Academic level	Summary statistics	Issues					Solutions				
		A	**B**	**C**	**D**	**E**	**V**	**W**	**X**	**Y**	**Z**
Third-year (n = 42 people)	Min	0.0322	0.0307	0.0305	0.0304	0.0333	0.0280	0.0388	0.0343	0.0405	0.0410
	Max	0.5112	0.5995	0.522	0.5147	0.6452	0.4140	0.4331	0.4413	0.4959	0.5169
	X bar	0.1768	0.1309	0.1680	0.1447	0.3796	0.1552	0.1618	0.2323	0.1838	0.2670
	S.D.	0.1568	0.1245	0.1265	0.1198	0.1793	0.1051	0.1086	0.1143	0.1183	0.1281
Fourth-year (n = 64 people)	Min	0.0307	0.0282	0.0310	0.0304	0.0321	0.0347	0.0343	0.1010	0.0542	0.0400
	Max	0.5434	0.5056	0.5253	0.5929	0.5650	0.4656	0.5077	0.5163	0.5075	0.3504
	X bar	0.1991	0.1528	0.2020	0.1958	0.2504	0.1969	0.1665	0.2814	0.2181	0.1372
	S.D.	0.1604	0.1487	0.1650	0.1668	0.1797	0.1062	0.0913	0.0952	0.1179	0.0806

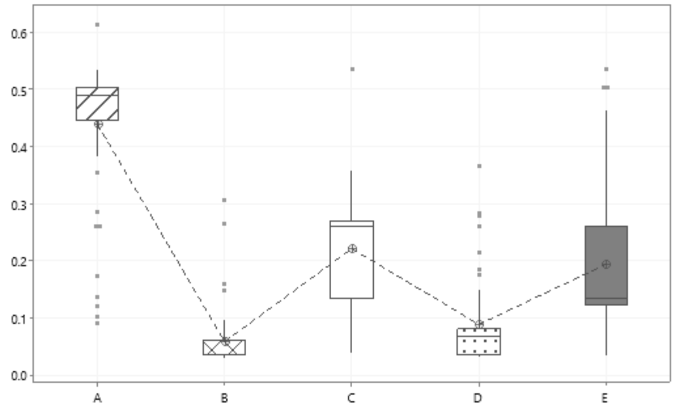
Considering the diverse challenges and guidelines influencing online learning in each academic year, **Table 13** and **Figures 3** and **4** consolidated and ranked these factors by weight, from highest to lowest based on the arithmetic mean.

Table 13. Sorting the importance of issues by students at each academic year level.

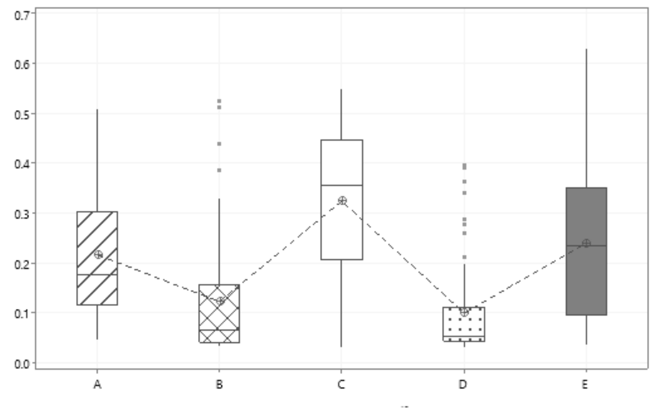
Academic level	Ranking of issues	Ranking of solutions
First-year	A > C > E > D > B	V > X > Y > Z > W
Second-year	C > E > A > B > D	X > Z > V > Y > W
Third-year	E > A > C > D > B	Z > X > Y > W > V
Fourth-year	E > C > A > D > B	X > Y > V > W > Z

Table 13 showcased the prioritization of issues and solutions related to online learning among students at each academic year level. The sorting was elucidated below:

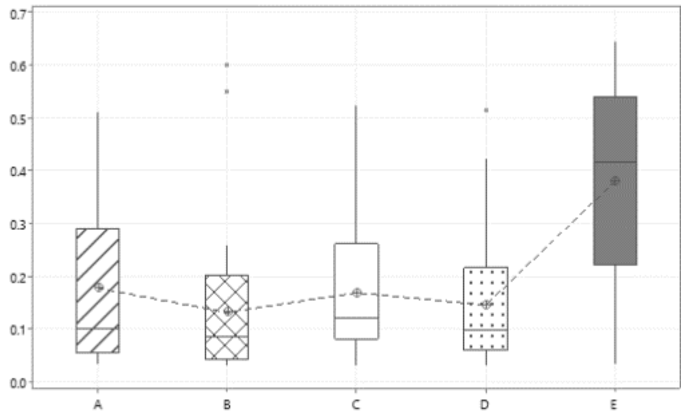
- For first-year students, Issue 'A', concerning the absence of practical subjects in university studies, emerged as the primary concern with a weight score of 0.4391 (43.91%), as depicted in **Figure 3a**.
- Second-year students predominantly focused on Issue 'C', associated with short assessment periods and excessive workloads, marked by a weight score of 0.3235 (32.35%) according to **Figure 3b**.
- Third and fourth-year students exhibited a central concern revolving around Issue 'E', encompassing health and mental well-being challenges such as the inability to participate in activities, leading to worsened physical condition and heightened stress. The associated weight scores were 0.3496 and 0.2504, respectively, as outlined in **Figure 3c,d**.



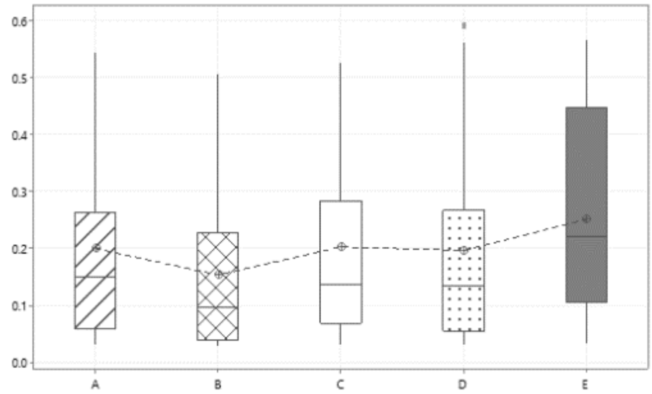
(a) 1st-year students.



(b) 2nd-year students.



(c) 3rd-year students.

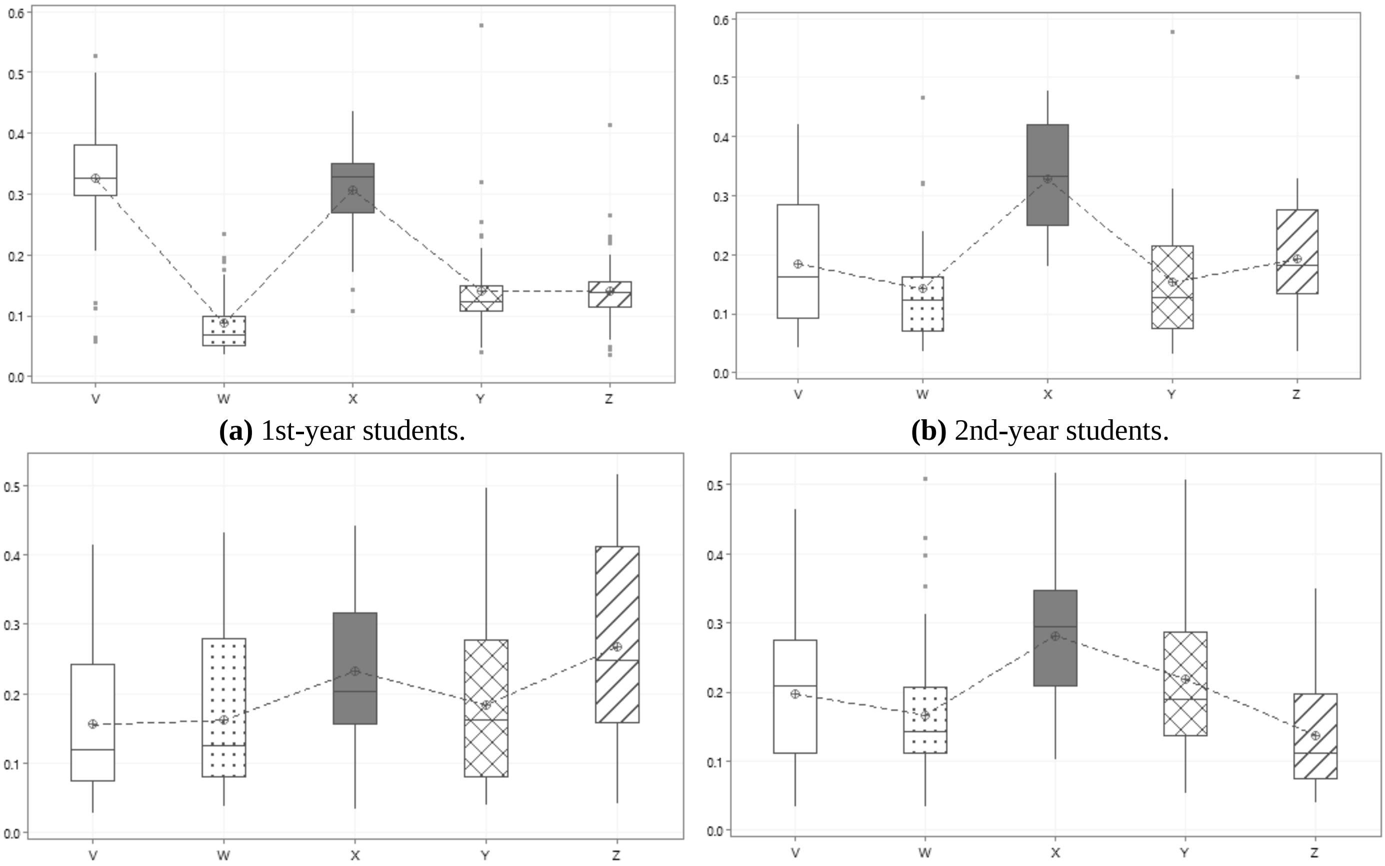


(d) 4th-year students.

Figure 3. The distribution of weight scores related to online learning issues.

In prioritizing solutions for online learning, the analysis revealed:

- First-year students identified the 'V' approach, emphasizing seeking additional knowledge outside class and enhancing classroom teaching (On-site), as their foremost priority, with an average weight of 0.3258, as depicted in **Figure 4a**.
- Second and fourth-year students prioritized the 'X' approach for appropriate adjustments to grading formats, workload, and modern exam regulations, with average weights of 0.3276 and 0.2814, respectively, as shown in **Figure 4b,d**.
- Third-year students, on the other hand, prioritized guideline 'Z' as their top choice, focusing on physical and mental stress relief activities, with an average weight of 0.2670, as illustrated in **Figure 4c**).



(a) 1st-year students. **(b)** 2nd-year students.

(c) 3rd-year students. **(d)** 4th-year students.

Figure 4. The distribution of weight scores related to online learning solutions.

4.3. Comprehensive comparison of issues and guidelines in online learning

The evaluation encompassed the weighting of the significance attributed to both problems and approaches by 221 students surveyed, without stratification based on academic year. The prioritization outcomes, determined through the calculation of the arithmetic mean, were presented as follows:

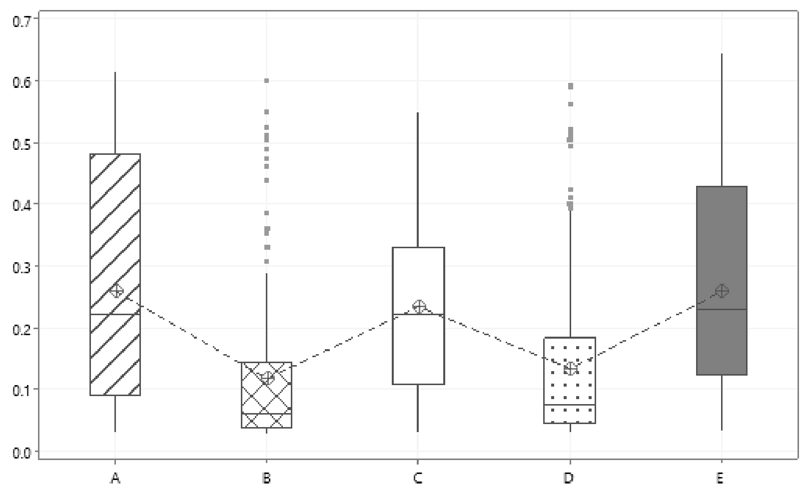


Figure 5. Box plots of overall issues without year-level division.

The primary concern, as illustrated in **Figure 5**, was identified as Issue 'A,' pertaining to impracticality in practical application. Subsequently, Issue 'E' emerged, addressing health and mental well-being matters, encompassing limitations in activity engagement such as deteriorating physical condition and stress. Ranked third in evaluation was Issue 'C,' associated with reduced examination time, alongside the burden of excessive workload.

The outcomes of prioritizing solutions, as depicted in **Figure 6**, revealed that the top-ranking solution was 'X,' involving the adjustment of measurement formats and workload allocation to align with modern standards. Following closely was Solution 'V,' which advocated for students to supplement their learning with additional self-study and augmented classroom instruction (on-site). Ranking third was Solution 'Z,' incorporating stress-alleviating activities to enhance both physical and mental well-being.

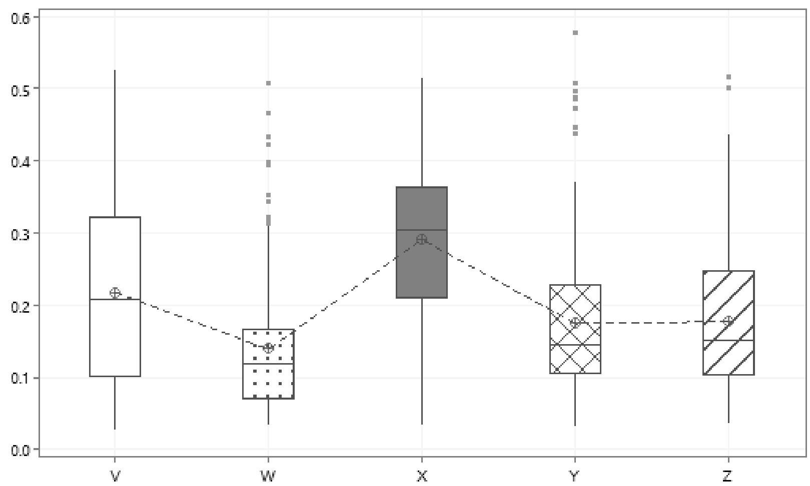


Figure 6. Box plots of overall solutions without year-level division.

5. Summary and discussion

During the COVID-19 pandemic, a sudden shift occurred in the delivery of engineering education in Thailand, transitioning from traditional onsite instruction to online modalities in response to governmental mandates. This rapid adaptation caught many students unprepared, necessitating an investigation into the challenges and remedies associated with online learning during such exigent circumstances, with a specific focus on the student perspective. This study engaged first- to fourth-year students within a branch of the Faculty of Engineering at a university in Bangkok to solicit their opinions and importance evaluations regarding the challenges impacting online learning. The aim was to analyze and prioritize these challenges, as well as to present and rank potential solutions, utilizing the Analytic Hierarchy Process (AHP) as the methodological framework.

Our findings regarding the prioritization of practical work (Issue 'A') as the most significant challenge echoed international studies highlighting the difficulties of replicating hands-on experiences in online environments (Dhawan, 2020; Selwyn, 2004). This challenge was particularly pronounced in engineering education, as emphasized in the literature, due to the discipline's reliance on practical skills development (Asgari et al., 2021; Popescu et al., 2022). Our study further nuanced this understanding by revealing the differential impact of this challenge across academic years, with freshmen being the most affected. This suggested a need for tailored interventions that addressed the specific needs of students at different stages of their academic journey.

The prioritization of health and mental well-being concerns (Issue 'E') aligned with global research documenting the negative psychological impact of online learning, including increased isolation, stress, and anxiety (Aristovnik et al., 2020; Maqableh and Alia, 2021). This finding emphasized the importance of prioritizing student well-being alongside academic achievement in online learning environments.

Our finding that adjusting measurement formats and workloads (Solution 'X') was the most preferred solution reflected a broader trend in educational research towards more flexible and student-centered assessment practices (Sangrà et al., 2012). This was particularly relevant in the context of crisis-induced disruptions, where traditional assessment methods might not be feasible or equitable.

For Students: The findings underscored the need for developing self-directed learning strategies, such as time management, resource utilization, and seeking help when needed. This was particularly crucial in online environments where traditional classroom structures and support systems might be less readily available. Furthermore, the prominence of mental health concerns (Issue 'E') highlighted the importance of proactively managing stress, seeking social support, and utilizing available mental health resources. Students were encouraged to communicate their challenges to faculty and peers, and institutions should provide easily accessible mental health services.

For Educators: This research emphasized the need for pedagogical adaptations that addressed the unique challenges of online learning in engineering. Educators should have focused on developing flexible assessment methods and providing resources to support practical learning experiences, even in an online format. Implementing activities to reduce stress (Solution 'Z') could also be integrated into the curriculum to support students' mental health. Additionally, educators needed training to facilitate effective online pedagogy, ensuring that students remained engaged and motivated. This was consistent with findings from studies in Sri Lanka and Malaysia, which emphasized the need for innovative teaching methods and support systems (Akuratiya and Meddage, 2020; Razami and Ibrahim, 2021).

For Institutions: The findings provided valuable insights for policy and resource allocation decisions. Universities and government agencies should invest in improving digital infrastructure and providing access to necessary technology to mitigate connectivity issues (Solution 'Y'). By prioritizing mental health services and creating a supportive online learning environment, institutions could address the well-being concerns highlighted in the study. Furthermore, adapting institutional policies to accommodate the unique challenges of online learning was crucial for maintaining educational quality during crises. The literature from Jordan and Indonesia supported these recommendations, highlighting the importance of system readiness and infrastructure improvements (Hasniati, 2022; Malkawi and Mohailan, 2022).

This study contributed to the understanding of online learning challenges and solutions in engineering education during crises, particularly in the Thai context. However, students' judgments were inherently subjective and varied based on individual experiences, biases, and perspectives. This subjectivity introduced some degree of uncertainty into the prioritization of challenges and solutions. By connecting our findings with international research, we demonstrated the global nature of these challenges while highlighting unique contextual nuances. Future research could build on these findings by exploring the long-term impact of the pandemic on engineering education, comparing experiences across different cultural contexts, and investigating the effectiveness of innovative solutions like virtual labs and hybrid learning models (Mushtaha et al., 2022; Popescu et al., 2022).

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