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Educational technology enhanced interprofessional E-learning for engaging cross-institutional and cross-border healthcare students: A mixed-methods study

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ABSTRACT

Aim: In the post-COVID-19 era, educators in higher education are exploring innovative pedagogies to deliver effective interprofessional education in an online learning environment. This study aimed to evaluate the effectiveness of the technology-enhanced e-learning modules for undergraduate healthcare students from different cultural backgrounds. The focus was on student engagement with interprofessional learning and diversity using innovative educational technology.

Methods: This is a mixed-methods study including pre- and post-test evaluations and focus group interviews. The educational intervention strategies focused on applying interprofessional learning among undergraduate healthcare students by integrating education technologies (i.e., virtual reality 360 and gamification) into two e-learning modules. Three time-points involving pre and post modules' evaluation (before and after the 1st learning module, and after the 2nd learning module) were collected using validated scales including Interprofessional Attitudes Scale and Online Student Engagement Scale. Linear mixed models were used to investigate the association between interventions and changes in outcomes from pre-to post-intervention by adjusting the covariates. To further validate the quantitative findings, focus-group interviews were conducted with a verbatim transcript obtained from participating students for content analysis.

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Results: A total of 75 undergraduate healthcare students from Hong Kong, Mainland China, South Korea, and Thailand participated in the study. A statistically significant positive change was detected in interprofessional attitude ($F = 5.90$, $p = 0.004$), interprofessional diversity and ethics ($F = 4.43$, $p = 0.014$) and student engagement ($F = 13.42$, $p < 0.001$) after the e-learning modules. A statistically significant correlation was also detected between student engagement and interprofessional attitude. From the qualitative content analysis, three core categories were identified. They were 'Cultural diversity recognition', 'Acquisition of interprofessional attitudes and skills' and 'Active learning engagement'.
Conclusions: The technology-enhanced e-learning modules significantly enhanced undergraduate healthcare students' interprofessional attitude and student learning engagement in terms of interprofessional education. Healthcare educators in higher education are encouraged to integrate educational technology as a pedagogical approach to stimulate interprofessional learning of undergraduate healthcare students.

Contribution of the paper

What is already known about the topic?

- Interprofessional education enhances student collaboration, attitudes, and skills, improving patient outcomes.
- Internationalization in healthcare education builds cultural awareness and intercultural skills critical for globalized care delivery.
- Both interprofessional education and internationalization synergistically prepare healthcare students for diverse, collaborative practice.

What this paper adds

- Demonstrates the use of technology-enhanced e-learning modules, including gamification and virtual reality, for effective cross-border interprofessional education.
- Highlights the impact of these modules in fostering interprofessional attitudes and cultural awareness among healthcare students.
- Proposes a scalable model for integrating innovative e-learning into internationalized healthcare education.

1. Introduction

Internationalization and interprofessional education are essential for success in an increasingly globalized world, where different health professions intersect and depend on each other to achieve optimal patient outcomes (Mendoza et al., 2023). By embedding the concept of interprofessional education into the curriculum, higher education can enhance quality by facilitating knowledge exchange among students. This preparation enables them to effectively collaborate with peers from diverse cultural backgrounds in their future careers, which is particularly pertinent in the health care field (Huang et al., 2023).

Internationalization is pivotal in healthcare education and is defined as integrating international, intercultural or global dimensions into higher education (Galan-Lominchar et al., 2024). This approach has been promoted and supported by a broad range of tertiary institutions and healthcare arenas as part of their agendas (Marginson, 2023). Through internationalization, students can ascertain knowledge and values that empower them to become global citizens. This initiative is embraced by academics and educators who have an interest in developing teaching and learning strategies to enhance students' intercultural learning (Breaden et al., 2023). Furthermore, international encounters can help students develop a global mindset regarding cultural practices and build intercultural skills (Lee and Levy, 2023). Establishing a sense of diversity among students and engaging them during intercultural learning activities are crucial elements of the internationalization process. Without these elements, students may experience stress and frustration in providing diversity-sensitive care to culturally diverse patients (Lauwers et al., 2024; Osmancevic et al., 2023; Tucker et al., 2011).

Another crucial component in both academia and healthcare settings is interprofessional education, which takes place when students from two or more different professions engage in learning about, from, and with one another. Interprofessional education fosters positive interprofessional attitudes and promotes mutual respect and knowledge exchange among healthcare peers (Saragih et al., 2024). Given the rapid advancements in technology and the rising costs of care, interprofessional practice has become a promising approach in the health care workforce. The challenges in healthcare today are highly complex that no single profession can address them effectively on its own (Warren and Warren, 2023). Instead, collaboration among relevant professions is necessary to achieve desired healthcare outcomes. This makes the integration of interprofessional education into the curriculum imperative (Warren and Warren, 2023). Interprofessional activities expose students to other health professions, facilitating the integration of knowledge and leading to better practices in an interprofessional working environment; particularly when arranged in an online learning setting (Mclnemey et al., 2022; Suryadinata et al., 2024). Awareness of the importance of improving interprofessional

attitudes towards other healthcare professions has been identified as a key factor for effective teamwork (Dassah et al., 2023; Oudenampsen et al., 2023). Additionally, evidence suggests that medical care provided by staff with high levels of interprofessional collaboration and cooperation skills is associated with reduced medical errors, lower hospitalization rates, reduced number of complications, and overall increasing patient safety (Shuyi et al., 2024). Moreover, it enhances coordination among healthcare providers by improving patient access to medical services (Wall, 2018; Bendowska and Baum, 2023).

Interprofessional education not only fosters innovation within collaborative teams, it also enhances student learning in a broad spectrum such as significantly improving students' attitude, knowledge, and capabilities regarding patient outcomes (Yang et al., 2024). With the current advancements in educational technology, there is potential for enhancing both internationalization and interprofessional education among healthcare students in terms of online learning engagement (Stutchbury et al., 2025). Research indicated that student engagement is closely associated with desirable learning outcomes, such as the development and application of critical thinking skills as well as achieving higher grades (Lv et al., 2022; Xu et al., 2022). Therefore, it is crucial to explore the potential synergic effects of the relationships among internationalization, interprofessional education and student engagement.

Interprofessional education is essential for preparing healthcare professionals to collaborate effectively; however, its implementation often lacks rigor, especially in cross-institutional and cross-border contexts. Most interprofessional education programs remain confined within single institutions, limiting exposure to diverse cultural and professional perspectives (Reeves et al., 2025). Additionally, despite the potential of educational technology to bridge geographic gaps, e-learning models frequently face challenges such as limited intercultural engagement and persistent interprofessional attitude barriers that hinder effective collaboration (Abdelaziz et al., 2021; Al-Samarraie et al., 2023). These shortcomings restrict the scalability and sustainability of interprofessional education initiatives globally. There is a critical need for innovative, technology-enhanced pedagogies that foster meaningful collaboration among healthcare students across institutions and countries. Addressing these gaps will enhance intercultural competence and interprofessional teamwork skills, ultimately improving patient outcomes in increasingly globalized healthcare systems.

2. Study aim

Through the integration of diversity concepts and interprofessional education within technology-enhanced online learning environment, this study aimed to evaluate the effectiveness of such approaches using mixed-methods to evaluate detailly on learning outcomes of undergraduate healthcare students from different universities and regions. Specifically, it focused on assessing their awareness of cultural diversity, interprofessional attitude, and engagement in online learning.

3. Framework

The Online Collaborative Learning Theory (Costa Marion et al., 2025) posits that knowledge is built through group interaction and dialogue in an online environment, emphasizing structured collaboration, shared responsibility, and facilitation to achieve learning outcomes. This theory offers a robust framework for designing interventions that facilitate interprofessional and cross-cultural collaboration in online learning environments.

By addressing the challenges of fostering engagement and cooperation among students from diverse professional and cultural backgrounds in a virtual setting, this theory is particularly relevant to the goals of this study. The integration of this theory is justified by its focus on creating structured, interactive learning experiences that enhance group collaboration, critical thinking, and mutual respect—key outcomes for interprofessional education. The theory's principles of creating effective learning groups, structuring activities, and facilitating interactions provided a clear roadmap for designing an intervention that promotes constructive collaboration and addresses the complexities of group dynamics in an online environment (Fig. 1). By leveraging this framework, the intervention aimed to cultivate an engaging and inclusive learning experience that fosters interprofessional skills, an understanding of cultural diversity, and active online engagement.

In applying this theory, the intervention incorporated its three foundational elements and characteristics of cooperative learning into the design of e-learning modules. Diverse teams of 8 students were formed based on their professional and cultural backgrounds,

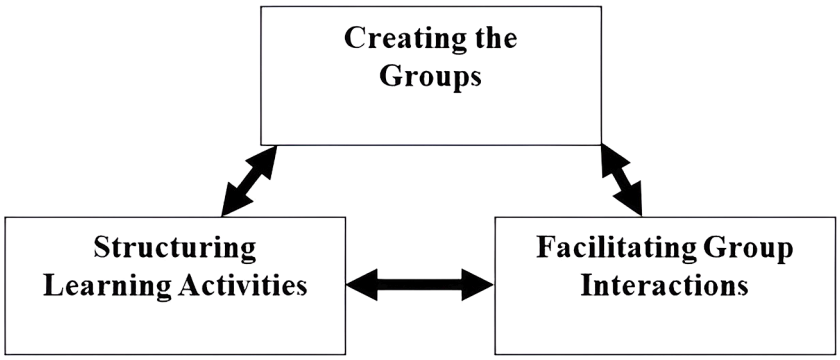

Fig. 1. Three Important Elements in Creating Effective Learning Groups.

as the theory underscores the cognitive benefits of heterogeneous groups. Learning activities were carefully structured to promote interdependence and shared responsibility. This was achieved through case-based scenarios, which were enhanced by gamified tasks, and Virtual Reality 360 clinical simulations, encouraging collaboration and problem-solving. Facilitators played a central role in supporting group interactions, mediating conflicts, and maintaining positive dynamics, adhering to the theory's emphasis on guided learning (Fig. 2).

Furthermore, collaborative learning principles such as positive interdependence, individual accountability, and group reflection were embedded into the intervention to enhance team cohesion and learning outcomes. This deliberate integration of the Online Collaborative Learning Theory ensured the intervention effectively addressed the logistical and cultural barriers of online interprofessional education. It also provided a transformative learning experience for students, enabling them to engage deeply with both the content and their peers.

4. Methods

4.1. Study design

This study used a mixed-methods design, incorporating both pre- and post-test evaluations and focus group interviews for comprehensive assessment.

4.2. Participants

Undergraduate healthcare students from universities in Hong Kong, Mainland China, South Korea and Thailand were invited to participate in the e-learning modules through their university-registered email. Considering the possibility of inflating effect sizes caused by uncontrolled confounding variables, it was determined to use half of the effect size reported in a study by Zhou et al. (2022). With an effect size of 0.385, to achieve a statistical power of 90 % with an alpha level of 0.05, 60 participants were needed from G*Power 3.1.9.7. Accounting for a 30 % dropout rate, a total of 86 participants were required. The final recruited sample was 88 participants. Participants who could communicate in English and were enrolled in health profession programmes were included for the study. Those who were pursuing postgraduate studies and did not have access to the internet were excluded.

4.3. Intervention

The themes of the learning modules focused on internationalization and interprofessional learning. Two e-learning modules were constructed using case-based scenarios. Teaching materials such as pre-reading notes were uploaded to a learning management system that facilitated student preparation for both learning modules. The case-based learning content related to healthcare and cultural diversity topics were integrated into the modules.

Sharing commonalities and differences of interprofessional skills and intercultural practices from respective health professions and diverse cultural backgrounds were a deliberate instructional design element. Participating students were arranged into ten groups with assigned facilitators.

The first e-learning module was conducted asynchronously via an interactive learning platform with gamification features, developed by a university collaborator using an education technology system. This allowed flexibility for students to participate across different time zones. The system comprised two parts: Participants first needed to answer basic knowledge questions about the teaching topic to gain tokens and then participated in the action-to-take scenarios related to the topic. Two weeks later, the second e-learning module was launched. It included the adoption of three purpose-designed Virtual Reality 360 videos to engage student learning via a synchronous session using Zoom. A total of six guiding questions were designed to initiate and stimulate discussions among participants. The entire interactive process in both modules was facilitated by university instructors from different health professions and different regions. The innovative pedagogical approach aimed to create insightful exchanges that cultivated a deep learning environment through student interaction.

4.4. Quantitative data collection

All healthcare students who enrolled in the e-learning modules were invited to complete an online pretest-posttest questionnaires. Data collection was conducted at three time-points – before the first e-learning module (Time 0), after the first e-learning module (Time 1), and after the second e-learning module (Time 2). The study protocol is highlighted in Fig. 3.

4.4.1. Sociodemographic questionnaire

Participants' sociodemographic information included age, gender, place of origin, programme of study and year of study, cultural experiences (experience of living in a culturally diverse environment, experience of overseas exchange programmes during university enrollment, experience of studying abroad prior to university enrollment, experience of attending cultural competence training workshops within the university), clinical experiences (clinical placement in the health system) and interprofessional learning experiences (experience of participating in interprofessional learning).

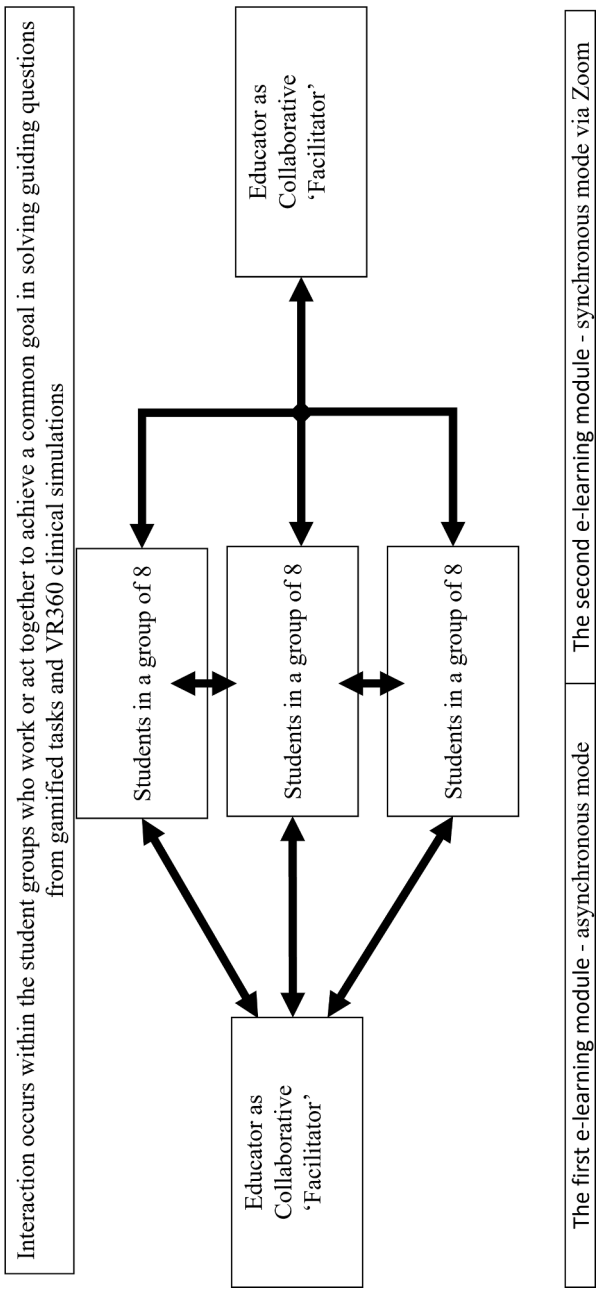

Fig. 2. Facilitators for Effective Collaborative Learning.

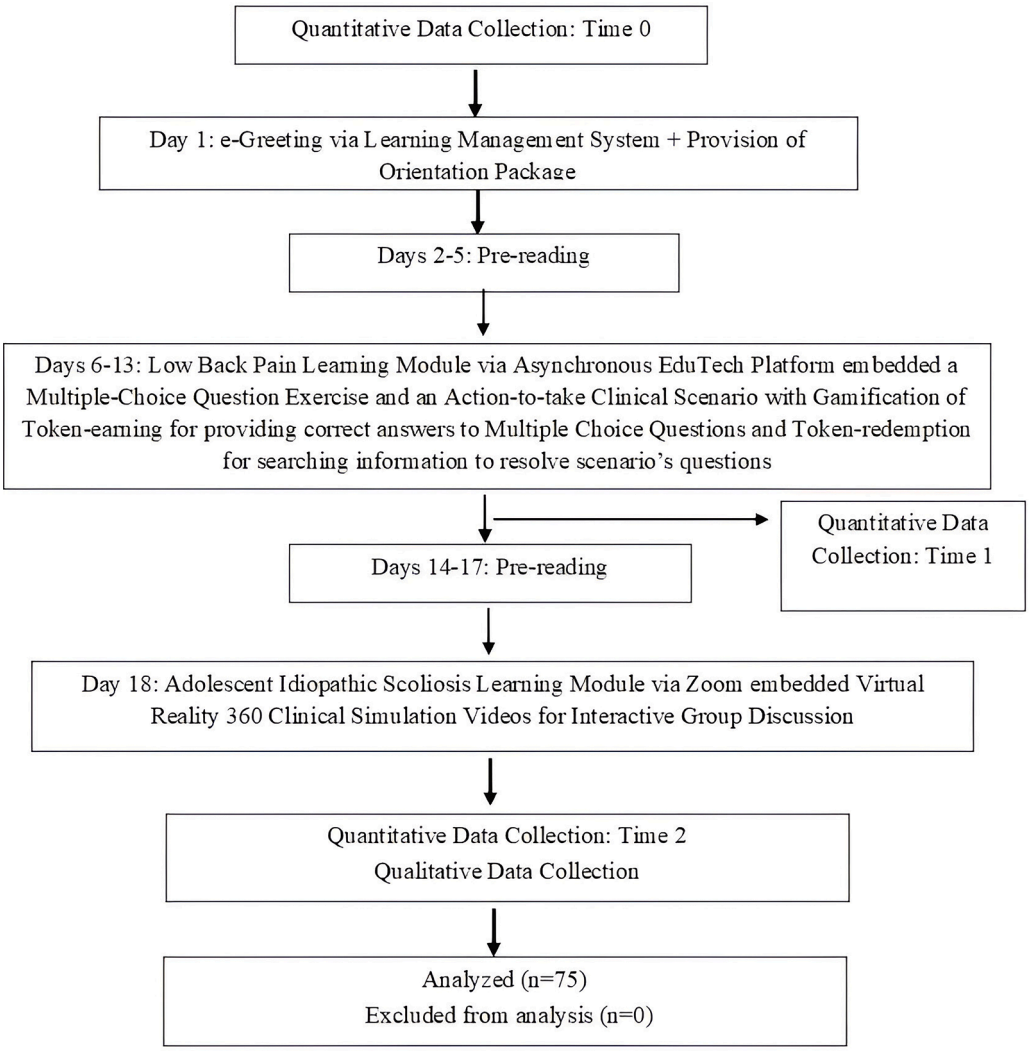

Fig. 3. Study Protocol.

4.4.2. Interprofessional attitudes scale

To evaluate student learning effectiveness in terms of interprofessional learning, the Interprofessional Attitudes Scale was used. The Interprofessional Attitudes Scale is designed to assess attitudes related to the 2011 Core Competencies for Interprofessional Collaborative Practice (Norris et al., 2016). It is a 27-item self-report questionnaire, developed to measure changes in the interprofessional attitude of students from healthcare programmes such as medicine, nursing, and other allied health. Each item is rated on a 5-point Likert scale with higher scores indicating better interprofessional attitudes. This questionnaire has five subscales: teamwork, patient centeredness, bias, diversity and ethics, and community centeredness. Notably, the diversity and ethics subscale measures participants' sense of cultural diversity. Content validity was confirmed by involving experts and students from various health fields to ensure the scale covers important areas like teamwork, patient focus, diversity, ethics, and community engagement (Norris et al., 2016). Cross-cultural validity has been demonstrated in diverse settings, affirming the scale's applicability across populations (Ganotice et al., 2021). The Cronbach alpha coefficient of the Interprofessional Attitudes Scale was 0.87 to 0.92 (Ganotice et al., 2021; Norris et al., 2016). In this study, it was 0.971 (Time 0), 0.961 (Time 1) and 0.938 (Time 2).

4.4.3. Online student engagement scale

To assess the effectiveness of online learning of students, the Online Student Engagement Scale was adopted. This 19-item self-report questionnaire measures student engagement, with a higher score indicating better engagement. This scale comprises four subcategories: emotional engagement, skills/cognitive engagement, participation/behavioral engagement, and performance engagement. Each item is rated on a 5-point Likert scale. The total engagement score ranges from 19 to 95, representing the sum score of the four engagement categories (Dixson, 2015). The Online Student Engagement Scale shows strong content validity through expert review and pilot testing, and construct validity confirmed by factor analyses revealing clear engagement dimensions. It also

demonstrates good criterion validity, supporting its use in diverse online learning settings (Dixson, 2015; Taghizade et al., 2024). The Scale has been shown to be internally consistent and reliable with a Cronbach alpha coefficient ranging from 0.91 to 0.95 (Kassab, 2023). In this study, it was 0.961 (Time 0), 0.957 (Time 1) and 0.955 (Time 2).

4.5. Qualitative data collection

Four focus group interviews (Mielke et al., 2024) were conducted to explore the learning experiences of students after the completion of the e-learning modules. A total of 16 students (12 of whom were female) from different regions expressed their interest in attending the interviews via the email invitation, with four participants in each group (two from Hong Kong, one from Thailand and one from South Korea). Based on the quantitative results, two researchers in the team formulated guiding questions including: "Tell me about your experience in the interprofessional education?", "What impacts do you think interprofessional education has on patient care?", "In what ways do you see cultural diversity affecting patient care?", "How would you comment the usefulness and engagement level of each e-learning modules?". The two researchers took turns as the facilitators for the four focus groups, inviting each participant to respond to the questions and encouraging spontaneous discussions built upon each other's comments. Facilitators ensured balanced participation while allowing natural conversation flow. The interviews were recorded after obtaining verbal approval from participants.

4.6. Data analysis

Quantitative data analysis involved presenting participants' demographic variables using descriptive statistics. Linear mixed

Table 1
Baseline socio-demographics of participants.

	All participants (n = 75) n (%) / (Mean ± SD)
Personal factors n (%)	
Age	
18 - 19	5 (6.7)
20 - 22	69 (92.0)
23 - 25	1 (1.3)
Gender	
Male	24 (32.0)
Female	51 (68.0)
Place of Origin	
Hong Kong	44 (58.7)
Mainland China	1 (1.3)
South Korea	9 (12.0)
Thailand	21 (28.0)
Programme of Study	
Bachelor of Nursing	35 (46.7)
Bachelor of Science in Biomedical Engineering	19 (25.3)
Bachelor of Science in Prosthetics and Orthotics	21 (28.0)
Year of Study	
First year	4 (5.3)
Second year	29 (38.7)
Third year	32 (42.7)
Fourth year	10 (13.3)
Cultural Experiences n (%)	
Experience of living in a culturally diverse environment	
Yes	42 (56.0)
No	33 (44.0)
Experience of overseas exchange programmes during university enrollment	
Yes	5 (6.7)
No	70 (93.3)
Experience of living or studying abroad prior to university enrollment	
Yes	10 (13.3)
No	65 (86.7)
Experience of attending training workshops related to developing cultural competence within the university	
Yes	34 (45.3)
No	41 (54.7)
Clinical Experiences n (%)	
Experience of clinical practice/clinical placement in the health system	
Yes	42 (56.8)
No	32 (43.2)
Interprofessional Experiences n (%)	
Experience of participating in interprofessional / interdisciplinary learning	
Yes	44 (58.7)
No	31 (41.3)

models with random intercept only were used to investigate the association between interventions and changes in outcomes from pre- to post-intervention by adjusting the covariates, with each model using time as a categorical variable. Omnibus F-test was used to analyze the statistical significance of the time effect. If the test were significant, post hoc pairwise comparison with Tukey's Honest Significant Difference would be done. The model factors included age, gender, country of origin, programme of study and year of study, cultural experiences, clinical experiences and interprofessional learning experiences as covariates. SPSS, version 26.0 (IBM Corp., Armonk, NY, USA) was used for the analysis.

Qualitative data analysis employed inductive content analysis (Kyngas, 2020). The data were first analyzed by identifying meaningful units and creating open codes, which were then grouped into sub-concepts based on patterns in content. Subsequently, categories were identified and confirmed by interpretations and discussion among the authors. To maintain analytical rigor, two researchers independently performed content analysis of the qualitative data, systematically documenting their coding decisions and category development. Any analytical discrepancies were resolved by consulting a third researcher ensuring a transparent decision-making process (Kyngas, 2020). Data saturation was achieved with 16 participants, as thematic saturation became evident and had no new themes or significant codes emerged from the later interviews, which indicated that sufficient data had been captured.

4.7. Ethical considerations

The study was approved by an institutional review board and it was conducted in accordance with the principles of the Declaration of Helsinki. Participants were provided with e-information highlighting the potential benefits of enhancing interdisciplinary and intercultural learning from the learning modules with minimal risks. Voluntary participation was ensured. E-consent was obtained from participants prior to their involvement in the study. They were invited to complete pretest-posttest questionnaires using a Qualtrics link and to participate in focus group interviews via Zoom. Focus group participants were recruited on a voluntary basis. Anonymity for quantitative data and confidentiality for qualitative data were assured. Participants were notified that the data would be aggregated and destroyed after 7 years.

5. Results

5.1. Demographic characteristics of participants

A total of 75 out of 88 healthcare students filled out the pretest-posttest questionnaires, with a response rate of 85.2 %. The sample contained 44 (58.7 %) were from Hong Kong, 1 (1.3 %) from Mainland China, 9 (12 %) (28 %) from South Korea and 21 from Thailand. Of which, 35 (46.7 %) were studying Bachelor of Nursing in Hong Kong, Mainland China and South Korea, 19 (25.3 %) were studying Bachelor of Science in Biomedical Engineering in Hong Kong, and 21 (28 %) were studying Bachelor of Science in Prosthetics and Orthotics in Thailand. The participants aged 18–25 with 98.7 % aged 18–22, 68 % were female, 56 % had experience of living in a culturally diverse environment, 13.3 % had experience of living or studying abroad prior to university enrollment, 6.7 % had experience of overseas exchange programmes during their university enrollment, 45.3 % had experience of attending training workshops related to developing cultural competence within the university, 56.8 % had experience of clinical practice/clinical placement in the health system, and 58.7 % had experience of participating in interprofessional / interdisciplinary learning (Table 1).

5.2. Quantitative findings

Table 2 and Table 3 show the outcome variable characteristics containing the scores of Interprofessional Attitudes Scale and its subscales, and the scores of Online Student Engagement Scale and its domains. Pearson's correlation analysis was conducted to examine the relationship between the Interprofessional Attitudes Scale and the Online Student Engagement Scale. The analysis revealed a statistically significant moderate positive correlation between the Interprofessional Attitudes Scale and the Online Student Engagement Scale ($r = 0.535$, $p < 0.001$).

5.2.1. Effects on interprofessional attitudes scale

Mixed-effects analyses (Table 4) revealed significant time effects for the Interprofessional Attitudes Scale (IPAS) total score ($F = 5.90$, $p = 0.004$) and several subscales, including Teamwork ($F = 8.45$, $p < 0.001$), Patient Centeredness ($F = 3.46$, $p = 0.034$), Diversity and Ethics ($F = 4.43$, $p = 0.014$), and Community Centeredness ($F = 4.25$, $p = 0.016$). The Bias subscale did not show a

Table 2
Outcome variables of interprofessional attitudes scale.

Interprofessional Attitudes Scale	Time 0 Mean ± SD	Time 1 Mean ± SD	Time 2 Mean ± SD
Interprofessional Attitudes Total	102.974 ± 19.342	110.733 ± 11.021	110.571 ± 11.944
Teamwork	33.566 ± 6.731	36.500 ± 3.877	36.800 ± 4.024
Patient Centeredness	20.382 ± 4.215	21.683 ± 2.467	21.886 ± 2.657
Biases	8.987 ± 2.943	9.350 ± 3.241	9.114 ± 3.246
Diversity and Ethics	16.184 ± 3.329	17.667 ± 2.184	17.314 ± 2.435
Community Centeredness	23.855 ± 4.963	25.533 ± 3.605	25.457 ± 3.654

Table 3
Outcome variables of online student engagement scale.

Online Student Engagement Scale	Time 0 Mean ± SD	Time 1 Mean ± SD	Time 2 Mean ± SD
Online Student Engagement Total	60.145 ± 13.577	69.817 ± 12.506	71.414 ± 11.846
Skills	19.197 ± 4.225	21.900 ± 4.193	22.386 ± 4.196
Emotion	16.132 ± 4.025	19.183 ± 3.422	19.786 ± 3.422
Participation	18.474 ± 4.838	21.517 ± 4.973	21.971 ± 4.236
Performance	6.342 ± 1.621	7.217 ± 1.776	7.271 ± 1.587

Table 4
Mixed effects analyses for the pre-post effects for interprofessional attitudes scale.

	Omnibus F-test value	P value	Time 1 Change from Time 0 (t-value)#	P value	Time 2 Change from Time 1 (t-value)#	P value
Interprofessional Attitudes Scale-total	5.895	0.004	2.740	0.019	0.184	0.982
Interprofessional Attitudes Scale-Teamwork	8.454	<0.001	3.125	0.006	0.467	0.887
Interprofessional Attitudes Scale-Patient Centeredness	3.464	0.034	1.988	0.119	0.316	0.946
Interprofessional Attitudes Scale-Bias	0.352	0.704	–	–	–	–
Interprofessional Attitudes Scale-Diversity and Ethics	4.432	0.014	2.625	0.026	0.306	0.950
Interprofessional Attitudes Scale-Community Centeredness	4.250	0.016	2.262	0.065	0.267	0.961

#post-hoc pairwise comparison.

significant effect over time ($F = 0.35$, $p = 0.704$). Post hoc pairwise comparisons using *t*-tests indicated that IPAS total scores significantly increased from Time 0 to Time 1 ($t = 2.74$, $p = 0.019$), with no significant difference between Time 1 and Time 2. Similar patterns were observed for the Teamwork and the Diversity and Ethics subscales, with significant improvements from Time 0 to Time 1 ($p < 0.05$). The whole model's parameter estimates with standard error and proportion of variance explained by the model are in the appendix (Supplementary Table 1–6).

5.2.2. Effects on online student engagement scale

Table 5 shows the mixed-effect model analyses for the Online Student Engagement Scale. It showed a significant effect of time for the total score ($F = 13.42$, $p < 0.001$) and across all subscales: Skills ($F = 6.35$, $p = 0.002$), Emotion ($F = 15.77$, $p < 0.001$), Participation ($F = 8.91$, $p < 0.001$), and Performance ($F = 7.09$, $p = 0.001$). Post hoc tests revealed significant increases in Online Student Engagement Scale total scores from Time 0 to Time 1 ($t = 2.98$, $p = 0.010$), with no significant difference between Time 1 and Time 2. Similar patterns were observed for the Emotion, Participation and Performance subscales, with significant improvements from Time 0 to Time 1 ($p < 0.05$) and no significant change was observed between Time 1 and Time 2. The whole model's parameter estimates with standard error and proportion of variance explained by the model are in the appendix (Supplementary Table 7–11).

5.3. Qualitative findings

From the results of content analysis, three core categories were identified regarding the findings, namely the cultural diversity recognition, the acquisition of interprofessional attitudes and skills, and the active learning engagement, with subcategories under each category. The country of origin was indicated by using the prefixes followed by a group number. Students from Hong Kong, South Korea and Thailand were identified using HK, SK and TH.

Table 5
Mixed effects analyses for the pre-post effects for online student engagement scale.

	Omnibus F-test value	P value	Time 1 Change from Time 0 (t-value)#	P value	Time 2 Change from Time 1 (t-value)#	P value
Online Student Engagement Scale-total	13.420	<0.001*	2.980	0.010	1.920	0.138
Online Student Engagement Scale-skills	6.349	0.002	1.410	0.337	1.970	0.125
Online Student Engagement Scale emotion	15.774	<0.001*	3.730	<0.001*	1.470	0.187
Online Student Engagement Scale-participation	8.913	<0.001*	2.450	0.016	1.540	0.275
Online Student Engagement Scale -performance	7.086	0.001	2.507	0.036	0.987	0.587

#post-hoc pairwise comparison.

5.3.1. Category 1: cultural diversity recognition

This category captured students' changes in recognizing cultural diversity. Students from respective countries were able to obtain cultural knowledge that enhanced their understanding of cultural diversity. Specifically, they expressed that the e-learning modules allowed them to gain cultural knowledge through interactions with students from other countries, leading to an appreciation of the importance of cultural sensitivity in clinical practice. Students acknowledged that this learning was crucial for their development as better healthcare professionals in the future. This category includes three subcategories: 'respect on cultural uniqueness', 'awareness of cultural diversity' and 'learning of cultural practices.'

5.3.1.1. Subcategory 1: respect for cultural uniqueness. The students expressed how their interactions with other students from different cultural backgrounds fostered their ability to respect and adapt to unique cultural aspects. These cross-cultural encounters significantly contributed to their appreciation for cultural diversity. The students' reflections revealed that learning to respect diverse cultural characteristics was fundamental to their professional growth.

> *'By interacting with students from Hong Kong, I was also able to learn how to adapt and respect unique aspects of their culture.' (TH-GROUP1)*

> *'The modules enabled me to learn from other people and respect their unique culture. This was important to me because it will make me a better professional.' (HK- GROUP1)*

5.3.1.2. Subcategory 2: awareness of cultural diversity. The students demonstrated a growing awareness of cultural diversity through their cross-cultural interactions. They particularly recognized how cultural backgrounds influence patients' responses to healthcare situations. Their reflections revealed an enhanced understanding of practical aspects of cultural diversity, such as dietary preferences across different cultures. Notably, students acknowledged the importance of familiarizing themselves with diverse cultural practices, which can improve patient comfort and care quality.

> *'I liked being able to interact with students outside of Hong Kong, it gave me new perspectives on how culture can influence a patient on reacting to certain situations' (HK- GROUP3)*

> *"It was interesting to learn about different foods patients may eat in different countries. It made me think that we should get ourselves familiarize with different food options that can be offered to culturally diverse patients, making them feel comfortable." (SK- GROUP4)*

5.3.1.3. Subcategory 3: learning of cultural practices. The students recognized the importance of understanding diverse cultural practices for their future healthcare roles, particularly when treating patients from different cultural backgrounds. They demonstrated an awareness of cultural sensitivities, including verbal and non-verbal communication taboos that could affect relationships with both peers and patients.

> *'What I learned about different cultural practices will be important because in the future we will most likely have to treat patients from diverse backgrounds, and knowing about their cultural practices can help me act in a way that will make them feel more at home.' (TH-GROUP1)*

> *'Different cultures have different religions and practices that are considered unacceptable. Sometimes words are off-limits and saying them can sour a relationship no matter it is among co-workers or between caregivers and patients.' (SK- GROUP4)*

> *'I found the process to be engaging because different cultures have different details, we have to pay attention to when treating patients. For example, I learned that in Thailand it is considered rude and impolite if you touch someone's head. Knowing about cultural peculiarities like this can be helpful so that I won't accidentally offend a patient in the future.' (HK- GROUP2)*

5.3.2. Category 2: acquisition of interprofessional attitudes and skills

This category highlights the interprofessional attitudes and skills that the participants obtained from the e-learning modules. Participants from respective countries valued the interprofessional interactions they gained throughout the modules. Engaging with students from different health professions helped them recognize the attitudes and skills necessary for effective teamwork in future patient care. Participants expressed a desire for an extension of these modules in the future. This category is with two subcategories: 'acquired skills of communicating and appreciating work of different professions' and 'enhanced attitudes towards interprofessional teamwork'.

5.3.2.1. Subcategory 1: acquired skills of communicating and appreciating work of different professions. The students demonstrated the acquisition of communication skills as well as an enhanced sense of appreciation of other health profession roles, particularly in professions that were different from their own. They gained understanding of the work that is put in from other health professions, and how each profession contributes to the sustainability of a healthcare system.

> *'Throughout the learning modules, I was able to talk with different professionals and learn about what their responsibilities were. This made me gain a new level of appreciation on other health professions that were different than mine.' (HK- GROUP1)*

'The modules taught me about some of the work that is put in from other health professions, and also the importance of what different professions bring to the table.' (HK- GROUP2)

'I found that different professions vary a lot from one another in terms of the thoughts and focus they have on the patient. For us we might focus more on the gaze and their biomechanics, whereas nurses might mainly focus on how the patient reacts, along with their physiological and psychological condition' (TH- GROUP2)

5.3.2.2. Subcategory 2: enhanced attitudes towards interprofessional teamwork. The students demonstrated an overall improvement in attitudes towards different health professions. They also gained new perspectives on how to communicate with other health professions to deliver effective healthcare. Notably, this motivated the students to learn in an interprofessional team effort.

'After learning about different professions, I can go through certain procedures more smoothly and confidently since I now know what others are doing while treating a patient. This also helps me with the communication process between other healthcare professionals.' (SK- GROUP3)

'The more I learned about different professions, the more I was able to realize how little I really know about them. Overall, the modules made me want to learn even more about different health professions so that I can have a more well-rounded understanding of all the intricacies that are involved in caring for a patient.' (HK- GROUP4)

'By being part of the modules, I learned about how important it is for us to work together. Also, I now have a better understanding about what is involved in the delivery of healthcare from other perspectives that are very different from mine. (TH- GROUP1)

5.3.3. Category 3: active learning engagement

This category highlights the essence of learning engagement among participating students. They showed a high level of engagement throughout the e-learning modules, asking questions and sharing their thoughts and ideas about interprofessional practice and intercultural learning. Students from respective countries expressed that the environment cultivated in the e-learning modules encouraged their active participation. This category is divided into two subcategories: 'learning engagement through facilitators' and 'technology enhanced engagement'.

5.3.3.1. Subcategory 1: learning engagement through facilitators. The students recognized the significance of facilitators' role in fostering online learning engagement. Through the guidance of facilitators, students became aware of the importance of active engagement during discussion with their peers.

'The facilitators made the process a lot more engaging by asking plenty of guiding questions that got us thinking.' (HK- GROUP3)

'The facilitators did a very good job in encouraging us to talk with one another, without that I don't think I would have shared as much as I did' (TH- GROUP4)

'One of the things that I really liked about the modules is that almost everyone had something unique to contribute to the discussion through the facilitator's guidance, this kept me interested in the learning process' (TH- GROUP3)

5.3.3.2. Subcategory 2: technology enhanced engagement. The students acknowledged that being exposed to cutting edge technology throughout the learning process was vital. Their reflections revealed that this technological integration was intriguing and enhanced their engagement level. Particularly, the use of interactive gamification learning platform and Virtual Reality 360 videos was effective in maintaining their interest.

'I found the material itself to be very engaging, especially the Virtual Reality 360 videos where we were able to scroll around the room. I've never seen anything like this before enrolling into the modules and were intrigued by it.' (HK- GROUP1)

'I was surprised how much I was able to learn from talking with other healthcare *students and being part of the conversation, from the asynchronous interactive learning platform to the discussion guided by the engaging Virtual Reality 360 videos via Zoom.' (SK-GROUP2)*

6. Discussion

6.1. Internationalization of E-learning modules

In an increasingly globalized world, it is essential to integrate international, intercultural and/or global dimensions into course content through the use of innovative teaching methods (Stubbe, 2020). The internationalization of higher education is evolving, driven by enhanced globalization (Adil et al., 2024). E-learning internationalization approaches can address international barriers and engagement challenges by enhancing virtual mobility (Avolio and Benzaquen, 2024). E-learning connects learners globally, moving professional and higher education into online settings in terms of internationalization (Singh and Matthees, 2021). Additionally, internationalizing the curriculum through e-learning helps learners address specific learning gaps by providing insight into what needs

to be learned and how it may be achieved (Stutchbury et al., 2025). In the e-learning modules, intercultural learning components were introduced, emphasizing the importance of recognizing cultural diversity. The study results for the Interprofessional Attitudes Scale subscale – diversity and ethics showed a statistically significant change ($F = 4.43$, $p = 0.014$). In addition, the e-learning modules were synthesized through the utilization of asynchronous online discussion board and synchronous zoom sessions allowing students from different countries and cultures to engage in the learning process despite being geographically separated (Alfoldi, 2024; Yeh et al., 2024). The qualitative analysis revealed a significant gain among students in understanding cultural diversity, a cornerstone concept in internationalization. This is consistent with findings from the studies that adopted similar approaches in e-learning (Chan et al., 2024; Grover et al., 2024; Kor et al., 2022). Hence, integrating this intervention strategy into the course level would create a sustainable change in internationalizing the healthcare curriculum. Introducing an internationalization process at home should be applied to all programmes across different educational levels (Huang et al., 2023).

6.2. Use of innovative pedagogical approach in E-learning

With the rising power of simulation and other cutting-edge technologies, education is entering an unprecedented transformative phase. Research consistently shows that incorporating such technological advancements into the curriculum is effective in improving the understanding of interprofessional attitudes (Georgadarellis et al., 2024; Jiang et al., 2024; Mitchell et al., 2024; Yu et al., 2024). In the learning modules, students from different professions and cultural backgrounds engaged in deep learning using a gamification-enhanced education technology system and Virtual Reality 360 clinical simulation videos (Bharathy et al., 2024; Yilmaz et al., 2020). This innovative pedagogical approach has proven to be a crucial step for interprofessional and intercultural learning (Georgadarellis et al., 2024; Jiang et al., 2024). Current studies on technology-enhanced teaching and learning methods including gamification highlights their efficacy in creating successful learning experiences for students (Khoshnoodifar et al., 2023). Furthermore, studies highlight the use of Virtual Reality 360 as an efficacious pedagogy in higher education enhancing educational experiences and learning engagement (Grainger et al., 2024; Koukourikos et al., 2021; Mcloughin et al., 2018). Systematic analyses also demonstrate that integrating such scenario-based technology has significantly improved student learning outcomes (Mitchell et al., 2024; Yu et al., 2024).

In this study, the gamification element, implemented prior to the Virtual Reality intervention, likely established a strong foundation of student motivation and engagement through interactive and rewarding learning experiences. Consequently, the subsequent Virtual Reality intervention may have had an impact comparable to that of gamification, primarily maintaining students' interprofessional learning attitudes and online engagement at a similar level rather than providing an additional enhancement. This is consistent with research suggesting that when gamification has already elevated learners' motivation and engagement, introducing other innovative methods such as Virtual Reality may result in sustaining rather than significantly increasing these outcomes (Lampropoulos and Kinshuk, 2024; Radianti et al., 2020; Ratinho and Martins, 2023).

6.3. Interprofessional education in an online learning environment

The integration of online platforms to enhance interprofessional education had been on the rise for decades (Tunningley et al., 2024). Online interprofessional education allows for broader participation by overcoming in-person barriers and facilitates the learning process more effectively (Key-Solle et al., 2024). Additionally, it encourages self-directed learning among learners (Brown et al., 2024; Mclnerney et al., 2022), equipping them with essential digital literacy skills in higher education (Mokhtari, 2023; Zawacki-Richter et al., 2025). This prepares them to work collaboratively as part of an interprofessional team, promoting a practice–ready workforce (Costa Marion et al., 2025; Zeeman et al., 2024).

In this study, progressive learning strategies were developed to integrate interprofessional education into e-learning modules. The approach began with an asynchronous online learning platform and transitioned to synchronous virtual meeting via Zoom. This allowed students to interact and become familiar with their assigned groups, enhancing the group learning dynamic. The study's overall results highlighted that the integration of these strategies significantly enhanced interprofessional attitudes and learning engagement among participants as indicated by the statistically significant changes in the quantitative analysis of the Interprofessional Attitudes Scale ($F = 5.90$, $p = 0.004$), and the Online Student Engagement Scale ($F = 13.42$, $p < 0.001$). Furthermore, a positive correlation between the Interprofessional Attitudes Scale and the Online Student Engagement Scale was observed ($r = 0.535$, $p < 0.001$). These findings align with prior research findings suggesting that higher motivation and engagement in students correlate with the success of e-learning modules in improving interprofessional education (Ganotice et al., 2024, 2021; Ganotice and Chan, 2021). This study further supports that interprofessional education can be effectively delivered and learned in an online environment (Ganotice et al., 2024; Singh and Matthees, 2021).

6.4. Insignificant findings in the interprofessional attitudes scale – Bias

In the study, improvements involving the Interprofessional Attitudes Scale subscale – biases were not statistically significant ($F = 0.35$, $p = 0.704$). This could be attributed to the psychometric properties of the instrument used. The negatively worded items under the subscale of the Interprofessional Attitudes Scale – bias was problematic (Ganotice and Chan, 2021; Ganotice et al., 2021). Negatively worded items can occasionally impact on a scale's reliability and validity by causing confusion among respondents. Although the intent behind using negative items is to eliminate bias in responses to a psychometric scale, it may have unintendedly altered the connotation of sentences, hence affecting overall psychometric properties of the scale (Lin et al., 2017; Setiawati et al.,

2022). Nonetheless, the reliability analysis of the Interprofessional Biases subscale showed strong internal consistency (Cronbach's alpha = 0.909), indicating that the presence of negatively worded items did not significantly undermine the scale's reliability. Since the Interprofessional Attitudes Scale is widely adopted, further assessment and refinement of the negatively worded items may be warranted to enhance the Scale's validity and reliability.

6.5. Limitations

This study investigated the effects of cultural diversity, interprofessional education, and learning engagement on healthcare students from different countries and cultures by integrating innovative strategies into e-learning modules. Although the development and implementation of these teaching and learning strategies are grounded in solid theoretical foundation, there are several limitations in this study. First, the absence of a control group prevents us from comparing the intervention group's changes in recognizing cultural diversity, enhancing interprofessional attitudes and skills, and improving online learning engagement. Without a control group, quantifying the magnitude of the intervention's effect through a baseline comparison is impossible. Additionally, the lack of randomization makes it difficult to determine whether the intervention effects were due to inherent differences among the participating students, or potential confounding factors outside the study's scope. Besides, the sample size was relatively small, making this study prone to the "small study effect" where random fluctuations can lead to over or underestimates of the effect's magnitude. Lastly, this study was limited to Asian countries, which restricts the generalizability of the study findings to a global scale.

6.6. Recommendations for future research and implications

While the qualitative data suggests the Virtual Reality module enhances student learning, the quantitative results are inconclusive. Future research using randomized controlled trial design may better clarify its effectiveness compared to the gamification module. Increasing sample size is also recommended to enhance the reliability and generalizability of results. Furthermore, conducting similar studies across different geographic and cultural contexts will help determine the broader applicability of findings. These research enhancements will provide clearer insights into how technology can best support student engagement and learning. The implications of such research are significant, as they can guide educators in developing more effective, inclusive curricula that prepare students for collaborative and culturally sensitive practice in diverse healthcare environments.

7. Conclusions

With the rise of educational technology, implementing effective interprofessional education and internationalization training has become more accessible when the appropriate pedagogies and technology are used. Creating an environment that encourages active engagement in the learning process enables students to achieve greater success in future learning settings, whether that be domestic, global, or both.

This study examined the impact of technology-enhanced interprofessional and intercultural learning on healthcare students. The study's objectives were mostly achieved with the findings indicate that students involved in the technology-driven intervention demonstrated enriched interprofessional skills, increased cultural awareness and enhanced learning engagement. The adoption of education technology effectively encouraged active participation among students from diverse healthcare disciplines and different cultural regions. Employing well-validated psychometric instruments and qualitative interviews enhanced the reliability and validity of the results. Overall, these findings highlight the potential of integrating technology to enrich learning experiences and better prepare students for collaborative, culturally sensitive practice in today's diverse healthcare settings.

Declaration of generative Al and Al-assisted technologies in the writing process

During the preparation of this manuscript, the authors used ChatGPT 4.0 to improve the clarity and consistency of the writing style and language across different sections of the manuscript after completing the initial draft. The first and third authors reviewed and edited the content after using this Al tool, and all authors take full responsibility for the content of the final draft submitted for publication.

Data Availability Statement: The data supporting this study cannot be made publicly available due to the following reasons:

1. **Participant Consent Limitations:**
   The informed consent obtained from participants explicitly addressed confidentiality and privacy, and it did not include provisions for sharing the data with external researchers or repositories. Ensuring participant trust and adhering to ethical standards, particularly concerning the protection of sensitive information, remains a top priority for this study.
2. **Institutional Restrictions on Data Sharing:**
   This research is part of an institutionally funded project. According to the institution's policies, the data is considered proprietary and cannot be shared externally without explicit permission. These restrictions ensure compliance with institutional governance over intellectual property and data management policies.

While the research data cannot be shared directly, detailed information about the study's methodology, design, and key findings is provided within the article. We are open to addressing specific inquiries about the research within the constraints of these limitations.

CRediT authorship contribution statement

Siu Ling Chan: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **John Tai Chun Fung:** Writing – review & editing, Writing – original draft, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Man Sang Wong:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Conceptualization. **Christopher Chi Wai Cheng:** Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Investigation, Formal analysis, Data curation. **Jay Jung Jae Lee:** Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Investigation, Data curation. **Hye Ri Choi:** Writing – review & editing, Writing – original draft, Validation, Resources, Investigation, Formal analysis, Data curation. **Wai Hin Wan:** Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Investigation, Formal analysis, Data curation. **Harrison Withrow:** Writing – review & editing, Writing – original draft, Validation, Software, Resources, Project administration, Investigation. **Seng-iad Sirirat:** Writing – review & editing, Validation, Resources, Project administration, Methodology, Investigation, Conceptualization. **Wai Ho Tse:** Writing – review & editing, Resources, Investigation. **Rebecca Po Wah Poon:** Writing – review & editing, Resources, Investigation. **Choi Fung Lam:** Writing – review & editing, Resources, Investigation. **Hemio Chung Yan Lam:** Writing – review & editing, Resources, Investigation. **Chun Kit Chan:** Writing – review & editing, Resources, Investigation. **Chia Chin Lin:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Conceptualization.

Declaration of competing interest

The authors declared there are no financial interests/personal relationships that influence the work reported in this paper.

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Supplementary materials

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