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ORIGINAL ARTICLE

Enhancing Military Medical Education: A Pilot Study Integrating Kolb's Experiential Learning and Diversified Teaching Strategies to Elevate Undergraduate Medical Student Learning Effectiveness

Yu-Chin An[1], Che-Yu Guan[2], Hung-Kai Shih[1], Yi-Da Tsai[1], Shih-Hung Tsai[1], Wen-I Liao[1,3]

[1]Department of Emergency Medicine, Tri-Service General Hospital, National Defense Medical Center, Taipei, [2]Department of Emergency Medicine, Taoyuan Armed Forces General Hospital, National Defense Medical Center, Taoyuan, [3]Combat and Disaster Casualty Care Training Center, National Defense Medical Center, Taipei, Taiwan

Background: The increasing frequency of natural disasters, pandemics, and geopolitical conflicts highlights the importance of military and disaster medicine. Taiwan's vulnerability to frequent natural disasters and potential geopolitical threats emphasizes the need for an integrated medical education curriculum that prepares healthcare professionals for large-scale emergencies. Traditional lecture-based teaching may be insufficient, requiring innovative approaches. **Aim:** This pilot study focused on four core components: combat casualty care, disaster medicine, emergency medical services, and wilderness medicine, to enhance student motivation and learning outcomes in military medicine by integrating Kolb's learning cycle with diverse teaching methods. **Methods:** One-week summer program was developed for 3rd-year medical and nursing students, structured around Kolb's learning cycle. The teaching modalities included lecture-based teaching, hands-on practice, simulation-based training, and gamified learning. Each component followed Kolb's framework, applying concrete experience, reflective observation, abstract conceptualization, and active experimentation. Posttraining surveys measured perceived learning effectiveness, practical skills development, and overall satisfaction. **Results:** Among 101 participants, simulation-based training and gamified learning received the highest ratings for perceived learning effectiveness (3.84/5 and 3.81/5). Hands-on practice followed (3.80/5), whereas lecture-based teaching scored lowest (3.62/5). Program diversity scored highest in satisfaction (3.88/5), demonstrating the value of interactive teaching strategies. **Conclusion:** Integrating Kolb's learning cycle with diverse teaching methods enhances critical thinking, decision-making, and practical skills essential for military medicine. Future experiential programs should explore virtual and augmented reality to further improve engagement and preparedness for real-world challenges.

Key words: Military medicine, military medical education, Kolb's experiential learning, diversified teaching strategies

INTRODUCTION

In recent years, the importance of military and disaster medicine has grown significantly due to the rising frequency of natural disasters, pandemics, and geopolitical conflicts.[1] Military medicine, which focuses on managing combat-related injuries and medical emergencies in conflict zones, and disaster medicine, which deals with the medical response to large-scale natural or man-made disasters, have become essential components of national and global health preparedness.[2] Events like the COVID-19 pandemic have highlighted the urgent need for robust medical systems capable of responding to large-scale emergencies and saving lives in rapidly evolving situations.[3] Global warming, geopolitical instability, and the risk of pandemics further highlight the critical role of disaster preparedness in health care.

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Corresponding Author: Dr. Wen-I Liao, Department of Emergency, Tri-Service General Hospital, National Defense Medical Center, No. 325, Sec. 2, Chenggong Road, Neihu 114, Taipei, Taiwan. Tel: +886-2-87923311 # 16877; Fax: +886-2-66008289. E-mail: qqww0139@yahoo.com.tw

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Taiwan, situated along the highly active Circum-Pacific seismic belt and in the path of seasonal typhoons, is frequently affected by natural disasters such as earthquakes, typhoons, and floods. Its high population density and concentrated urban areas intensify the impact of these disasters, significantly affecting the nation's economy, environment, and public health.[4] According to a 2005 World Bank report, 73% of Taiwan's land and population are exposed to three or more natural hazards, including earthquakes, landslides, and floods, with nearly 99% of the population facing at least two risks.[5] These factors place Taiwan among the world's most hazard-prone regions. Furthermore, the increasing frequency and severity of extreme weather events driven by climate change further heightens the country's vulnerability. Taiwan's exposure to frequent natural disasters and potential geopolitical conflicts emphasizes the need to incorporate military and disaster medicine into its medical education curriculum. This integration is vital for equipping healthcare professionals to manage large-scale emergencies effectively. The Association of American Medical Colleges has recommended that disaster medicine and mass casualty incident (MCI) management be core components of medical training, a reform that could benefit Taiwan significantly.[6] In countries like Germany, federal laws mandate the inclusion of disaster medicine in medical education.[7] However, similar to the United States, disaster medicine training remains minimal or absent in many Taiwanese medical schools. The complexity and unpredictability of disasters, coupled with regional military threats, highlight the critical need for Taiwan's medical education system to adopt a more structured and comprehensive approach to military medicine, ensuring future healthcare professionals are adequately prepared for emergency responses.

Traditional medical education, often dominated by lecture-based teaching, may fail to prepare students for the practical challenges of military medicine. Addressing this gap requires the integration of diverse teaching strategies to enhance undergraduate learning effectiveness. Kolb's learning cycle, a renowned educational framework, describes experiential learning as a four-stage process: concrete experience, reflective observation, abstract conceptualization, and active experimentation.[8] Its application in medical education has shown promising outcomes. For instance, surgical education studies report that incorporating all four stages improves technical skills and knowledge retention among residents.[9] Similarly, using Kolb's framework in emergency medicine has been associated with enhanced critical thinking and decision-making skills.[10] By enabling students to transition from theoretical knowledge to practical application, Kolb's model enhances their preparedness for real-world medical scenarios. Integrating diverse teaching methods–such as hands-on practice, simulation-based training, and gamified learning–alongside traditional lectures can significantly improve student engagement and learning outcomes.[11,12]

This pilot study evaluated the effectiveness of combining lecture-based teaching, hands-on practice, simulation-based training, and gamified learning within Kolb's learning cycle to enhance student motivation and outcomes in military medicine. Lecture-based teaching provides concrete experience, whereas hands-on training encourages reflective observation. Debriefing sessions following simulations foster abstract conceptualization, and gamified learning scenarios promote active experimentation. Together, these methods offer immersive experiences simulating real-world scenarios, helping students develop critical thinking, decision-making, and practical skills essential in high-pressure situations typical of military and disaster medicine. The study addresses theoretical and practical gaps in medical education, fostering an interactive learning environment to prepare students for the complexities of military medicine.

MATERIALS AND METHODS

Framework of the curriculum

The goal of the curriculum is to immerse 3rd-year medical and nursing students in military medicine through a 1-week summer program with a focus on practical training [Figure 1]. The program aims to strengthen medical and nursing students' competencies in core structures such as combat casualty care, disaster medicine, emergency medical services, and wilderness medicine [Figure 2]. The curriculum references the U. S. military's Tactical Combat Casualty Care (TCCC) guidelines, adapted with civilian medical practices to ensure relevance across both military and civilian settings.[13] This integration ensures students gain practical skills applicable to both emergency response scenarios and clinical environments. The TCCC framework, widely recognized for its effectiveness in combat zones, emphasizes early hemorrhage control, airway management, and evacuation strategies–essential competencies for both military and high-threat civilian environments. Disaster medicine training and emergency medical services ensure that students are prepared to respond to MCIs and environmental hazards, which are associated with civilian emergency preparedness. Similarly, wilderness medicine teaches adaptability by exposing students to care in resource-scarce settings, a concept that parallels battlefield conditions. The combined training not only enhances clinical competence but also promotes resilience and rapid decision-making, critical for both military and disaster settings. This interdisciplinary approach broadens students' abilities, making them capable of addressing emergencies in any

Table 1: Student Demographics

Characteristic	Category	*n*	%
Sex	Male	65	64.4%
	Female	36	35.6%
Age	20	4	4.0%
	21	36	35.6%
	22	34	33.7%
	23	16	15.8%
	24	10	9.9%
	25	1	1.0%
Funding Status	Military-funded students	73	72.3%
	Non-military-funded students	28	27.7%
Department	Medicine	92	91.1%
	Nursing	9	8.9%

Demographic characteristics of students who completed the survey, including sex, age distribution, funding status, and department affiliation. Percentages are calculated based on a total of 101 respondents

environment, whether on the battlefield or in disaster-affected regions.

Teaching format

To implement Kolb's learning cycle effectively, the curriculum integrates four key teaching modalities: lecture-based instruction, hands-on practice, simulation-based training, and gamified learning [Figure 3]. Lecture-based teaching establishes a solid foundation of knowledge, equipping students with theoretical frameworks and providing essential concrete experience. Hands-on training, such as trauma care practice, reinforces practical skills and fosters reflective observation, enabling students to internalize their experiences and refine their techniques through feedback.

Simulation-based training offers high-fidelity experiences, immersing students in diverse scenarios, including acute heat injury management, chemical, biological, radiological, and nuclear decontamination drills, portable hyperbaric chamber training, and helicopter medical crew operations. These scenarios promote abstract conceptualization by incorporating debriefing sessions, where students analyze their performance, identify areas for improvement, and deepen their understanding of critical interventions.

Finally, gamified learning focuses on MCI management, immersing participants in dynamic, real-time challenges where they must apply learned concepts, adapt strategies, and collaborate under pressure. In this interactive format, students engage in structured decision-making processes, similar to team-based emergency situations. In our board game "Emergency on Fire" scenarios replicating mass casualty incidents, students are required to triage patients, allocate resources, and prioritize care within a limited timeframe. Immediate feedback, often in the form of scoring systems, reinforces learning by providing a structured framework that links actions to outcomes. Our gamified learning supports the active experimentation stage of Kolb's cycle, where students test their understanding in a controlled yet high-stakes environment.

Evaluations and knowledge tests

Following the curriculum, students voluntarily completed self-assessment surveys measuring learning effectiveness in both professional knowledge and practical skills. The questions are listed in Supplementary Table 1. Questions also evaluated overall satisfaction with the course content and teaching methods [Supplementary Table 2]. Scores were reported on a 5-point Likert scale (5 = strongly agree, 1 = strongly disagree).

At the conclusion of the training, students completed posttraining knowledge assessments designed to evaluate their understanding of core concepts. While a preassessment was initially considered, our focus shifted toward the posttraining assessment to ensure students demonstrated competency after exposure to the curriculum. This strategy allowed us to concentrate on measuring immediate learning outcomes, gauging how well students grasped key theoretical and practical elements following the program.

Ethics

This study was carried out in compliance with the ethical principles outlined in the World Medical Association's Declaration of Helsinki. As the study protocol was embedded within routine program assessments, obtaining individual consent from participants was deemed unnecessary, in accordance with guidelines provided by the Ministry of Health and Welfare, Taiwan (1010265075, https://regulation.cde.org.tw/data/downloadfile.php?sid = 912).

Statistical analysis

Descriptive statistics, including means and standard deviations, were used to summarize survey responses. Independent *t*-tests and one-way ANOVA were conducted to examine differences in learning effectiveness and satisfaction based on student demographics, including sex, age, funding status, and department. All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) version 26.0 (SPSS Inc., Chicago, IL, USA), with a two-sided p-value of less than 0.05 considered statistically significant.

RESULTS

Of the 174 students who participated in the program, 101 voluntarily completed the post-training survey. Among the respondents, 92 (91.1%) were medical students and 9 (8.9%)

Day 1

Time	Topic
10:00—10:50	Military Combat Casualty Care Framework and Development
11:00—11:50	Overview and Demonstration of Combat Casualty Care Assessment and Management
Recess	

Time	Trauma Airway Management	Needle Decompression and Emergency Thoracostomy	Tourniquet and Pelvic Binding Techniques	Walking Blood Bank
13:30—14:20	A	B	C	D
14:30—15:20	D	A	B	C
15:30—16:20	C	D	A	B
16:30—17:20	B	C	D	A

Day 2

Time	Topic
10:00—10:50	Burn Care and Wound Management Overview
11:00—11:50	Introduction to Aeromedical Evacuation
Recess	

Time	Fracture Immobilization	Acute Heat Injuries	Helicopter Medical Crew Operations	Mass Casualty Incident Tabletop Exercise
13:30—14:20	A	B	C	D
14:30—15:20	D	A	B	C
15:30—16:20	C	D	A	B
16:30—17:20	B	C	D	A

Day 3

Time	Topic
09:00—09:50	Introduction to Military Psychiatry
10:00—10:50	Diagnosis and Management of Diving-Related Disorders
11:00—11:50	Wilderness Patient Assessment and Medical Issues
Recess	

Time	Hyperbaric Oxygen Therapy Experience	Portable Hyperbaric Chamber Practical Training	High Altitude Illnesses	Trauma Ultrasound Techniques
13:30—14:20	A	B	C	D
14:30—15:20	D	A	B	C
15:30—16:20	C	D	A	B
16:30—17:20	B	C	D	A

Day 4

Time	Topic
09:00—09:50	Radiation Injuries and Introduction to Radiation Protection Centers
10:00—10:50	Introduction to Emerging Infectious Diseases and Biological Protection
11:00—11:50	Management of Snake Bites in Taiwan
Recess	

Time	Protective Gear Operation	Chemical Decontamination Simulation Training	Biological Detectors and Rapid Pathogen Detection	Tactical Rope Techniques
13:30—14:20	A	B	C	D
14:30—15:20	D	A	B	C
15:30—16:20	C	D	A	B
16:30—17:20	B	C	D	A

Figure 1: One-Week Schedule for Military Medicine Training Program One-Week Summer Training Program for Third-Year Medical and Nursing Students: A detailed schedule of topics and activities

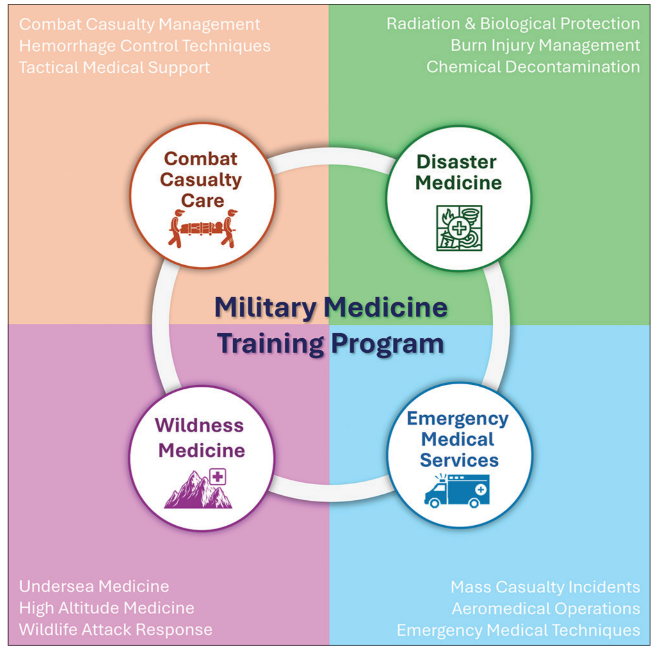

Figure 2: Core Structure of the Military Medicine Training Program. This diagram illustrates the program's core components, covering essential military medical disciplines such as Combat Casualty Care, Disaster Medicine, Emergency Medical Services, and Wilderness Medicine

were nursing students. The sample included 65 (64.4%) male and 36 (35.6%) female students. Additionally, 73 (72.3%) were military-funded students, while 28 (27.7%) were non-military-funded students. The age distribution ranged from 20 to 25 years, with the majority being 21 (35.6%) and 22 (33.7%) years old [Table 1]. Statistical analysis [Supplementary Tables 3-10].

indicated no significant differences in perceived learning effectiveness and satisfaction scores when comparing students by sex, funding status, or department ($p > 0.05$ for all comparisons).

Perceived learning effectiveness of professional knowledge and practical skills

The perceived learning effectiveness of professional knowledge and practical skills is presented in Table 2 and Figure 4. For professional knowledge, the results indicate that simulation-based training and gamified learning received the highest average scores of 3.84 and 3.81, respectively. Hands-on training followed with an average score of 3.80, whereas lecture-based teaching received the lowest score at 3.62. The overall impact of the program on professional knowledge was evaluated at 3.65.

For practical skills, simulation-based training received the highest rating with an average score of 3.89. Hands-on training followed closely with an average score of 3.85.

Gamified learning received an average score of 3.82, whereas lecture-based teaching was rated lowest at 3.61. The overall impact of the program on practical skills was evaluated at 3.75.

Satisfaction survey

The satisfaction survey of the program, as presented in Table 3 and Figure 5, showed that overall satisfaction was rated at 3.88. Among the teaching methods, gamified learning had the highest satisfaction score of 3.90, followed by hands-on training at 3.88 and simulation-based training at 3.82. Lecture-based teaching received a score of 3.74. Program content and diversity were both rated highly, with scores of 3.80 and 3.88, respectively. Program practicality received a score of 3.74, whereas program difficulty was rated at 3.72. Instructors received an average rating of 3.77, and both the classroom environment and teaching equipment were rated at 3.74.

DISCUSSION

This pilot study demonstrates the effectiveness of integrating Kolb's learning cycle with diverse teaching strategies in military medical education. While the results did not reveal significant differences in perceived effectiveness based on student demographics, the overall positive feedback across lecture-based teaching, hands-on training, simulation-based training, and gamified learning highlights the value of a blended educational approach that is broadly effective across different student backgrounds. Notably, program diversity received a high average satisfaction score of 3.88 out of 5, indicating that students appreciated the variety of teaching methods and the dynamic learning environment. These findings emphasize the importance of employing varied instructional techniques to maintain student engagement and motivation, even when individual methods perform similarly.

Kolb's learning cycle provides a structured framework for experiential learning, consisting of four stages: concrete experience, reflective observation, abstract conceptualization, and active experimentation. This model effectively bridges the gap between theoretical knowledge and practical application, which is critical in fields such as military and disaster medicine. Foundational lectures offered students concrete experiences, whereas reflective observation was promoted during debriefing sessions following practical scenarios. These debriefings encouraged students to evaluate their decisions in simulated crises, a practice supported by Yardley *et al*., who emphasize the importance of embedding learners in meaningful, authentic

Table 2: Perceived learning effectiveness of Professional Knowledge and Practical Skills

Learning method	1	2	3	4	5	Mean (±SD)
Overall Impact - Professional Knowledge	1	6	38	38	18	3.65±0.88
Lecture-based Teaching	1	4	42	39	15	3.62±0.82
Hands-On Training	1	2	34	43	21	3.80±0.82
Simulation-based Training	0	2	35	41	23	3.84±0.80
Gamified Learning	1	2	36	38	24	3.81±0.86
Overall Impact - Practical Skills	1	3	37	39	21	3.75±0.93
Lecture-based Teaching	1	4	45	34	17	3.61±0.85
Hands-On Training	1	1	32	45	22	3.85±0.85
Simulation-based Training	0	2	31	44	24	3.89±0.77
Gamified Learning	1	2	36	37	25	3.82±0.77

This table presents students' evaluations of various aspects of learning effectiveness, categorized into professional knowledge and practical skills. The scores range from 1 to 5, with 1 representing the lowest and 5 the highest perceived effectiveness. The mean score (± SD) reflects the overall assessment for each learning method

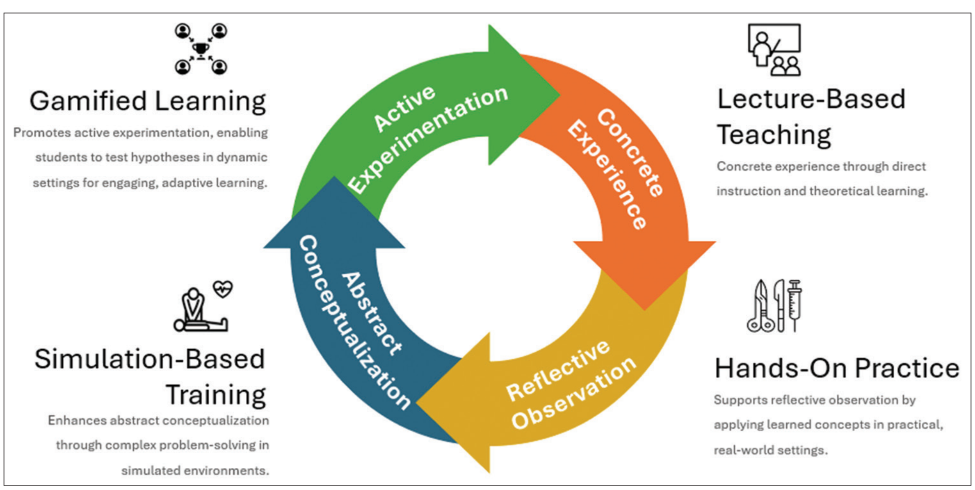

Figure 3: Kolb's Learning Cycle in Military Medicine Training. This figure demonstrates how Kolb's experiential learning theory is applied within the training, integrating lecture-based teaching, hands-on practice, simulation-based training, and gamified learning to enhance learning outcomes

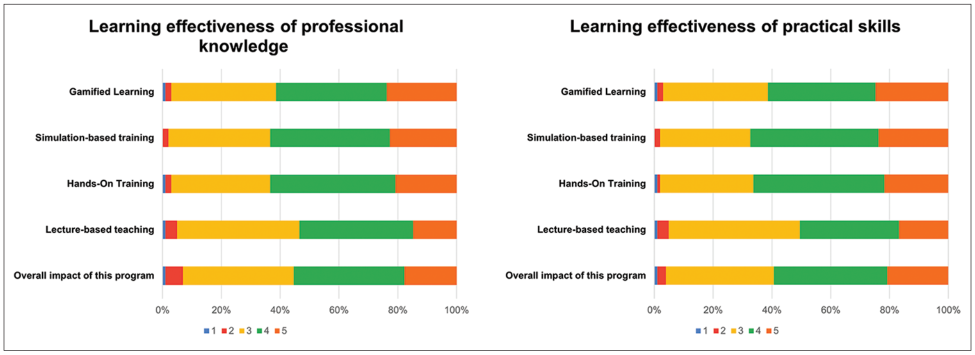

Figure 4: Learning Effectiveness of Professional Knowledge and Practical Skills. Self-assessment results from participants show the perceived learning effectiveness across different teaching methods. (A) Professional Knowledge and (B) Practical Skills, including overall impact, lecture-based teaching, hands-on training, simulation-based training, and gamified learning

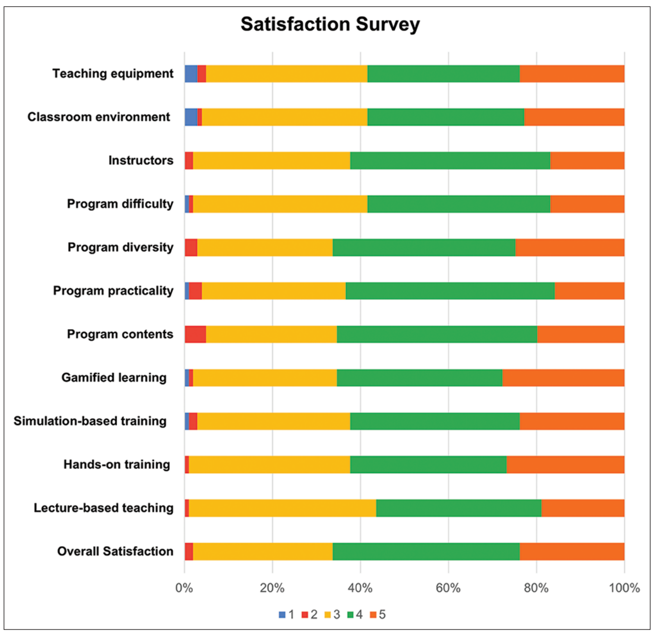

Figure 5: Satisfaction Survey. This figure shows participants' overall satisfaction with various aspects of the program, including teaching methods, equipment, instructors, and classroom environment

Table 3: Satisfaction Survey

Program events	1	2	3	4	5	Mean (±SD)
Overall Satisfaction	0	2	32	43	24	3.88±0.81
Lecture-based Teaching	0	1	43	38	19	3.74±0.79
Hands-On Training	0	1	37	36	27	3.88±0.85
Simulation-based Training	1	2	35	39	24	3.82±0.79
Gamified Learning	1	1	33	38	28	3.90±0.81
Program Content	0	5	30	46	20	3.80±0.7
Program Practicality	1	3	33	48	16	3.74±0.81
Program Diversity	0	3	31	42	25	3.88±0.77
Program Difficulty	1	1	40	42	17	3.72±0.92
Instructors	0	2	36	46	17	3.77±0.95
Classroom Environment	3	1	38	36	23	3.74±0.81
Teaching Equipment	3	2	37	35	24	3.74±0.78

This table presents students' evaluations of various aspects of program satisfaction, categorized by different teaching and learning events. The scores range from 1 to 5, with 1 representing the lowest and 5 the highest satisfaction level. The mean score (± SD) reflects the overall satisfaction for each program event.

contexts.[14] Kolb's iterative learning process, as discussed by Akella, fosters adaptability and critical thinking, enhancing students' ability to connect theoretical knowledge to real-world applications.[15] Realistic simulations further enrich this process, as highlighted by Buragohain *et al*., who note their role in improving knowledge retention and professional competence under controlled conditions.[16]

Simulation-based training and hands-on practice received high satisfaction scores, emphasizing the importance of immersive learning experiences. Simulation-based scenarios, such as acute heat injury management and chemical decontamination, provided students with high-fidelity learning environments that improved practical skills. These findings affiliate with research showing that simulations enhance problem-solving abilities and build confidence in applying learned concepts.[17] Hands-on activities, such as trauma care training, supported the reflective observation stage of Kolb's cycle by allowing students to internalize critical skills in realistic but risk-free settings.[18] Furthermore, hyperbaric chamber simulation training, a high-fidelity tool, mirrored the demands of real-world hyperbaric and acute care environments, fostering technical proficiency, teamwork, and readiness for high-stress scenarios.[19] These methods not only strengthened practical skill development but also bridged the gap between theoretical learning and real-world application, preparing students for high-pressure situations.

Gamified learning, focused on MCI management, achieved the highest satisfaction score (3.9/5), demonstrating its ability to engage students and promote interactive learning. This finding associates with literature suggesting that gamification enhances motivation, cognitive engagement, and behavioral adaptability through challenge-based learning.[20,21] In this study, gamified scenarios were implemented as tabletop exercises, requiring students to strategize actively under time constraints. These exercises fostered peer collaboration, problem-solving, and adaptive decision-making, replicating high-stakes conditions typical of real-world MCIs. Chiang *et al*. validated the effectiveness of tabletop exercises, showing that they help refine practical skills in controlled but realistic settings.[20] In addition, Castro Delgado *et al*. emphasized the structured nature of tabletop simulations, which incorporate briefing, action, and debriefing phases to enhance knowledge retention and integrate theoretical and practical insights.[22] This structure aligns with Kolb's active experimentation stage, where iterative testing of strategies fosters deeper understanding. Gamification also allows the integration of localized and experiential knowledge, as noted by Toyoda and Tanwattana, who demonstrated its effectiveness in extracting and applying context-specific knowledge.[21] Similarly, Smiderle *et al*. found that elements such as rankings, real-time feedback, and badges significantly enhanced student engagement and supported trial-and-error learning.[23] By adopting gamification, this program mirrors the complexities of real emergencies and encourages students to actively participate in learning through practical experimentation, ultimately internalizing critical competencies.

Lecture-based teaching provided essential theoretical frameworks but received the lowest scores in both satisfaction and perceived effectiveness. This result is consistent with prior research showing that while lectures are fundamental to medical education, they are less effective at fostering critical thinking and practical skill acquisition compared to experiential learning methods. However, lectures remain valuable as part of Kolb's concrete experience stage, offering students a foundation for engaging in more interactive and hands-on activities.[24,25] Students who reported lower perceived learning effectiveness across all teaching methods often struggled to establish a strong foundation during the concrete experience stage, which may have disrupted their progression through subsequent stages of learning. Programs like the Parkinson's Disease Buddy Program, which emphasize real-world engagement and community interaction, illustrate the importance of meaningful initial engagement in fostering knowledge retention and comprehension.[26] Socially integrated, active learning opportunities can bridge these gaps, enabling smoother transitions through Kolb's stages. Young highlights the importance of balancing "hands-on" and "minds-on" activities to ensure a complete and meaningful learning cycle.[27] Techniques such as reflective observation, guided discussions, and conceptual mapping enhance learning by linking practical experiences to theoretical concepts.

As a pilot study, this research offers valuable guidance for future curriculum development and evaluation. Of the 174 students who participated in the program, 101 completed the survey (58%). While not capturing every participant's perspective, this response rate is consistent with voluntary educational research and provides meaningful insights into student engagement and learning preferences.[28,29] The diversity of responses, including a range of scores across different teaching methods, suggests a balanced representation of student experiences. Notably, the lower ratings for lecture-based teaching indicate that students critically evaluated different instructional approaches rather than uniformly providing high scores.

Our analysis revealed no significant differences in perceived learning effectiveness and satisfaction scores between military-funded and non-military-funded students ($P > 0.05$, Supplementary Tables 7-8). This suggests that funding status did not influence students' engagement with or perceptions of the curriculum. Prior study indicate that factors such as motivation and learning environment may play a more critical role in shaping educational outcomes than financial sponsorship alone.[30] This result support the idea that a well-structured and interactive curriculum can be equally effective across students with different funding backgrounds. However, as this study was conducted within a specific cohort of third-year medical and nursing students, future research should assess the adaptability of this curriculum across diverse healthcare populations, including students from different academic levels, training institutions, and professional settings.

This study has several strengths. First, it addresses the historically limited focus on military medicine education in Taiwan by introducing engaging and effective teaching methods. The curriculum's diversified approach, structured around Kolb's learning cycle, combines theoretical knowledge with practical skills, providing students with a comprehensive learning experience that facilitates the transition from theory to practice. Second, aligning the curriculum with TCCC guidelines while incorporating relevant civilian practices enhances its applicability. The inclusion of disaster medicine and wilderness medicine further prepares students for diverse environments, from battlefield scenarios to resource-limited settings, equipping them to handle emergencies across various contexts.

Despite its strengths, this study has several limitations. First, the lack of pre-assessment makes it challenging to objectively measure improvements in students' knowledge and skills. Future studies should incorporate pre- and post-assessments to better evaluate learning outcomes and examine the long-term impact on clinical performance. Additionally, this study primarily focuses on short-term learning effectiveness, and future research should explore knowledge retention and skill application over time through longitudinal studies. Second, the group size varied between different teaching sessions, with 174 students attending lectures while smaller groups of approximately 40 students participated in hands-on and simulation-based training. While qualitative feedback did not indicate dissatisfaction related to group size, the number of students per session may influence engagement and learning effectiveness. Future research should systematically assess the impact of group size on student performance and satisfaction. Third, the one-week program duration may limit in-depth learning and long-term retention of complex concepts. However, this study primarily aims to examine the effectiveness of this learning framework in military medical education and its potential for future curriculum development. Expanding the curriculum could facilitate more iterative learning experiences and allow students to reinforce their skills over time, ultimately enhancing competency in military medical education. Finally, this study relied on self-reported assessments without objective performance evaluations, which may introduce response bias. While survey responses showed a diverse range of ratings, future studies should integrate standardized skill assessments and incorporate emerging technologies such as virtual reality (VR) and augmented reality (AR) to enhance experiential learning and provide more objective outcome measurements.

CONCLUSION

This pilot study highlights the effectiveness of integrating Kolb's learning cycle with diverse teaching methods in military medical education. By combining lecture-based teaching, hands-on practice, simulation-based training, and gamified learning, the curriculum bridges the gap between theoretical knowledge and practical application. The positive student feedback, particularly on program diversity and engagement, highlights the value of adopting interactive and experiential learning approaches. Focusing on the program's four core areas–combat casualty care, disaster medicine, wilderness medicine, and emergency medical services–the curriculum provides students with a well-rounded skill set to address the complex demands of military medicine. Each component plays a key role in equipping students to manage real-world emergencies, offering targeted training to develop critical competencies such as adaptability, decision-making, and technical expertise in high-pressure environments. As military medicine evolves to meet increasing challenges, incorporating innovative and experiential teaching strategies is essential for preparing healthcare professionals. Future enhancements, including virtual and AR tools, could further enhance the learning experience, making training more immersive and adaptable to the dynamic needs of healthcare and emergency response.

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Conflicts of interest

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Supplementary Table 1. Questions assessing the medical students' self-perceived learning effectiveness knowledge and skills after the program

What is the impact of "gamified learning" on the learning effectiveness of "professional knowledge"?
What is the impact of "simulation-based training" on the learning effectiveness of "professional knowledge"?
What is the impact of "hands-on practice courses" on the learning effectiveness of "professional knowledge"?
What is the impact of "lecture-based teaching" on the learning effectiveness of "professional knowledge"?
What is the overall impact on the learning effectiveness of "professional knowledge"?
What is the impact of "hands-on practice courses" on the learning effectiveness of "practical skills"?
What is the impact of "gamified learning" on the learning effectiveness of "practical skills"?
What is the impact of "simulation-based training" on the learning effectiveness of "practical skills"?
What is the impact of "lecture-based teaching" on the learning effectiveness of "practical skills"?
What is the overall impact on the learning effectiveness of " practical skills "?

Supplementary Table 2. Questions assessing the students' satisfaction

Were you satisfied with the Teaching equipment?
Were you satisfied with the Classroom environment?
Were you satisfied with the Instructors?
Were you satisfied with the Program's difficulty?
Were you satisfied with the Program's diversity?
Were you satisfied with the Program's practicality?
Were you satisfied with the Program contents?
Were you satisfied with the Gamified learning?
Were you satisfied with the Simulation-based training?
Were you satisfied with the Hands-on training?
Were you satisfied with the Lecture-based teaching?
Were you satisfied with the overall Program?

Supplementary Table 3: Perceived learning effectiveness of Professional Knowledge and Practical Skills according to age

Learning method	20-21 years (*n* = 40)	22-23 years (*n* = 50)	24-25 years (*n* = 11)	*P* value
Overall Impact - Professional Knowledge	3.55 ± 0.85	3.70 ± 0.95	3.82 ± 0.60	0.586
Lecture-based Teaching	3.58 ± 0.81	3.64 ± 0.88	3.73 ± 0.65	0.849
Hands-On Training	3.73 ± 0.85	3.88 ± 0.85	3.73 ± 0.65	0.647
Simulation-based Training	3.75 ± 0.84	3.90 ± 0.79	3.91 ± 0.70	0.650
Gamified Learning	3.85 ± 0.80	3.76 ± 0.94	3.91 ± 0.70	0.820
Overall Impact - Practical Skills	3.70 ± 0.82	3.76 ± 0.92	3.91 ± 0.70	0.772
Lecture-based Teaching	3.58 ± 0.75	3.58 ± 0.95	3.91 ± 0.70	0.478
Hands-On Training	3.80 ± 0.76	3.84 ± 0.87	4.09 ± 0.70	0.568
Simulation-based Training	3.73 ± 0.72	4.02 ± 0.84	3.91 ± 0.70	0.210
Gamified Learning	3.83 ± 0.84	3.80 ± 0.93	3.91 ± 0.70	0.932

This table presents students' evaluations of various aspects of learning effectiveness, categorized into professional knowledge and practical skills. The scores range from 1 to 5, with 1 representing the lowest and 5 the highest perceived effectiveness. The mean score (± SD) reflects the overall assessment for each learning method.

Supplementary Table 4: Satisfaction Survey according to age

Program events	20-21 years (*n* = 40)	22-23 years (*n* = 50)	24-25 years (*n* = 11)	*P* value
Overall Satisfaction	3.78 ± 0.80	3.96 ± 0.83	3.91 ± 0.54	0.545
Lecture-based Teaching	3.70 ± 0.79	3.76 ± 0.80	3.82 ± 0.60	0.883
Hands-On Training	3.88 ± 0.85	3.90 ± 0.84	3.82 ± 0.60	0.955
Simulation-based Training	3.80 ± 0.82	3.84 ± 0.93	3.82 ± 0.60	0.976
Gamified Learning	3.93 ± 0.86	3.90 ± 0.91	3.82 ± 0.60	0.936
Program Content	3.73 ± 0.88	3.82 ± 0.80	4.00 ± 0.63	0.600
Program Practicality	3.60 ± 0.87	3.84 ± 0.77	3.82 ± 0.60	0.348
Program Diversity	3.73 ± 0.85	3.96 ± 0.81	4.09 ± 0.70	0.267
Program Difficulty	3.65 ± 0.86	3.74 ± 0.78	3.91 ± 0.54	0.618
Instructors	3.65 ± 0.70	3.82 ± 0.77	4.00 ± 0.77	0.320
Classroom Environment	3.65 ± 1.03	3.74 ± 0.85	4.09 ± 0.83	0.378
Teaching Equipment	3.70 ± 0.94	3.68 ± 0.96	4.18 ± 0.87	0.265

This table presents students' evaluations of various aspects of program satisfaction, categorized by different teaching and learning events. The scores range from 1 to 5, with 1 representing the lowest and 5 the highest satisfaction level. The mean score (± SD) reflects the overall satisfaction for each program event.

Supplementary Table 5: Perceived learning effectiveness of Professional Knowledge and Practical Skills according to sex

Learning method	Male (*n* = 65)	Female (*n* = 36)	*P* value
Overall Impact - Professional Knowledge	3.69 ± 0.92	3.58 ± 0.81	0.552
Lecture-based Teaching	3.68 ± 0.85	3.53 ± 0.77	0.386
Hands-On Training	3.86 ± 0.86	3.69 ± 0.75	0.332
Simulation-based Training	3.92 ± 0.80	3.69 ± 0.79	0.168
Gamified Learning	3.86 ± 0.93	3.72 ± 0.70	0.437
Overall Impact - Practical Skills	3.83 ± 0.91	3.61 ± 0.73	0.217
Lecture-based Teaching	3.65 ± 0.89	3.56 ± 0.77	0.610
Hands-On Training	3.86 ± 0.85	3.83 ± 0.74	0.867
Simulation-based Training	3.98 ± 0.80	3.72 ± 0.74	0.109
Gamified Learning	3.86 ± 0.92	3.75 ± 0.77	0.537

This table presents students' evaluations of various aspects of learning effectiveness, categorized into professional knowledge and practical skills. The scores range from 1 to 5, with 1 representing the lowest and 5 the highest perceived effectiveness. The mean score (± SD) reflects the overall assessment for each learning method.

Supplementary Table 6: Satisfaction Survey according to sex

Program events	Male (n = 65)	Female (n = 36)	P value
Overall Satisfaction	3.92 ± 0.83	3.81 ± 0.71	0.477
Lecture-based Teaching	3.80 ± 0.77	3.64 ± 0.76	0.316
Hands-On Training	3.92 ± 0.85	3.81 ± 0.75	0.491
Simulation-based Training	3.86 ± 0.90	3.75 ± 0.77	0.532
Gamified Learning	3.95 ± 0.93	3.81 ± 0.71	0.406
Program Content	3.82 ± 0.79	3.78 ± 0.87	0.825
Program Practicality	3.78 ± 0.78	3.67 ± 0.83	0.478
Program Diversity	3.91 ± 0.80	3.83 ± 0.85	0.663
Program Difficulty	3.75 ± 0.71	3.67 ± 0.93	0.597
Instructors	3.75 ± 0.77	3.81 ± 0.71	0.741
Classroom Environment	3.80 ± 0.81	3.64 ± 1.10	0.404
Teaching Equipment	3.80 ± 0.92	3.64 ± 0.99	0.415

This table presents students' evaluations of various aspects of program satisfaction, categorized by different teaching and learning events. The scores range from 1 to 5, with 1 representing the lowest and 5 the highest satisfaction level. The mean score (± SD) reflects the overall satisfaction for each program event.

Supplementary Table 7: Perceived learning effectiveness of Professional Knowledge and Practical Skills according to funding status

Learning method	Military-funded students (n = 65)	Non-military-funded students (n = 36)	P value
Overall Impact - Professional Knowledge	3.67 ± 0.93	3.61 ± 0.74	0.744
Lecture-based Teaching	3.63 ± 0.86	3.61 ± 0.74	0.901
Hands-On Training	3.82 ± 0.89	3.75 ± 0.65	0.697
Simulation-based Training	3.88 ± 0.85	3.75 ± 0.65	0.477
Gamified Learning	3.82 ± 0.90	3.79 ± 0.74	0.850
Overall Impact - Practical Skills	3.77 ± 0.89	3.71 ± 0.76	0.782
Lecture-based Teaching	3.64 ± 0.90	3.54 ± 0.69	0.569
Hands-On Training	3.85 ± 0.84	3.86 ± 0.71	0.965
Simulation-based Training	3.95 ± 0.81	3.75 ± 0.70	0.266
Gamified Learning	3.86 ± 0.92	3.71 ± 0.71	0.442

This table presents students' evaluations of various aspects of learning effectiveness, categorized into professional knowledge and practical skills. The scores range from 1 to 5, with 1 representing the lowest and 5 the highest perceived effectiveness. The mean score (± SD) reflects the overall assessment for each learning method.

Supplementary Table 8: Satisfaction Survey according to funding status

Program events	Military-funded students (n = 65)	Non-military-funded students (n = 36)	P value
Overall Satisfaction	3.89 ± 0.81	3.86 ± 0.76	0.851
Lecture-based Teaching	3.77 ± 0.79	3.68 ± 0.72	0.607
Hands-On Training	3.92 ± 0.85	3.79 ± 0.74	0.469
Simulation-based Training	3.84 ± 0.90	3.79 ± 0.74	0.794
Gamified Learning	3.92 ± 0.91	3.86 ± 0.71	0.751
Program Content	3.81 ± 0.81	3.79 ± 0.83	0.902
Program Practicality	3.75 ± 0.74	3.71 ± 0.94	0.826
Program Diversity	3.86 ± 0.80	3.93 ± 0.86	0.720
Program Difficulty	3.70 ± 0.79	3.79 ± 0.79	0.622
Instructors	3.74 ± 0.78	3.86 ± 0.65	0.482
Classroom Environment	3.71 ± 0.94	3.82 ± 0.90	0.598
Teaching Equipment	3.74 ± 0.97	3.75 ± 0.89	0.961

This table presents students' evaluations of various aspects of program satisfaction, categorized by different teaching and learning events. The scores range from 1 to 5, with 1 representing the lowest and 5 the highest satisfaction level. The mean score (± SD) reflects the overall satisfaction for each program event.

Supplementary Table 9: Perceived learning effectiveness of Professional Knowledge and Practical Skills according to department

Learning method	Medicine (n = 92)	Nursing (n = 9)	P value
Overall Impact - Professional Knowledge	3.65 ± 0.87	3.67 ± 1.00	0.963
Lecture-based Teaching	3.62 ± 0.81	3.67 ± 1.00	0.871
Hands-On Training	3.79 ± 0.83	3.89 ± 0.78	0.742
Simulation-based Training	3.84 ± 0.79	3.89 ± 0.93	0.853
Gamified Learning	3.78 ± 0.86	4.11 ± 0.78	0.275
Overall Impact - Practical Skills	3.75 ± 0.85	3.78 ± 0.97	0.926
Lecture-based Teaching	3.59 ± 0.84	3.89 ± 0.93	0.310
Hands-On Training	3.84 ± 0.80	4.00 ± 0.87	0.565
Simulation-based Training	3.89 ± 0.78	3.89 ± 0.93	0.993
Gamified Learning	3.80 ± 0.87	4.00 ± 0.87	0.520

This table presents students' evaluations of various aspects of learning effectiveness, categorized into professional knowledge and practical skills. The scores range from 1 to 5, with 1 representing the lowest and 5 the highest perceived effectiveness. The mean score (± SD) reflects the overall assessment for each learning method.

Supplementary Table 10: Satisfaction Survey according to department

Program events	Medicine (n = 92)	Nursing (n = 9)	P value
Overall Satisfaction	3.88 ± 0.80	3.89 ± 0.78	0.976
Lecture-based Teaching	3.73 ± 0.77	3.89 ± 0.78	0.553
Hands-On Training	3.87 ± 0.83	4.00 ± 0.71	0.649
Simulation-based Training	3.82 ± 0.86	3.89 ± 0.78	0.806
Gamified Learning	3.89 ± 0.87	4.00 ± 0.71	0.718
Program Content	3.79 ± 0.81	3.89 ± 0.93	0.739
Program Practicality	3.75 ± 0.79	3.67 ± 0.87	0.766
Program Diversity	3.88 ± 0.81	3.89 ± 0.93	0.977
Program Difficulty	3.73 ± 0.79	3.67 ± 0.87	0.824
Instructors	3.76 ± 0.73	3.89 ± 0.93	0.626
Classroom Environment	3.73 ± 0.88	3.89 ± 1.36	0.621
Teaching Equipment	3.70 ± 0.95	4.22 ± 0.83	0.111

This table presents students' evaluations of various aspects of program satisfaction, categorized by different teaching and learning events. The scores range from 1 to 5, with 1 representing the lowest and 5 the highest satisfaction level. The mean score (± SD) reflects the overall satisfaction for each program event.