Progress in Medical Education
ISSN: 3007-0007

Zentime

Research Article https://doi.org/10.1189/680530ermmyu

Construction and practice of the diversified assessment system for disaster medicine courses

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Acknowledgement: This work was supported by the Anesthesiology Department Teaching Development Foundation of Naval Medical University under grant (2024MZQN02 and 2024MZQN03).

Declaration of conflict of interest: None.

Received June 12, 2025; Accepted July 29, 2025; Published September 30, 2025

Highlights

- A comprehensive disaster medicine assessment system is established based on the "cognitive-skill-attitude" triad, incorporating six evaluation components: pre-class preparation, pre-class tests, case discussions, skills assessment, post-class tests, and post-class feedback.
- The system features multiple simulated disaster scenarios and integrates high-fidelity mannequins to achieve a "teaching-training-assessment" integration, with 91% of students reporting that it enhanced their disaster response capabilities.
- An innovative multi-subject evaluation framework ("self-peer-teacher", 40% weighting) is introduced, shifting learners into active evaluator roles to foster teamwork and reflective practice.

Abstract

This study addresses the limitations of traditional disaster medicine course assessments, including single evaluation formats, delayed feedback mechanisms, and gaps in competency mapping, by developing a diversified assessment system leveraging the Rain Classroom platform. The system incorporates six interconnected evaluation components across the learning cycle: pre-class preparation, pre-class tests, case discussions, skills assessment, post-class tests, and post-class feedback, collectively forming a three-dimensional "cognitive-skill-attitude" assessment framework. In the assessment design, the weighting of practical skill evaluation is elevated to 40% to prioritize the development of students' disaster response competencies. Additionally, an innovative multi-subject evaluation model ("self–peer–teacher") is implemented within disaster scenario simulations, utilizing standardized scoring rubrics. This methodology not only enables comprehensive performance evaluation but also fosters critical teamwork and reflective practice. Implementation outcomes demonstrated that the system effectively evaluates learning progress through multi-modal assessments, enhances disaster rescue knowledge and skill proficiency, and successfully achieves predefined pedagogical objectives.

Keywords: Disaster medicine, rain classroom, competency evaluation, scenario simulation

Introduction

In the context of increasingly frequent novel disasters, such as the global COVID-19 pandemic and nuclear contamination crises, disaster medicine education has become a critical component of public health security [1]. According to the 2023 Global Natural Disaster Assessment Report, 326 major natural disasters occurred worldwide, affecting 117 countries and regions. Asia was the most severely affected, accounting for 42.33% of global disaster incidents and 37.46% of economic losses [2]. Given China's vast territory, complex geography, and dense population, the country faces significant risks from various natural disasters and public emergencies. In 2023 alone, floods and typhoons affected 95.44 million people in

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China, resulting in direct economic losses of RMB 345.45 billion [2]. In this context, medical schools and their affiliated hospitals—as core components of the national disaster medicine rescue system—play irreplaceable roles due to their specialized personnel, technical resources, and emergency response capabilities [3]. Multiple studies have shown that regular educational programs and drills are essential for equipping students and healthcare professionals to manage disasters effectively [4–6]. Therefore, establishing and refining the disaster medicine education system constitutes a strategic initiative to enhance national emergency management capabilities, safeguard security, and protect public health [1].

Disaster medicine is inherently interdisciplinary, with core competencies in clinical decision-making, resource allocation, teamwork, and rapid response capabilities [7]. However, current research on disaster medicine education predominantly focuses on content, format, and methods, with limited attention to assessing teaching quality and learning outcomes [8-10]. Traditional written examinations remain widely used, despite their limitations in evaluating integrated competencies in complex disaster scenarios. Informed by contemporary competency-based medical education principles, we developed a diversified assessment system for disaster medicine courses [11]. This system targets key learning stages through six evaluation units, employing multiple modalities to assess student performance. The initiative aims to enhance the acquisition and application of disaster response knowledge and skills, thereby achieving the course's intended educational objectives.

Limitations of the traditional disaster medicine course assessment model

Monotonous evaluation format

The traditional assessment model for disaster medicine courses has long relied on a binary structure of "final examination+attendance records," which significantly limits the effectiveness of practical teaching. Research indicates that final examinations constitute more than 70% of assessments in many Chinese medical schools, reflecting an overemphasis on knowledge retention while neglecting the evaluation of practical skills, comprehensive competencies, and emergency response abilities [12]. Furthermore, standardized test formats are prone to creating "correct answer traps," where students rely on predetermined responses rather than applying knowledge flexibly in open-ended or complex scenarios. This undermines their adaptability in real-world emergencies. More critically, such an assessment model distorts teaching objectives, leading instructors to reduce practical teaching time in pursuit of exam performance and students to prioritize memorization over skill development. This ultimately results in the "high scores but low competence" phenomenon.

Lack of interactive feedback

The traditional assessment model follows a one-way process of "teacher-proposed questions—student-oriented examination—score evaluation," which exhibits three core deficiencies: (1) Delayed feedback: students only receive scores after completing the exams, often when they have progressed to subsequent units. This delay prevents timely error correction and perpetuating misconceptions; (2) Absence of effective teacher-student dialogue: the model does not facilitate meaningful interaction between teachers and students, failing to address cognitive biases developed during learning process; (3) Lack of peer evaluation: exclusion of peer evaluation hinders the cultivation of teamwork and interdisciplinary collaboration—competencies vital to disaster medicine. The traditional teacher-centered paradigm fosters a "silent classroom" environment, diminishing student engagement, declining initiative, and lowering overall course satisfaction.

Failure to implement competency evaluation

Empirical studies show that an integrated disaster medicine education combining theory and practice significantly enhance responders' core competencies [12]. However, the traditional assessment system structurally misaligns with the principles of competency-based medical education: knowledge-based evaluations account for 80-85% of assessments, while critical skills like clinical decision-making and emergency response account for less than 20% [13]. Comparative studies reveal that students using the objective structured clinical examination (OSCE) model achieved an excellence rate of 81.6%, markedly surpassing the 71.45% achieved by traditional cohorts, underscoring the inadequacy of conventional assessments in meeting disaster response demands [14].

Furthermore, the traditional system adopts a fragmented approach to skill evaluation, reducing complex clinical procedures, such as endotracheal intubation, to isolated multiple-choice questions. This approach neglects essential procedural rigor (e.g., aseptic technique, patient

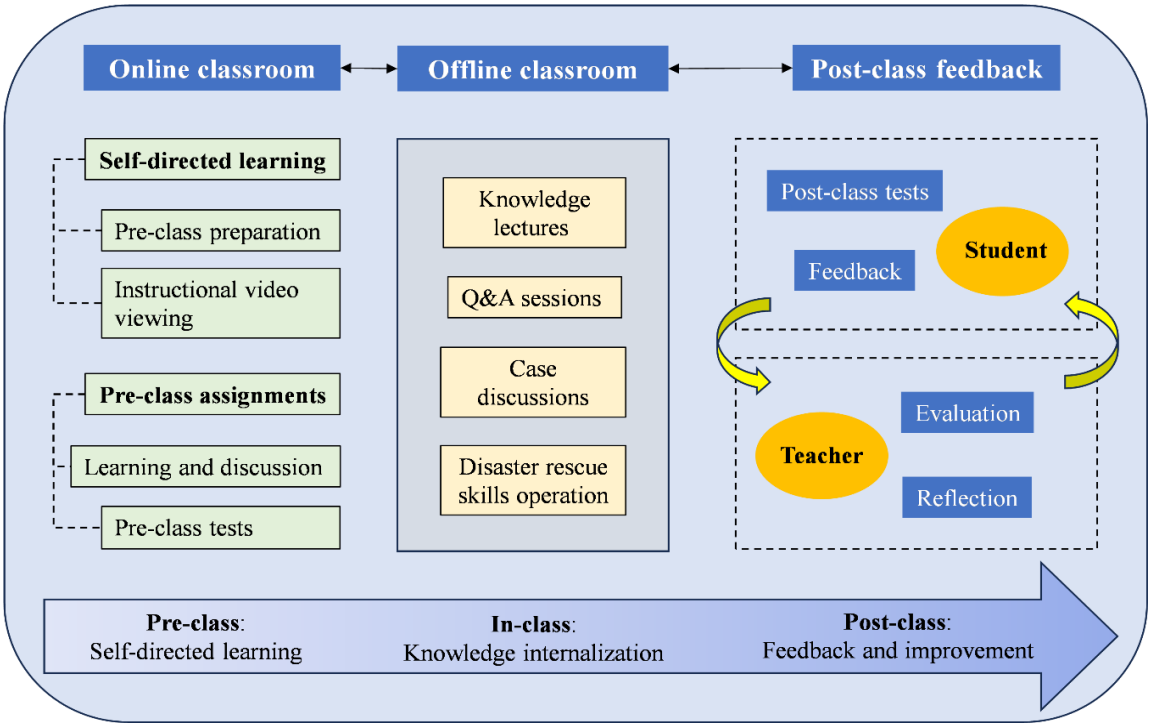

Figure 1. Blended learning model for disaster medicine courses.

positioning, and real-time vital sign monitoring). Standardized tools for assessing higher-order competencies, particularly in dynamic disaster environments requiring resource allocation and team coordination, are conspicuously absent. These systemic biases in the current assessment framework not only compromises education quality but also pose operational risks in real-world disaster scenarios.

Construction of a diverse assessment system for disaster medicine courses

Rain Classroom, an open educational platform jointly developed by Tsinghua University and Xuetang X, offers innovative teaching experiences through efficient online resource sharing, real-time testing, and interactive discussions. The platform also generates comprehensive data outputs across the entire teaching cycle—pre-class, in-class, and post-class phases [15]. By leveraging these features, we designed a blended teaching model for disaster medicine courses that integrates both online and offline instruction (**Figure 1**), aiming to enhance learning effectiveness by combining traditional and digital methodologies.

Online teaching enables teachers to overcome traditional time and space constraints by distributing learning videos, lecture slides, and case discussions through the platform. This empowers students to independently grasp core concepts before class and reinforce key areas afterward, cultivating self-directed learning capabilities. Additionally, Rain Classroom serves as an interactive platform where students can pose questions, and teachers can respond in real-time or address queries collectively during class. This timely feedback mechanism allows teachers to monitor student progress while facilitating knowledge retention and enhancing in-class instruction effectiveness. After the course concludes, teachers utilize the platform to release post-class assessments and surveys, tracking learning outcomes and gathering feedback for continuous improvement. With its advanced features, Rain Classroom has become a vital tool in modern education, significantly improving teaching efficiency and learning quality. Based on this teaching model, we developed a diversified, comprehensive assessment system for disaster medicine courses.

Diversified assessment dimensions

This course maximizes the use of online resources and emphasizes student participation throughout the learning process, from pre-class preparation to post-class reflection. The assessment system integrates six components: 10% for pre-class preparation, 10% for pre-class tests, 20% for case discussions, 40% for skills assessment, 10% for post-class test, and 10% for post-class feedback (**Figure 2**). Each component is structured to form a comprehensive evaluation loop that integrates cognitive, skill, and attitudinal dimensions.

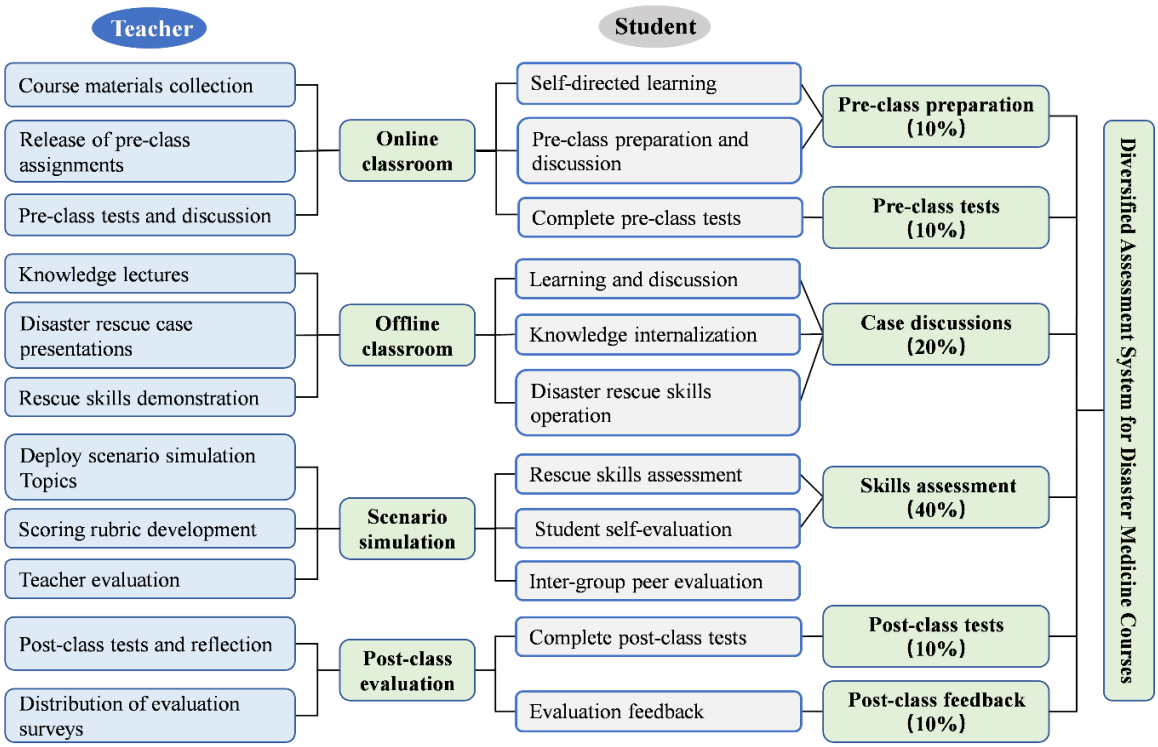

Figure 2. Diversified assessment system for disaster medicine courses.

Online digital learning assessment (20%)

The online classroom focuses on self-directed learning and evaluation of student preparation and understanding through a structured approach. (1) Pre-class preparation (10%): The platform records the completeness of video watching (with a single-session duration≥80% considered valid) and students' understanding of key concepts through knowledge-based questions. This assessment evaluates the quality of pre-class preparation. (2) Pre-class tests (10%): A structured test format is used, including multiple-choice questions (to evaluate knowledge retention), true/false questions (to identify common misconceptions), and case analysis questions (to assess the application of knowledge). Teachers utilize the data analysis function to analyze error distributions and manually annotate typical cognitive biases. The pre-class test verifies students' pre-learning outcomes, enabling targeted lesson planning. This process ensures that in-class instruction aligns with students' actual needs, enhancing both teaching effectiveness and learning efficiency. Additionally, the pre-class tests help students identify knowledge gaps, fostering self-awareness and motivating them to focus on areas requiring improvement during class.

Offline blended classroom assessment (20%)

The offline classroom combines the Rain Classroom platform with in-person instruction, using both mediums to facilitate learning. Teachers design key and challenging course topics, delivering instruction through various teaching methods, such as in-class questioning, case discussions, and practical demonstrations of skills in disaster scenarios. During the session, real-time tests, sorting activities, and case discussions were utilized to enhance student engagement and participation in the learning process. In the case discussion section, students are guided to explore critical issues and complex cases in disaster medicine. This interactive approach fosters knowledge exchange and intellectual stimulation among students, enabling them to analyze disaster-related topics from multiple perspectives. Additionally, the offline classroom includes hands-on practical exercises in disaster rescue and wilderness survival skills, such as wound dressing, CPR, fracture immobilization, and casualty transport. These activities not only increase student engagement but also equip them with essential life-saving skills for effective disaster response.

Assessment of scenario-based rescue competence (40%)

Simulation in medical education provides a safe and controlled environment for students to practice disaster response skills without real-world consequences. The course incorpo-

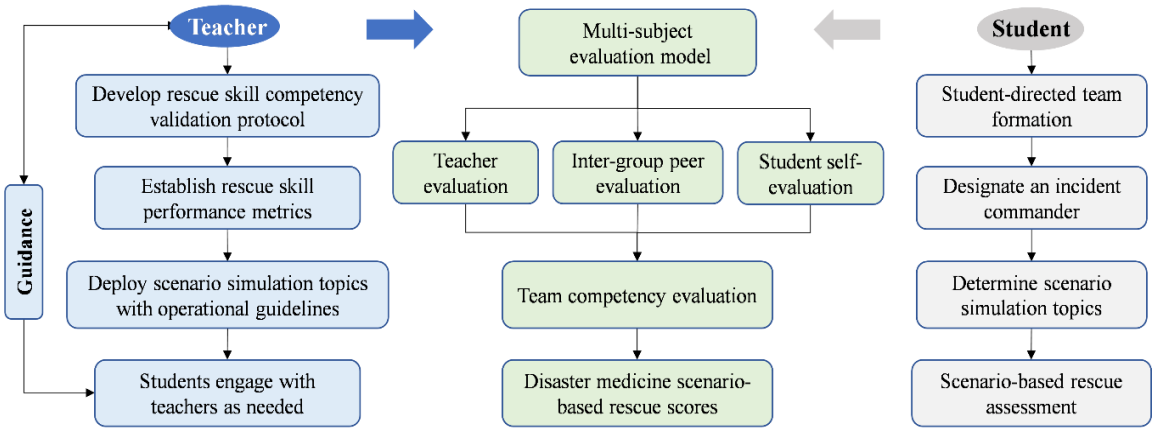

Figure 3. Multi-subject evaluation model for scenario-based simulation in disaster medicine courses.

rates specialized trauma simulations based on various disaster scenarios, including crush injuries, heatstroke, drowning, and high-altitude pulmonary edema - typical injuries encountered in disasters settings. Realistic injury scenarios employ high-fidelity mannequins capable of generating dynamic vital signs, combined with modular first aid training kits that cover standardized procedures such as hemostasis, bandaging, immobilization, and casualty transport. Students are required to complete a full-scale Mass Casualty Incident response within 30 minutes, focusing on three key components: (1) Application of the Simple Triage and Rapid Treatment triage system; (2) Formulation and practical execution of damage control resuscitation strategies; (3) Decision-making for prioritizing medical evacuation.

Post-class teaching effect evaluation (20%)

After course completion, a comprehensive evaluation is conducted through two components: (1) post-class assessment (10%): An analysis of students' responses helps identify areas where teaching outcomes were ineffective, pinpointing knowledge gaps and instructional weaknesses; (2) post-class feedback (10%): A structured questionnaire with open-ended questions gathers students' opinions on course content, teaching effectiveness, and self-perceived improvements in competency. The collected data is used to refine teaching approaches.

At the course conclusion, scores from all six evaluation components are weighted, combined, and used to determine final grades. This systematic process ensures both students and teachers reflect on learning experiences, enabling continuous improvements in instruction.

Multi-subject evaluation model

The core competencies of disaster medicine include clinical decision-making, resource allocation, teamwork, and rapid response capabilities. By incorporating students as evaluators, this approach not only reinforces their retention and mastery of theoretical and practical knowledge, but also enhances their engagement and collaborative capabilities. Therefore, in the disaster simulation assessment section, we developed a multi-subject evaluation model based on a "self-peer-teacher evaluation" framework (**Figure 3**). This model ensures a comprehensive and dynamic evaluation process, promoting both individual and collective learning outcomes.

First, teachers publish the assessment plan and scoring criteria for scenario-based rescue skills in advance through the platform. On the assessment day, the scenario topic and requirements are released. Students then collaborate in groups to complete the triage and medical rescue procedures at the simulated disaster scene. Finally, the multi-subject evaluation model provides multi-dimensional scoring for each group, including: (1) Student self-evaluation: Students evaluate their own performance by referring to the scoring criteria and identify areas for improvement; (2) Inter-group peer evaluation: Members of other groups evaluate the students' performance, focusing on the accuracy of injury assessment, the effectiveness of first aid procedures, and the efficiency of teamwork; (3) Teacher evaluation: Teachers conduct a comprehensive evaluation based on both process and final outcomes.

To validate the reliability of the multi-subject evaluation model, we analyzed the correlations among evaluation components and their relationships with final scores. A rigorous correlation analysis was performed on the complete dataset (n=26) using IBM SPSS Statistics ver-

Table 1. Correlations between components and final grade

Evaluation Comparison	Correlation Coefficient	Significance (p-value)	Sample Size (N)
Peer evaluation vs. Self-evaluation	0.050	0.807	26
Teacher evaluation vs. Self-evaluation	-0.210	0.302	26
Final grades vs. Self-evaluation	-0.086	0.676	26
Teacher evaluation vs. Peer evaluation	0.890**	<0.001	26
Final grades vs. Peer evaluation	0.029	0.889	26
Final grades vs. Teacher evaluation	0.200	0.327	26

Note: **, correlation is significant at the 0.01 level (2-tailed).

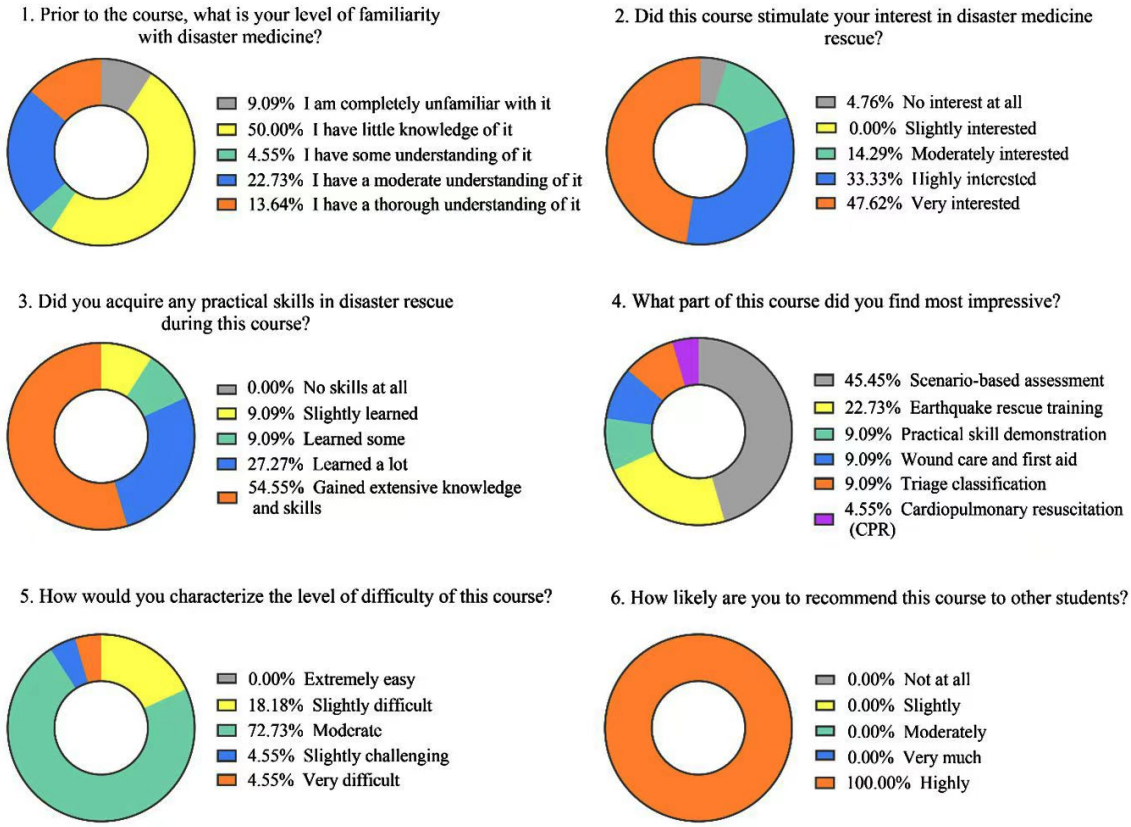

Figure 4. Student's perceptions of course instruction and assessment model.

sion 27.0 (**Table 1**).

A statistically significant correlation was observed between peer and teacher evaluations ($r=0.890$, $p<0.001$), confirming high inter-rater reliability. Teacher evaluations demonstrated a moderate correlation with final grades ($r=0.200$), whereas peer evaluations ($r=0.029$) and self-evaluations ($r=-0.086$) showed non-significant relationships with final grades ($p>0.05$). This pattern indicates that peer and teacher assessments measure distinct clinical competency dimensions, whereas final grades incorporate supplementary factors (e.g., theoretical knowledge mastery and case discussion performance).

Throughout the process, the teacher acts primarily as a facilitator, guiding students to consolidate and deepen classroom knowledge while minimizing direct intervention in their critical thinking. The multi-subject evaluation model encouraging students to actively engage in self-reflection, analyze the performance of others, and develop a clearer understanding of their own strengths and weaknesses. It also helps students set clear learning goals and adjust their learning strategies accordingly.

Implementation outcomes of the disaster medicine course assessment system

To assess the effectiveness of the disaster medicine curriculum and its diversified assessment system, we conducted an anonymous post-course questionnaire survey among all 26 students enrolled in this elective course. After excluding incomplete submissions, 22 valid responses were obtained (response rate: 84.6%). As shown in **Figure 4**, the majority of students reported limited prior familiarity with disaster medicine but developed significant interest through the course. By integrating theoretical instruction with practical skill training, students

acquired essential disaster response competencies (**Figures 4A-4C**).

The most memorable part of the course for students was the scenario-based simulation assessment (**Figure 4D**), which demonstrated the advantages of the diversified assessment system. Through multiple assessment modes, the course enhanced students' understanding and internalization of material, achieving its educational objectives—improving disaster response knowledge and skills. The survey revealed that 72.73% of students found the course moderately challenging and suitable for an elective, while 100% expressed willingness to recommend it to peers (**Figure 4E** and **Figure 4F**). Student feedback consistently indicated strong satisfaction with the course and evaluation methods, demonstrating that the diversified system effectively stimulates interest and fosters a supportive learning environment. This approach contributes to students' holistic development and enhances the teaching quality in disaster medicine education.

Conclusion

Driven by the dual imperatives of higher education digitalization and the paradigm shift in medical education reform, the diversified assessment system for disaster medicine courses developed in this study achieves three foundational innovations.

(1) Assessment dimensions: the system moves beyond traditional single-mode examinations, establishing a multi-dimensional framework integrating cognitive, skill, and attitudinal competencies. (2) Skill practice: it overcomes the spatial- temporal barriers between classrooms and disaster scenes, achieving a closed-loop integration of "teaching, training, and assessment" through scenario-based simulations and high-fidelity mannequins. (3) Teacher-student dynamics: the system incorporates self- and peer-evaluation, transforming students from passive recipients into active participants, fostering a co-constructed evaluation community that enhances reflective engagement.

The innovation lies not only in evaluation tools but also in reconfiguring disaster medicine education logic. By establishing a "scenario simulation-competency evaluation" dynamic mapping model, competency evaluation is transformed into a reverse mechanism that drives capability development. With the rapid advancement of AI technology, future research will focus on virtual simulation of pre-hospital Mass Casualty Incident scenarios, integrating virtual reality, augmented reality, and mixed reality technologies to create a disaster scenario simulation platform capable of high-precision reproduction of complex environments (e.g., collapsed buildings, nuclear contamination zones, and bioterrorism sites) [16-18]. An embedded dynamic variable module sill adjust critical parameters, including casualty volume or meteorological conditions, in real-time throughout the 72-hour golden rescue window. Additionally, a multi-user collaborative training platform will support cross-regional joint rescue exercises, while eye-tracking, gesture recognition, and voice interaction technologies will provide comprehensively evaluation of students' decision-making and team collaboration, offering technological empowerment for disaster medicine talent cultivation.

This study has several limitations. First, while the six-component structure (pre-class preparation/tests, case discussions, skills assessment, post-class tests/feedback) enables comprehensive competency evaluation, its resource-intensive demands, such as assignment design, grading, and data analysis, increase faculty's workload. Leveraging AI's transformative potential in healthcare education, future implementations will utilize integrated AI platforms (e.g., Rain Classroom's automated test generation, intelligent scoring, and learning analytics) to streamline preparatory and evaluative tasks, enabling personalized student guidance [19-21].

Furthermore, the multi-subject evaluation model, using the standardized Disaster Scenario Simulation Rescue Rubric, demonstrated high peer-teacher concordance ($r=0.890$, $p<0.001$), validating inter-rater reliability. However, self-evaluations showed a non-significant correlation with instructor scores ($r=-0.210$, $p=0.302$). To improve students' self-assessment accuracy, future iterations will incorporate calibration training additionally increase the weighting of peer/teacher evaluations (from 30% to 40%) to enhance multi-subject evaluation model reliability, and ultimately adapt this evaluation framework for cross-disciplinary contexts.

Ethics approval and consent to participate: All the participants provided informed consent prior to participating in the study. The ethics approval was obtained from the Committee on Ethics of Medicine at Naval Medical University.

Author contributions: Linlin Chen, Shuo Yang conceptualized and designed the study, conducted data collection and analysis, and draft-

ed the manuscript. Zhanheng Chen responsible for the data analysis, and interpretation of the results. Zixin Li, Mi Li contributed to the literature, collection of materials and refined the manuscript. Zui Zou, Zhibin Wang supervised the project, provided critical revisions to the manuscript, and approved the final version for submission.

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