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Job competency-oriented reconstruction of a graduate course in Environmental Hygiene: a practice-based curriculum reform and its evaluation

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Research Article

Keywords: Job competency, Environmental hygiene, Postgraduate course, Teaching reform, Blended learning, Problem-based learning

Posted Date: November 12th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11368924/v1

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Additional Declarations: No competing interests reported.

Abstract

Background Environmental Hygiene is a core course in graduate public health training, yet its teaching remains disconnected from professional practice and dominated by lectures and recall-based assessment. We constructed and evaluated a job competency-oriented blended curriculum.

Methods Interviews with 22 department heads from 16 municipal Centers for Disease Control and Prevention (CDCs) in Shandong Province identified core job competency requirements. The course was reconstructed into a modular "basic theory plus thematic practice" structure, supported by an online open course and an industry-informed problem-based learning (PBL) case library, and delivered through a blended flipped-classroom model with formative assessment. Because only one cohort is enrolled annually, the preceding year's cohort (n = 68) served as a non-equivalent historical control for the post-reform cohort (n = 65); the two were comparable in age, sex, admission score, prior coursework performance, and undergraduate major. Final grades and self-rated job competency (four dimensions, 20 items, 5-point Likert scale) were compared using independent-samples t tests and χ^2 tests (SPSS 26.0; two-sided $P < 0.05$), with effect sizes and 95% confidence intervals.

Results Four core job competency modules were identified: environmental health monitoring and assessment; environmental epidemiology and data analysis; environmental health risk communication and emergency management; and research innovation and lifelong learning. The course comprised 32 teaching hours, an online open course (10 chapters, 74 videos), and a 31-case PBL library. Final grades (91.6 ± 4.3 vs 83.2 ± 5.8; t = 9.45, df = 131, $P < 0.001$; Cohen's d = 1.64) and self-rated job competency (4.4 ± 0.4 vs 3.1 ± 0.5; t = 16.51, df = 131, $P < 0.001$; Cohen's d = 2.86) were higher in the post-reform cohort (n = 65) than in the pre-reform cohort (n = 68), with the largest difference in risk communication and emergency management (+ 1.5 points). Speaking participation was 100%; 94.3% agreed the PBL cases reflected real CDC workflows, and 91.4% reported improved self-directed learning and teamwork.

Conclusions Job competency-oriented reconstruction, integrating needs assessment, modular content, blended teaching and process-oriented assessment, was associated with improved comprehensive practical competence. The largest between-cohort difference was in risk communication and emergency management, reflecting the authenticity of the PBL scenarios. As the design used a single-institution, non-equivalent historical control, these associations need confirmation in multicentre studies with concurrent controls.

Background

Public health governance and the national biosecurity strategy place increasingly high demands on the practical competence and innovative capacity of high-level public health personnel [1]. Environmental health is a core domain of public health, and there is an urgent need to train interdisciplinary professionals who are competent in environmental monitoring, risk assessment, emergency response and research innovation.

Within public health education, Environmental Hygiene is a core compulsory course through which this competence is developed. It provides the disciplinary foundation for identifying, monitoring, assessing and controlling the physical, chemical and biological hazards in air, water, soil and food that shape population health, and it is where the general principles of public health are translated into the practical skills applied at the front line of disease prevention and control. The graduates it trains form the core of the environmental health workforce, carrying out routine environmental monitoring, health risk assessment, environmental emergency preparedness and response, and risk communication with the public and policymakers. The course is therefore the bridge between basic public health theory and professional practice, and strengthening it is a direct investment in the capacity of the public health system to anticipate, assess and respond to environmental threats.

National policy documents, including the Guidance of the General Office of the State Council on Accelerating the Innovative Development of Medical Education and the Ministry of Education's opinions on the classified development of academic and professional graduate degrees, call for strengthening practical ability and job competency with occupational needs as the orientation. Competency-based education has become a guiding principle in health professions education worldwide [2], and competency profiles have been mapped both for schools of public health [3] and across international public health training consortia [4] to inform workforce education. At the same time, the integration of public health content into medical and health professional curricula has been repeatedly debated and remains unevenly realised in practice [5]. Nevertheless, graduate teaching of Environmental Hygiene in China still faces several problems.

First, course content is disconnected from job practice: classical theory predominates, while frontier issues and core skills are insufficiently covered [6, 7]. A survey of medical schools in the United States likewise found that environmental health had not yet been systematically integrated into the curriculum and that the curricular time devoted to it remained limited [8]. Second, teaching methods remain rigid and lecture-based, with insufficient use of interactive approaches such as problem-based learning (PBL) [9, 10]. Third, assessment overemphasises the recall of theoretical knowledge and pays too little attention to the formative assessment of practical skills [11]. Collectively, these problems create a gap between the training of public health graduates and the requirements of their posts, making curriculum reform imperative [12], especially for this core course. Dedicated competency frameworks for environmental health education, such as the 15 core competencies in children's environmental health proposed for students, trainees and healthcare providers, provide an international reference point for what such reform should target [13].

Taking Shandong Second Medical University as an example, and drawing on evidence that curriculum development should be anchored in analyses of workforce and employer needs [14], this study implemented a systematic, job competency-oriented reform in four areas: reconstruction of course content, development of teaching resources, implementation of blended teaching, and construction of a multidimensional assessment system. The aim was to bridge the gap between theoretical teaching and

job practice, strengthen graduate students' practical application and research innovation competencies, and provide an actionable reform model for comparable institutions.

Methods

Study design

This was a single-institution, quasi-experimental educational intervention study with a non-equivalent historical control cohort, conducted in three phases. In phase one, semi-structured interviews were used to clarify job competency requirements. In phase two, the curriculum was restructured and teaching resources were developed on the basis of the interview findings. In phase three, blended teaching was implemented and its effects were evaluated. Because only one cohort is enrolled each academic year and the class size is small, randomisation and a concurrent parallel control group were not feasible; the cohort that had completed the original lecture-based course in the preceding academic year therefore served as the non-equivalent historical control, and all effect estimates were derived from between-cohort comparisons. This design cannot exclude cohort, period and co-intervention effects, and the results should be interpreted accordingly (see Limitations). Designs of this kind, in which a historical cohort serves as the comparison group for a curriculum intervention, have been used and reported in comparable educational evaluations [15, 16]. The study design is shown in Fig. 1.

Needs assessment for job competency

The research team conducted semi-structured interviews with 22 heads of departments related to environmental health and emergency management from 16 municipal CDCs in Shandong Province. Participants were purposively sampled to cover managerial, technical, and operational posts. Interviews were conducted between January and June 2023, either face-to-face or online according to participant preference, and each lasted approximately 30–40 minutes. All interviews were audio-recorded with written informed consent, transcribed verbatim, and analysed using thematic analysis. The four interview dimensions and corresponding questions are shown in Table 1.

Table 1
Interview dimensions and questions for employers

Interview dimension	Interview questions
Dimension 1: Main challenges and frontier issues in the current environmental health field	1.Drawing on your practice, what are the most complex or urgent challenges when dealing with health problems related to air, water or soil pollution (for example, identification of emerging pollutants, assessment of combined exposure, or the superimposed effects of climate change)? 2.In your view, which emerging technologies or interdisciplinary directions (for example, exposome research, geographic information systems, big data and artificial intelligence) will most profoundly change environmental health practice in the next 5–10 years, and how should our training respond? 3. What obstacles currently exist in collaboration between environmental health and other fields such as urban planning, energy policy and sustainable development, and what cross-disciplinary knowledge and communication skills should an ideal professional with a "health in all policies" perspective possess?
Dimension 2: Core expectations of newly recruited master's graduates and their current shortcomings	1.What core knowledge or skills do you consider most essential for newly recruited master's graduates, and how do current graduates generally perform in these areas? 2. Compared with solid professional knowledge, what are your expectations of newcomers in terms of comprehensive qualities such as teamwork, project management, official document writing or public communication, and in which of these are they usually most lacking? 3. When graduates apply the theories and methods learned at university to actual work, in which specific steps does the "disconnection between theory and practice" most commonly appear, and how should university education bridge this gap?
Dimension 3: Key operational competencies required by specific work tasks	1.Taking the initial emergency response to a sudden environmental pollution incident (such as a chemical leak) as an example, please describe in detail the key actions, technical judgements and reporting tasks that a qualified professional must complete between receiving the report and completing the preliminary on-site assessment. 2. When carrying out a regional environmental health risk assessment, from data collection and selection of exposure assessment models to uncertainty analysis and report writing, which step in the whole process is most prone to error or most in need of rigorous training, and why? 3. In the routine review of environmental monitoring data or the analysis of epidemiological survey data, apart from proficiency in software, which aspects of data quality control awareness and logical reasoning do you value most in staff, and could you give an example?
Dimension 4: Career development and personal qualities supporting research	1.In your institution, where do the main motivations and opportunities for professional and technical staff to conduct applied research or innovate technical methods come from (for example, project-driven, problem-oriented or policy demand), and what support mechanisms does the institution provide?

Interview dimension	Interview questions
innovation and lifelong learning	2. How do you personally keep your professional knowledge up to date, and which efficient channels and methods for tracking the latest domestic and international policies, standards, research literature or advanced practice would you recommend to newcomers? 3. Besides professional knowledge, which inner qualities or habits of mind (for example, critical thinking, responsibility, curiosity or stress resilience) are essential for long-term development in this field, and how are these qualities manifested in daily work?

Thematic analysis of the interviews with the 22 CDC department heads generated four core job competency modules: environmental health monitoring and assessment; environmental epidemiology and data analysis; environmental health risk communication and emergency management; and research innovation and lifelong learning. The detailed results are presented in Table 2. These findings constituted the core empirical basis for the subsequent reconstruction of course content.

Table 2
Analysis of employer interview results

Interview dimension	Summarised results
Dimension 1: Main challenges and frontier issues in the current environmental health field	1. Capacity to address emerging combined pollution: the ability to identify and assess the environmental occurrence, migration and transformation, and potential health risks of emerging pollutants such as antibiotics, microplastics and perfluorinated compounds. 2. Capacity to apply interdisciplinary methods: mastery of research approaches that combine environmental science, big data and molecular biology with conventional environmental health problems. 3. Capacity to assess climate change health risks: understanding and assessment of the indirect and direct effects of climate change (for example, extreme weather and heatwaves) on vector-borne infectious diseases, air quality and public health. 4. Capacity to handle environmental health big data: basic skills in using multi-source environmental monitoring data and health and medical data for association analysis and visualisation. 5. Implementation of the "health in all policies" concept: the ability to provide a professional environmental health perspective and evidence-based recommendations in cross-sectoral collaboration such as urban planning and energy policy.
Dimension 2: Core expectations of newly recruited master's graduates and their current shortcomings	1. Solid methodological foundation: proficiency in environmental epidemiological survey design, exposure assessment models and basic statistical software is expected; common shortcomings include insufficient research design ability and a shallow understanding of confounder control. 2. Standardised field practice skills: familiarity with standardised collection, preservation, transport and quality control of environmental samples (water, air and soil) is expected; common shortcomings include weak hands-on ability and unfamiliarity with standard operating procedures. 3. Professional report writing and communication: the ability to independently write logically clear and data-rich monitoring or risk assessment reports and to communicate risk effectively with management departments and the public is expected; common shortcomings include insufficient written expression and communication skills. 4. Proactive emergency response awareness: sensitivity to sudden environmental events and knowledge of preliminary on-site response procedures are expected; common shortcomings include a disconnection between theory and practice and an underdeveloped emergency mindset. 5. Basic project management and teamwork: the ability to take partial responsibility for coordinating small projects under supervision, with good team spirit.

Note: The table summarises the main themes identified from the four interview dimensions. Representative quotations are available from the corresponding author on reasonable request.

Interview dimension	Summarised results
Dimension 3: Key operational competencies required by specific work tasks	1. Design and execution of environmental monitoring schemes: the ability to formulate monitoring schemes defining indicators, sites and frequency according to purpose, and to organise their implementation. 2. Quantitative health risk assessment: the ability to apply exposure assessment and dose-response models to conduct preliminary quantitative risk characterisation for specific pollutants. 3. Rapid on-site assessment of emergencies: the ability to rapidly identify the main pollution sources and exposure pathways under emergency conditions, make preliminary judgements of health impact and propose key recommendations for population protection. 4. Statistical analysis of environmental health data: proficiency in using statistical software to perform descriptive analysis, association tests and interpretation of environmental and health data. 5. Application of regulations and standards: the ability to accurately locate and apply national and local environmental quality standards, emission standards and health specifications to guide practice. 6. Laboratory safety and quality control awareness: strict compliance with laboratory safety rules and understanding and implementation of whole-process quality control in monitoring and analysis.
Dimension 4: Career development and personal qualities supporting research innovation and lifelong learning	1. Capacity to translate research questions and design preliminary studies: the ability to keenly identify researchable scientific questions or technical improvement points from daily practice, policy needs or sudden events, to convert them into explicit research hypotheses, and to design preliminary feasible research proposals or technical roadmaps. 2. Capacity for autonomous updating and integration of frontier information: information literacy to proactively and efficiently track and screen the latest research advances, technical standards, policies and regulations and industry best practice in environmental health, and to critically integrate them into practice or study to solve new problems. 3. Critical thinking and evidence-based practice: the ability to remain independent-minded when facing complex information or divergent views, to use logic and evidence for careful analysis and judgement without blindly following authority, and to adhere to evidence-based decision-making and practice. 4. Resilience and intrinsic drive for self-development: good psychological resilience and adaptability in the face of research setbacks, work pressure or rapid knowledge turnover, together with curiosity, a sense of responsibility and a strong willingness for continuous learning, and the ability to plan and manage one's own long-term career development.
Note: The table summarises the main themes identified from the four interview dimensions. Representative quotations are available from the corresponding author on reasonable request.	

Curriculum reconstruction and resource development

Based on these findings, the course was reconstructed through curriculum mapping according to the principles of “competency orientation, progressive layering, and integration of practice” [17]. The original structure, in which chapters were organised by environmental medium, was replaced by a dual modular structure comprising “basic theory” (8 teaching hours) and “thematic practice” (24 teaching hours). The thematic practice component consisted of four topics, each mapped to one of the four competency modules: environmental monitoring and exposure assessment; environmental epidemiological methods and applications; environmental toxicology techniques and advances; and public health response to sudden environmental events. Real work scenarios and problems obtained from the interviews were integrated into these topics. In addition, six industry experts from national and municipal CDCs, ecological and environmental monitoring centres, and universities formed a curriculum development advisory group. A graduate online open course was built on the XuetangX platform, and PBL teaching cases were compiled and published jointly with industry experts. Curriculum mapping was used to ensure transparent alignment between intended competencies, learning activities, and assessment [17].

Teaching implementation and assessment

Teaching was implemented using a blended learning model, defined here as the deliberate combination of asynchronous online self-directed learning with synchronous face-to-face instruction [18]. The face-to-face component was organised as a flipped classroom, so that foundational content was acquired online before class and class time was reserved for active, case- and problem-based learning rather than for lecturing; the overall model is therefore described as “self-directed online learning plus flipped offline classroom”. Concretely, before class students completed online video learning and chapter tests, and offline classes were used for PBL discussion, case analysis, and scheme design, with teachers and industry experts acting jointly as facilitators and assessors. Assessment adopted a multidimensional approach dominated by formative assessment (90%) and supplemented by summative assessment (10%). Formative assessment comprised online learning (video viewing 15%, chapter exercises 20%, online midterm test 10%, discussion forum participation 5%) and offline performance (classroom participation 15%, PBL group project output 25%); summative assessment consisted of an open case analysis or research design proposal (10%). The assessment scheme was explained to students at the beginning of the course.

To evaluate the effects of the reform, the post-reform cohort (n = 65) was compared with the pre-reform cohort of the preceding academic year (n = 68), which served as a non-equivalent historical control. Baseline comparability between the two cohorts was examined with respect to age, sex, admission examination score, prior coursework performance, and undergraduate major. None of these five characteristics differed significantly between the two cohorts (all $P > 0.05$; Table 3), which supports the reasonableness of the subsequent between-cohort comparison. The self-developed “Environmental Hygiene Job Competency Scale” was administered to the students of both cohorts, and the scores of the two cohorts were compared with one another (a between-cohort comparison) rather than analysed as paired within-individual measurements. The scale contained four dimensions and 20 items scored on a

5-point Likert scale. The scale's content validity was reviewed by 8 experts, and its internal consistency was good in the pre-reform cohort (n = 68; Cronbach's α was 0.92 for the total scale and 0.85, 0.83, 0.89 and 0.90 for environmental health monitoring and assessment, environmental epidemiology and data analysis, environmental health risk communication and emergency management, and research innovation and lifelong learning, respectively). Data were analysed using SPSS 26.0. Independent-samples t tests were used for all continuous between-cohort comparisons (final grades, and the four competency dimensions and the total score), because the two cohorts were independent groups; categorical variables were compared with χ^2 tests. Cohen's d and 95% confidence intervals are reported for all between-cohort comparisons. A two-sided $P < 0.05$ was considered statistically significant.

Table 3
Baseline comparability of the pre-reform and post-reform cohorts

Characteristic	Pre-reform cohort (n = 68)	Post-reform cohort (n = 65)	t / χ^2	*P* value
Age, years (mean ± SD)	23.5 ± 0.9	23.2 ± 1.1	1.72	0.090
Sex, male (n (%))	33 (48.5)	32 (49.2)	0.007	0.940
Admission examination score (mean ± SD)	335.6 ± 10.5	337.2 ± 12.3	-0.81	0.420
Prior coursework performance (mean ± SD)	91.4 ± 8.9	90.3 ± 10.2	0.66	0.508
Undergraduate major, public health (n (%))	29 (42.6)	29 (44.6)	0.052	0.819

Note: Continuous variables are presented as mean ± SD and compared with independent-samples t tests; categorical variables are presented as n (%) and compared with χ^2 tests. All five baseline characteristics were comparable between the two cohorts (all $P > 0.05$).

Results

Reconstructed curriculum and teaching resources

Based on the four core job competency modules, the course was reconstructed into the dual structure of "basic theory" and "thematic practice"; the corresponding relationships are shown in Table 4.

Table 4
Correspondence between core job competency modules and course modules

Core job competency module	Corresponding course module or topic	Main teaching content and competency development focus
Environmental health monitoring and assessment	Basic theory (introduction; environmental media and health); Thematic practice 1: environmental health monitoring and exposure assessment	Basic theory: explanation of the migration and transformation of pollutants in multi-media environments, key human exposure pathways and common health effect mechanisms, building a systematic theoretical framework. Topic 1: focus on monitoring scheme design (for emerging pollutants and others), application of exposure assessment models (internal dose back-calculation and biomarkers) and whole-process quality control. Real cases (such as water quality assessment of the Yellow River) are used to train comprehensive monitoring scheme design and exposure characterisation.
Environmental epidemiology and data analysis	Basic theory (environmental media and health); Thematic practice 2: environmental epidemiology and data analysis	Basic theory: understanding of the biological basis and population distribution of health effects caused by environmental exposure, providing the theoretical premise for causal inference in epidemiology. Topic 2: training in the selection of research designs for different environmental health problems (long-term exposure and acute events, such as cohort and case-crossover designs), modelling analysis of complex data (spatiotemporal and multilevel) and interpretation of results. Actual research projects are used as examples for simulated research design.
Environmental health risk communication and emergency management	Thematic practice 3: environmental health risk communication and emergency management	Topic 3: taking the "emergency response workflow for sudden events" as the main thread, linking risk identification, rapid assessment, emergency monitoring, risk communication and post-event evaluation. PBL simulated scenarios are used to train students in writing risk assessment briefs, drafting key points for public communication and formulating temporary protective measures, strengthening the translation of scientific knowledge into management decisions.
Research innovation and lifelong learning	Runs through all modules and is concentrated in Thematic practice 4: research innovation and sustainable practice	Cross-cutting development: a "frontier advances commentary" session is included in each module to guide students to follow emerging pollutants, exposomics and other frontiers. Core task of Topic 4: students complete, in groups, an "innovative research proposal" addressing a real environmental health problem, systematically training the full process of research innovation from problem identification and literature integration to research design, and laying the methodological foundation for lifelong learning.

With regard to teaching resources, a graduate online open course was built on the XuetangX platform, covering 10 chapters with 74 lecture videos (914 minutes in total); national-level industry experts were invited to record frontier topics. The course team developed 31 original PBL teaching cases jointly with industry experts, covering core themes such as air pollution, water eutrophication, exposure to emerging pollutants, and sudden environmental events (Table 5). The case library was constructed as a reusable teaching resource intended to support future course expansion and to allow teachers to select cases appropriate to their teaching objectives and to the profile of each class; it was not assumed that all cases would be used within a single delivery of the course.

Table 5
Teaching case resources

Resource type	No.	Case title
Case library: Modern Environmental Hygiene Teaching Case Library	1	Beneath the dome: the current status of air pollution in China
	2	The pain of Kunming Lake: water pollution in Dianchi Lake, Yunnan
	3	Something in the water: the Lanzhou "4·11" tap water contamination incident
	4	Healthy living indoors: the indoor environment and health
	5	Eating into trouble or eating for health: soil and health
	6	Humans and the Earth: the past and present of endemic fluorosis
	7	Environmental diagnosis: the air quality index
	8	"Made-up" health: cosmetics and health
	9	The consequences of illegal chromium slag dumping: a sudden environmental pollution incident
	10	Tracking the trail: research on polycyclic aromatic hydrocarbon biomarkers
	11	How harmful are particulate matters to health: risk assessment
Digital textbook: PBL Teaching Cases in Environmental Hygiene	1	Beneath the dome: tracing a city's "breathing pain"
	2	Fingerprinting haze: cracking the chemical code of $PM_{2.5}$
	3	Hunting PM2.5: who is the "prime culprit" of air pollution?
	4	From source to sickbed: mapping the health damage of $PM_{2.5}$
	5	The office mystery: tracking a hidden "health assassin" in the air
	6	Elegy for clear water: when farmland residues seep into the source of life
	7	Norovirus storm on campus: 24 tense hours in the water supply system
	8	The lake's "green" warning: when algal blooms become health killers
	9	Wounds of the land: the health debt hidden in soil

Resource type	No.	Case title
	10	The "sweet" trap of the plastic age: the hidden threat of bisphenol A
	11	Nowhere to hide: the journey of microplastics through the human body
	12	"Disinfection" by-products in tap water: hidden concerns behind safe drinking water
	13	Metal "assassins" in haze: assessing the lethal risk of $PM_{2.5}$ components
	14	Countdown to crisis: life and death after a sudden chemical leak
	15	The "chemical footprint" in the body: tracing evidence of polycyclic aromatic hydrocarbon exposure
	16	Attack of an unknown disease: an epidemiological detective action
	17	Silent accumulation: the chronic duel between cadmium pollution and human health
	18	The "liver" trouble of microplastics: revealing health effects from a genetic perspective
	19	Small fish, big use: zebrafish reveal the black box of environmental toxins
	20	Invaders of the second brain: how environmental pollutants reshape the gut microbiota

Implementation of the reform

The reformed course was delivered to master’s students majoring in public health from March to July 2024, with 65 students enrolled. The course strictly followed the dual structure of “basic theory” (8 teaching hours) and “thematic practice” (24 teaching hours), comprising 32 teaching hours in total. The teaching arrangement and delivery mode for each topic are shown in Table 6.

Table 6
Teaching arrangements and delivery modes

Teaching phase	Teaching content	Teaching hours	Delivery mode	Competency development focus
Basic theory	General principles of environment-health interactions; migration and transformation of pollutants; mechanisms of health effects	8	Online video learning plus offline flipped classroom discussion	Building a systematic theoretical framework
Thematic practice 1	Environmental health monitoring and exposure assessment	6	Online case-based guided learning plus offline scheme design workshop	Monitoring scheme design and exposure characterisation
Thematic practice 2	Environmental epidemiology and data analysis	6	Online methodological guided learning plus offline hands-on data analysis	Research design and complex data analysis
Thematic practice 3	Environmental health risk communication and emergency management	6	Online workflow guided learning plus PBL scenario simulation	Risk communication and emergency response
Thematic practice 4	Research innovation and sustainable practice	6	Online frontier advances plus offline research proposal defence	Translation of research questions and project design

The delivery followed the blended model of “self-directed online learning plus flipped offline classroom” [18]. Before class, students completed video learning and chapter tests for the assigned chapters on the XuetangX platform(a MOOC platform) to acquire basic theoretical knowledge. During class, offline sessions focused on PBL discussion, case analysis, and scheme design, with teachers and industry experts acting jointly as facilitators and assessors. After class, students submitted assignments online and took part in extended discussion forum exchanges, with teachers providing answers and feedback.

The PBL process was organised as follows. One week before class, teachers published case-based guided learning materials on the online platform (including case background, initial questions, and learning objectives), and students uploaded their preliminary analysis online. Classroom implementation comprised four steps: first, intra-group discussion (4–5 students per group) to brainstorm the key issues of the case; second, cross-group discussion and scheme design, in which groups integrated their views and formed a preliminary solution framework; third, group presentation and defence, in which students responded to questions and challenges from teachers, industry experts, and other groups; and fourth, teacher commentary and summary, focusing on the core knowledge points and practical issues in the case. Six PBL sessions were held during the course, covering eight teaching cases selected from the 31-case library. The eight cases were chosen by the teaching team to match the four thematic practice

topics, and the remaining cases were retained in the library for future course expansion and for teachers to draw on in subsequent deliveries of the course.

Evaluation of teaching effectiveness

The mean final grade of the pre-reform cohort was 83.2 ± 5.8 (n = 68) and that of the post-reform cohort was 91.6 ± 4.3 (n = 65); the post-reform mean was higher than the pre-reform mean (mean difference 8.4 points, 95% CI 6.7 to 10.1; t = 9.45, df = 131, $P < 0.001$; Cohen's d = 1.64). The distribution of formative and summative assessment scores in the post-reform cohort is shown in Table 7.

Table 7
Distribution of course assessment scores

Assessment item	Assessment type	Full marks	Mean score (mean ± SD)
Online video viewing	Formative	15	14.5 ± 0.8
Chapter exercises	Formative	20	18.2 ± 1.5
Classroom participation	Formative	15	13.8 ± 1.2
PBL group project output	Formative	25	23.1 ± 1.6
Online midterm test	Formative	10	8.8 ± 0.9
Discussion forum participation	Formative	5	4.6 ± 0.5
Final open-ended assessment	Summative	10	8.9 ± 0.9
Total	Composite	100	91.6 ± 4.3

The results of the self-rated job competency questionnaire (maximum 5 points per dimension) in the pre-reform and post-reform cohorts are shown in Table 8. The mean total score was higher in the post-reform cohort than in the pre-reform cohort (4.4 ± 0.4 vs 3.1 ± 0.5; mean difference 1.3 points, 95% CI 1.2 to 1.5; t = 16.51, df = 131, $P < 0.001$; Cohen's d = 2.86). Among the dimensions, "environmental health risk communication and emergency management" showed the largest between-cohort difference (+ 1.5 points).

Table 8
Between-cohort comparison of the self-rated job competency questionnaire in the pre-reform (n = 68) and post-reform (n = 65) cohorts

Dimension	Pre-reform cohort (n = 68) (mean ± SD)	Post-reform cohort (n = 65) (mean ± SD)	Mean difference(95% CI)	*P value*
Environmental health monitoring and assessment	3.3 ± 0.6	4.5 ± 0.4	1.2 (1.03 to 1.37)	< 0.001
Environmental epidemiology and data analysis	3.0 ± 0.7	4.2 ± 0.5	1.2 (0.99 to 1.41)	< 0.001
Environmental health risk communication and emergency management	2.9 ± 0.6	4.4 ± 0.5	1.5 (1.31 to 1.69)	< 0.001
Research innovation and lifelong learning	3.1 ± 0.6	4.3 ± 0.5	1.2 (1.01 to 1.39)	< 0.001
Total mean score	3.1 ± 0.5	4.4 ± 0.4	1.3 (1.15 to 1.45)	< 0.001

Note: Cronbach's α, computed in the pre-reform cohort (n = 68), was 0.92 for the total scale and 0.85, 0.83, 0.89 and 0.90 for environmental health monitoring and assessment, environmental epidemiology and data analysis, environmental health risk communication and emergency management, and research innovation and lifelong learning, respectively.

Classroom observation showed that the student speaking participation rate was 100%, and approximately 85% of students actively raised questions or challenges during group presentation and defence sessions.

The anonymous questionnaire administered at the end of the course showed that 94.3% of students agreed that "the PBL cases were highly realistic and helped me understand the actual workflow of the CDC", and 91.4% reported that "the blended teaching model improved my self-directed learning and teamwork abilities". Representative student feedback included: "Through the 'sudden chemical leak' case, I simulated the entire CDC emergency response process for the first time and truly put knowledge to use"; and "Industry experts participating in classroom commentary helped me understand the real considerations in actual work, which cannot be replaced by textbook learning alone."

Discussion

This study conducted a systematic reconstruction and blended teaching reform of a graduate course in Environmental Hygiene oriented by job competency. The results suggest that a needs-assessment-based curriculum design, an integrated online–offline teaching model, and a process-oriented assessment system were associated with improved graduate students' comprehensive practical competence and job competency.

Curriculum reconstruction bridges the gap between theoretical teaching and job practice

This study shifted the logic of curriculum design from a “disciplinary knowledge system” to “job competency requirements”. Employer interviews were used to identify core competency expectations such as assessment of emerging pollutants and emergency response, consistent with documented gaps between public health training and practice [6]. On this basis, the dual structure of “basic theory plus thematic practice” was constructed. The results showed that the “risk communication and emergency management” dimension had the largest between-cohort difference (+ 1.5 points) and that 94.3% of students recognised the practical value of the PBL cases, which suggests that needs-oriented curriculum design may contribute to these gains. Integrating the insights of employers and industry experts, informed by public health job-landscape analysis, is a key pathway for addressing the disconnection between learning and application [14]. Systematic curriculum mapping is essential to keep intended competencies, learning activities, and assessment aligned throughout such a redesign [17], while the mixed evidence on competency-based curricula underlines the importance of evaluating outcomes rather than assuming benefit [19].

Blended learning provides an effective pathway for developing higher-order competencies

In the “self-directed online learning plus flipped offline classroom” model, theory is delivered efficiently online, while offline classes use PBL cases to simulate the uncertainty and multiple constraints of real work, training problem identification, collaboration, and decision-making [9, 10]. Combining online and flipped classroom components in this way was shown to be feasible in public health higher education more than a decade ago [20], and a flipped classroom has since been reported to be an acceptable and feasible way of teaching introductory epidemiological reasoning to public health students [21]. A meta-analysis of flipped classroom approaches in health professions education reported consistent benefits for knowledge and skill acquisition [22], and a network meta-analysis of novel teaching strategies found that case-based and problem-based learning were among the most effective approaches for improving learning outcomes in clinical curricula [23]. A flipped-classroom reform combining case-based learning in a Chinese Introduction to Environmental Health Science course likewise demonstrated the value of authentic cases in enhancing student engagement and learning outcomes [24]. Our findings are consistent with this evidence and suggest that the model may be feasible and potentially advantageous in graduate environmental health education. At the same time, PBL is demanding to implement, and barriers related to tutor availability, resources and institutional support have been documented in other settings [25], which is relevant to the transferability of the present model. Methodological guidance on qualitative research in medical education further indicates that in-depth qualitative inquiry is needed to understand how such processes work in situ rather than only through post-hoc perception surveys [26].

The largest between-cohort difference was observed in the “environmental health risk communication and emergency management” dimension, and this observation deserves specific comment. This

dimension also had the lowest score in the pre-reform cohort (2.9 ± 0.6), indicating the greatest baseline deficiency and therefore the largest room for improvement. More importantly, this competency is inherently difficult to develop through traditional lecture-based teaching, because it requires not only knowledge of risk assessment and emergency procedures but also the ability to integrate scientific evidence, communicate uncertainty, and make decisions under time pressure — skills that are contextual and experiential in nature. The PBL scenarios in the thematic practice topic on risk communication, particularly the “sudden chemical leak” case, simulated the full emergency response process, including risk identification, rapid assessment, emergency monitoring, risk communication, and post-event evaluation, thereby providing students with authentic cognitive demands that lecture-based teaching cannot easily replicate. This is consistent with evidence that case-based, problem-based and simulation-based learning are particularly effective for competencies involving decision-making under uncertainty [9, 23]. It may also indicate that needs-oriented curriculum design should prioritise the competencies least developed by traditional teaching, since these may yield the greatest marginal gains. Because PBL depends on how basic and applied content are integrated, differences between teachers’ and students’ perceptions of that integration may further modulate its effectiveness [27].

The multidimensional assessment system acts as an effective driver of learning

An assessment system dominated by formative assessment embeds evaluation throughout the learning process, while the summative component uses higher-order tasks such as open case analysis, guiding students to shift from “cramming for the final examination” to “engagement throughout the course” and thus promoting learning and competence through assessment [11]. In the post-reform cohort, the mean final grade reached 91.6 ± 4.3, with balanced scores across components, which may reflect the motivating effect of process-oriented assessment. Assessment should be designed as an integral programme intertwined with the education programme rather than as a collection of isolated methods, as emphasised in work on programmatic assessment [11, 28], and the same principle applies to competency-based curricula, in which assessment determines whether benchmarked levels of competence have been achieved [19].

Limitations and future directions

This study has several limitations. First, it lacks longitudinal tracking data on graduates’ long-term career development. Second, the sample size is small and drawn from a single institution, which limits external validity. Third, blended learning and PBL place high demands on “dual-qualified” teaching staff and on class size, which may constrain transferability to programmes without such resources. Fourth, the competency measure was self-reported and may be subject to social desirability bias, so the self-reported gains should be confirmed with more objective measures of practical competence. Fifth, and most importantly, the study design was constrained by enrolment: because only one cohort is enrolled each academic year, a concurrent parallel control group could not be formed, and the pre-reform cohort of the preceding academic year served as a non-equivalent historical control. Between-cohort comparisons of this kind cannot exclude differences in student composition and baseline motivation

between academic years, co-interventions, or secular trends. Although age, sex, admission examination score, prior coursework performance, and undergraduate major were comparable between the two cohorts, and unadjusted between-cohort comparisons were therefore considered appropriate, residual confounding by unmeasured characteristics cannot be excluded; designs using historical control cohorts have nevertheless been used and reported as acceptable in comparable curriculum evaluations in medical education [15, 16]. Sixth, the competency questionnaire was completed by two different cohorts rather than by the same students on two occasions, so individual-level change cannot be traced and the comparison is between groups rather than within individuals. Seventh, the assessment scheme itself was changed as part of the reform (process-based components accounted for 90% of the total score after the reform), and mean scores for most assessment components exceeded 90% of the full marks; the higher final grades therefore cannot be attributed to the teaching reform alone and probably partly reflect the change in assessment method and ceiling effects. In addition, the reform was delivered by teachers who were aware of the group allocation and of the intended outcomes, so expectancy and Hawthorne effects cannot be excluded. Future work should involve multicentre studies with concurrent control groups and larger samples, randomised or stepped-wedge designs where feasible, objective assessment of practical competence, and graduate follow-up cohorts, and should explore sustainable mechanisms for the routine participation of industry experts in teaching [29].

Conclusions

In summary, this study suggests that reconstructing a course system oriented by job competency may be valuable. Through a systematic reform pathway, the reform was associated with improved graduate students' comprehensive practical competence and may provide a reference for training high-level interdisciplinary public health professionals. Larger, multicentre studies with concurrent control groups and longer follow-up are now needed to confirm the durability and transferability of these gains.

Abbreviations

CDC
Center for Disease Control and Prevention
PBL
problem-based learning
$PM_{2.5}$
fine particulate matter with an aerodynamic diameter of 2.5 μm or less
SD
standard deviation
SPSS
Statistical Package for the Social Sciences.

Declarations

Ethics approval and consent to participate

This study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of Shandong Second Medical University. Written informed consent was obtained from all interview participants and from all students who completed the questionnaires.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Funding

General Project of Undergraduate Teaching Reform Research of Shandong Provincial Department of Education (M2022077); Teaching Reform Project of Shandong Second Medical University (2026YB047); Medical Education Research Project of the Medical Education Branch of the Chinese Medical Association (2025B223); Curriculum Ideological and Political Demonstration Course of Shandong Second Medical University (Environmental Hygiene); Graduate Education Teaching Reform Research Project of Shandong Second Medical University (2025YJS05)

Author Contribution

Xiaohong Li and Dongqun Xu conceived and designed the study (conceptualization). Wanwei Li, Fengjiao Tan, Mengxiao Luan, Xiaolin Han and Chunlei Li conducted the interviews and collected the data (investigation). Yumei Liu and Qin Wang contributed to the development of the teaching resources and the PBL case library (resources). Yunfeng Tang performed the statistical analysis (formal analysis). Wanwei Li and Fengjiao Tan drafted the manuscript (original draft). Xiaohong Li critically revised the manuscript (review and editing). Xiaohong Li supervised the project (supervision). All authors read and approved the final manuscript.

Acknowledgement

The authors thank the heads of department from the municipal Centers for Disease Control and Prevention in Shandong Province who took part in the interviews, and the industry experts who contributed to the online open course and the PBL case library.

Data Availability

The datasets generated and analysed during the current study are not publicly available because they contain institutional teaching data and personal information of interviewees and students, but are available from the corresponding author on reasonable request.

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Figures

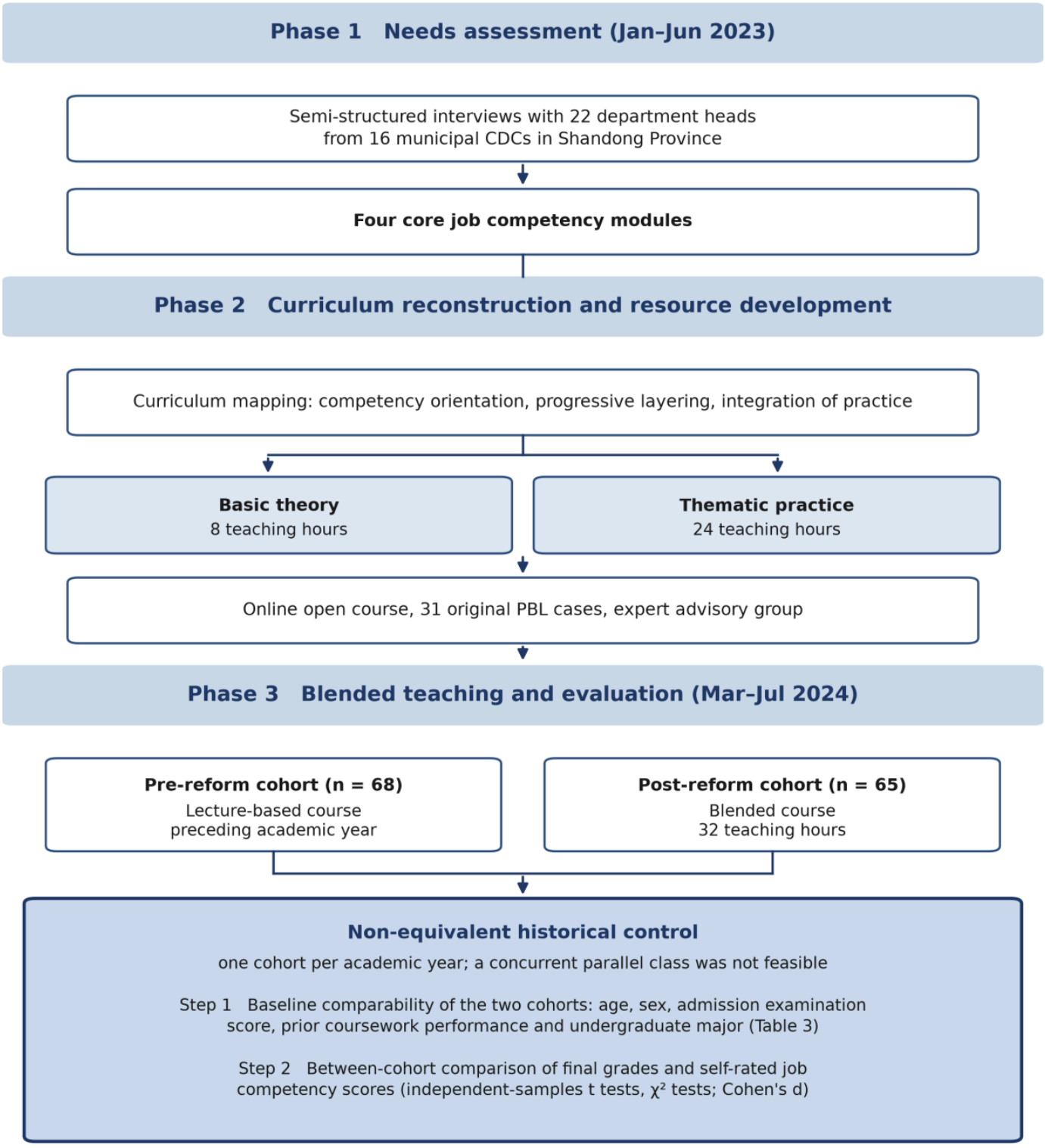


Figure 1

Study design and technical route. The reform was implemented in three phases: needs assessment through employer interviews, curriculum reconstruction with resource development, and blended teaching implementation and evaluation. Because only one cohort is enrolled each academic year, the pre-reform cohort (n = 68) served as a non-equivalent historical control and was compared with the post-reform cohort (n = 65).