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Innovative Integration of Multidisciplinary Teaching and Science Popularization Resources in Marine Environment and Global Change Education

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Abstract: Marine Environment and Global Change is a master's-level course that adopts an ocean-centred perspective to connect Earth-system science, marine chemistry, ecology, pollution, climate policy, and public communication. Building on a multidisciplinary curriculum, the reform coordinates multiple teaching elements and converts course materials into resources for science popularisation. Unlike physically oriented climate courses that focus primarily on ocean dynamics, observing systems, and forecasting, this course foregrounds marine chemical and environmental change, including carbon cycling, acidification, atmospheric deposition, toxic pollutants, ecological restoration, and anthropogenic impacts. Its six thematic modules are taught through an integrated combination of lectures, seminars, disaster films, recent environmental events, and video materials, with AI-assisted inquiry, numerical simulation, and field practice incorporated as extensible components. A qualitative comparison of the Spring and Autumn 2025 teaching rounds indicated broader observable classroom participation following the introduction of the diversified format. The core model is applicable to graduate and undergraduate education as well as public outreach, although its advanced components require appropriate teaching expertise, digital resources, and access to field settings.

Keywords: marine environment, global change, multidisciplinary teaching, science popularisation, AI-assisted instruction

1. Introduction

Teaching global change presents a particular challenge because its subject matter extends across disciplinary boundaries. Climate processes, ocean circulation, atmospheric composition, ecosystem responses, environmental pollution, human activity, economic development, and public policy are closely interconnected. Students may acquire knowledge of individual topics while remaining unable to explain how those topics interact within a changing Earth system. The educational challenge therefore concerns not only conceptual understanding but also the ability to establish relationships among concepts. Research on climate change education has accordingly emphasised personally relevant content, active engagement, discussion, and the explicit treatment of misconceptions (Monroe et al., 2019).

Multidisciplinary integration provides the curricular foundation, but the course gives that foundation a specific pedagogical structure. Climate science, oceanography, chemistry, ecology, and policy are not treated as parallel bodies of knowledge. Instead, teaching proceeds from a recognisable environmental problem to interdisciplinary explanation and, ultimately, communication beyond the classroom. Disaster films and recent environmental events introduce socially relevant questions and stimulate student interest. AI-assisted instruction supports visualisation, comparison, and inquiry, while course materials and student outputs can be adapted as science-popularisation resources for non-specialist audiences. Seminars, concept maps, and mechanism chains connect these elements across the six thematic modules. Films, recent events, seminars, videos, and science-popularisation resources were incorporated into the diversified 2025

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round; AI-assisted inquiry and more systematic development of public-facing resources are planned for the subsequent stage.

The ocean provides a coherent organising framework for this complexity. It stores heat, transports energy, regulates climate, participates in the carbon cycle, exchanges matter and energy with the atmosphere, sustains marine ecosystems, records long-term environmental change, and receives the consequences of human activity. The Intergovernmental Panel on Climate Change (IPCC, 2019) reported that the global ocean has warmed continuously since 1970 and has absorbed more than 90% of the excess heat in the climate system. Global change cannot therefore be understood adequately without its oceanic dimension. The UNESCO-IOC ocean literacy framework likewise emphasises reciprocal relationships between the ocean and humanity (UNESCO-IOC, n.d.), while research on ocean literacy has examined both the assessment of marine knowledge and its connection with public engagement (Fauville et al., 2019; Kelly et al., 2022). An ocean-centred approach can thus support specialist education in marine science while also contributing to public science communication.

Marine Environment and Global Change, offered by the School of Marine Sciences at Sun Yat-sen University, provides a case through which this approach can be examined. The syllabus defines it as a 2-credit, 36-hour master's-level course in a professional specialisation and research methods. Students are expected to understand the composition and dynamics of the ocean system, the principal drivers of global change, interactions among marine physical, chemical, and biological processes, the regulatory role of the marine environment within the Earth climate system, the coupled effects of natural variability and human activity, and methods for monitoring key indicators (Sun Yat-sen University, n.d.). The course differs in emphasis from physically oriented ocean-climate courses. Physical processes establish the Earth-system context, but the principal analytical focus is marine chemical and environmental change, particularly carbon cycling, acidification, atmospheric deposition, toxic pollutants, ecological restoration, and anthropogenic impacts on the ocean. Science-popularisation activities further connect specialist learning with national policies for responding proactively to global climate change.

Student activity remained central across both teaching rounds. The reform was designed to help students progress from fragmented disciplinary knowledge to an ocean-centred understanding and from classroom study to scientific practice and public communication. The diversified 2025 round incorporated films, recent environmental events, seminars, videos, and science-popularisation resources. AI-assisted observation, field investigation, research-vessel sampling, marine heat-wave risk assessment, pollutant analysis, and numerical simulation remain planned extensions.

2. Curriculum Background and Educational Value

2.1 Comprehensive nature of the course

Marine Environment and Global Change is structured around relationships between the ocean system and global change rather than around a single branch of oceanography. Its knowledge base encompasses the Earth climate system, marine meteorology, environmental chemistry, atmospheric pollution, physics, biology, climatology, palaeobiogeochemistry, and economics. These fields are connected rather than juxtaposed. Physical processes establish the climatic context, after which the course examines how chemical transformations and human activities modify the marine environment and generate feedbacks within the Earth system. A common question integrates the different fields: how does the ocean participate in, regulate, record, and respond to Earth-system change under natural variability and anthropogenic pressure?

The syllabus organises the course around six thematic areas: the Earth climate system and marine environment, global carbon cycle and dual-carbon strategy, global climate change and marine ecological effects, sea-air exchange and climate change, polar regions and global change, and the relationship among atmospheric chemical composition, toxic pollutants, and global change. The modules provide a clear curricular structure, but their value depends on the connections among them. A course on global change should not leave students with six separate topic folders; it should help them build pathways among climate mechanisms, ocean processes, ecological effects, pollution, policy, and public responsibility.

The course also serves several educational contexts. At graduate level, it develops research-oriented reasoning and methodological awareness; at undergraduate level, it can bridge foundational disciplinary knowledge and integrated Earth-system understanding. For public education, topics such as ocean warming, sea-level rise, extreme weather, carbon neutrality, marine pollution, mangrove restoration, and environmental risk can be adapted into accessible science-popularisation resources.

2.2 Value education embedded in ocean-centred global change teaching

The ocean provides a distinctive lens for understanding Earth-system change. This lens supports systems thinking because the ocean connects the atmosphere, cryosphere, lithosphere, biosphere, and human society. It also provides a natural space for value education. Climate change, marine pollution, ecological restoration, and carbon neutrality are scientific topics, but they also involve responsibility, governance, and the relationship between individual learning and national development.

Value education is most effective when it grows out of concrete cases. Ocean circulation introduces energy transport and regional climate. Ocean acidification brings together atmospheric carbon dioxide, carbonate chemistry, marine organisms, and fishery risk. Marine pollutants connect human activity, environmental chemistry, ecosystem health, and governance. The carbon neutrality topic in the syllabus provides a direct channel for linking scientific mechanisms with the dual-carbon strategy. These cases allow China's active response to global climate change, the construction of a marine power, marine ecological restoration, pollution control, and sustainable development to be discussed within the scientific logic of the course rather than as detached policy statements.

The student-centred character of value education lies in the work students perform. They analyse evidence, discuss mechanisms, enter field sites, and produce science communication materials. Ocean-centered education translates abstract climate concepts into visible and explainable cases, such as coral bleaching, marine heat waves, typhoons, storm surges, sea-level rise, polar ice loss, mangrove restoration, and pollutant transport. Through these cases, students link professional learning with the national policy of actively responding to global climate change, while also learning how to communicate climate knowledge to the public.

2.3 Necessity of multi-method teaching reform

The interdisciplinary scope and public orientation of the course cannot be addressed adequately through lectures alone. Lectures remain necessary for the systematic explanation of concepts and mechanisms, but students must also observe, discuss, simulate, verify, and communicate. Evidence from STEM education indicates that active learning can improve student performance relative to lecture-only instruction (Freeman et al., 2014). The teaching model therefore combines lectures with seminars, video presentation, disaster-film analysis, AI-assisted simulation, field investigation, and science-popularisation tasks.

UNESCO's guidance on generative AI in education stresses a human-centred vision of AI and the development of human capacity in education and research (UNESCO, 2023). Research on large language models in education likewise identifies both opportunities for personalized support and risks involving accuracy, bias, and overreliance (Kasneci et al., 2023). In the next stage of course development, AI can support rather than replace teachers or scientific judgment. It may assist visualisation, simulation, comparison, and inquiry. Used with disaster films, environmental events, fieldwork, and numerical models, AI can help students form a more three-dimensional understanding of Earth-system change while learning to verify and question digital outputs.

3. Teaching Challenges in Marine Environment and Global Change Education

3.1 Fragmentation of multidisciplinary knowledge

Knowledge fragmentation constitutes a persistent teaching difficulty. Because the course draws on several disciplines, units taught in isolation can appear to students as a collection of unrelated topics. Climate-system science addresses radiation and circulation; marine meteorology examines air-sea interaction; environmental chemistry considers pollutants; biology explains ecosystem responses; economics addresses policy and cost; and palaeobiogeochemistry reconstructs long-term Earth history. Effective learning requires students to understand the interactions among these areas.

The challenge lies less in the amount of content than in its organisation. The ocean provides a unifying thread through which energy, matter, organisms, pollutants, human activities, and policy responses can be related. This emphasis accords with sustainability-education frameworks that identify systems thinking and the integration of different forms of knowledge as core academic competencies (Wiek et al., 2011). Such an organisation encourages students to move beyond terminological recall towards systemic understanding.

3.2 Difficulty of making abstract Earth-system processes visible

Many processes associated with global change are abstract, spatially extensive, or temporally prolonged. Ocean heat uptake, thermohaline circulation, radiative forcing, carbon cycling, polar amplification, ocean acidification, and pollutant transport cannot be observed directly in an ordinary classroom. Definitions and equations are indispensable, but alone may not enable students to develop an integrated representation of these processes.

Visual media render these processes more accessible to classroom inquiry. Disaster films, documentaries, satellite imagery, climate animations, and three-dimensional observation products situate abstract mechanisms within recognisable problems. Studies of climate-disaster narratives show that films can influence perceptions of climate change, although science-communication research cautions that narrative engagement must remain anchored in evidence (Dahlstrom, 2014; Lowe et al., 2006). Students are therefore asked to identify the represented phenomenon and its underlying mechanism, assess the scientific plausibility of the explanation, and determine what evidence would be required for verification. Moving from visual representation to scientific reasoning supports a more grounded understanding of complex Earth-system processes. AI-assisted simulation can extend this work when students are prepared for more open-ended inquiry.

3.3 Insufficient connection between classroom learning and scientific practice

Students may understand concepts in class but still lack direct experience of how marine environmental data are collected, analysed, and used for risk assessment. Global change education therefore needs to extend beyond explanation. It can guide students toward field sites, research platforms, laboratories, and modelling tasks when conditions allow.

Research-vessel sampling helps students understand marine observation methods and sample collection. Marine heat-wave risk assessment connects climate data with ecological and social impact. Mangrove field investigation shows the importance of ecological restoration. Pollutant analysis reveals the influence of human activities on the environment. Numerical simulation helps students estimate environmental impact risks under different scenarios. These activities connect scientific concepts with real environmental processes and national needs.

3.4 Need to transform course resources into science popularisation resources

Marine environment and global change are academic topics and public concerns. Course materials, case discussions, field investigation results, AI simulations, and student projects can be developed into short videos, public lectures, posters, online articles, and exhibition materials.

This transformation works in two directions. For students, it improves communication ability and strengthens social responsibility. For society, it supports public understanding of global climate change and the role of the ocean. Science popularization is therefore part of course reform rather than an external supplement.

4. Integrated Curriculum Design Based on Six Thematic Modules

The six thematic modules form an integrated learning system rather than six parallel blocks of content. The ocean provides their common organising centre, linking climate-system structure, carbon cycling, ecological responses, air-sea exchange, polar feedbacks, pollutant transport, and environmental governance. Each module contributes a distinct explanatory perspective, while student tasks establish connections through concept maps, mechanism chains, field observations, AI-assisted simulations, and science-popularisation products. Concept maps can support knowledge retention, although their effects vary with the task and instructional setting (Nesbit & Adesope, 2006). The modules define the knowledge framework; the teaching elements determine how students encounter, relate, and communicate that knowledge

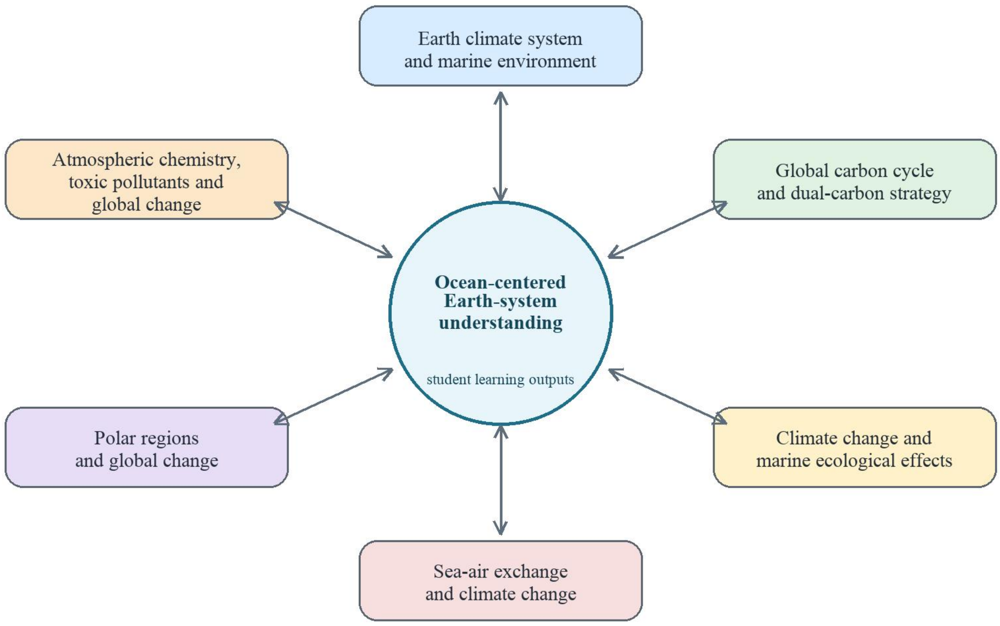

Figure 1. Schematic Diagram of Six-module Curriculum Integration Design

Figure 1 presents the integrative logic of the six modules. Visual media and recent environmental events first generate questions, after which relevant disciplinary concepts are introduced within the appropriate modules. Through discussion, visual analysis, and practice-oriented tasks, students reconstruct the underlying mechanism chains and subsequently translate their learning into science-popularisation products. Films and environmental events initiate inquiry, AI-assisted instruction supports visualisation and comparison, and science-popularisation tasks extend learning to non-specialist audiences. This sequence prevents multidisciplinary content from becoming a catalogue of disconnected terms and positions students as active participants in relating evidence, mechanisms, risks, and societal responses.

4.1 Earth climate system and marine environment

This module provides the basic Earth-system framework for the whole course. It introduces the atmosphere, hydrosphere, cryosphere, lithosphere, and biosphere as coupled components, with the ocean emphasized as a major heat reservoir, water-vapour source, and energy transporter. Its role in integration is to give students a system map into which later topics can be placed.

Students analyse how uneven solar radiation requires heat transport from low latitudes to high latitudes, how ocean currents contribute to this process, and how changes in circulation may influence regional climate. Visual materials help students distinguish climate variability from climate change. Later modules return to this framework when discussing carbon cycling, ecological effects, sea-air exchange, polar feedback, and pollution.

4.2 Global carbon cycle and dual-carbon strategy

This module connects the global carbon cycle with China's dual-carbon strategy. It includes greenhouse gases, radiative forcing, ocean carbon uptake, carbonate chemistry, biological pump, marine negative emissions, and climate governance. Its integrative function is to link molecular and geochemical processes with policy-oriented climate action.

Students can compare different carbon-flow pathways, including atmospheric emissions, ocean absorption, biological fixation, sedimentation, and long-term geological cycling. They discuss why the ocean matters to carbon cycling, why carbon sinks have limits, and how marine science may contribute to carbon neutrality. In this way, the module connects scientific knowledge, national policy, and student responsibility. AI-assisted diagrams or simulations can be added in later teaching to make these pathways more visible.

4.3 Global climate change and marine ecological effects

This module links climate drivers with ecological consequences. It includes ocean warming, ocean acidification, marine heat waves, coral bleaching, hypoxia, sea-level rise, habitat change, and biological response. The National Oceanic and Atmospheric Administration (NOAA, n.d.) explains that surface ocean pH has fallen by about 0.1 pH units, representing approximately a 30% increase in acidity. This evidence connects chemical change with ecological risk and helps students see how one environmental signal can cross disciplinary boundaries.

Teaching can begin with recent environmental events or visual materials, such as marine heat waves, coral bleaching events, or coastal ecological degradation. Students identify the knowledge points involved and reconstruct the mechanism: climate forcing changes ocean temperature and chemistry; environmental stress affects organisms; ecosystem change influences fisheries, coastal protection, and human welfare. The module therefore integrates physical forcing, chemical change, biological response, and social risk.

4.4 Sea-air exchange and climate change

Sea-air exchange links marine science with atmospheric science. This module includes heat flux, water vapor transport, gas exchange, aerosol production, atmospheric deposition, clouds, precipitation, and biogeochemical feedbacks. Its integrative role is to show that the boundary between ocean and atmosphere is an active interface where energy, matter, and pollutants are continuously exchanged.

Students use animations, model outputs, or visualisations to understand how solar radiation heats the ocean surface, how evaporation transfers latent heat to the atmosphere, how atmospheric circulation redistributes water vapor and energy, and how pollutants or aerosols may influence the marine-atmospheric system. These activities connect meteorology, physics, chemistry, and environmental monitoring through one process chain. AI-supported visualisation can further enrich this module in future implementation.

4.5 Polar regions and global change

Polar regions are sensitive indicators of global change. This module includes sea ice loss, ice sheet melting, permafrost thawing, polar amplification, polar ecosystems, and high-latitude ocean circulation. Its integrative role is to connect distant polar processes with global sea level, ocean circulation, climate feedback, and coastal risk.

Documentary clips, disaster-film comparison, satellite images, and model simulations can support teaching in this module. Students analyse why sea ice decline can reduce albedo, how ice sheet melting contributes to sea-level rise, how freshwater input may affect ocean circulation, and why permafrost thawing may release greenhouse gases. These links show why polar change is not a distant issue, but a global environmental signal connected with coastal risk, climate feedback, and international scientific cooperation.

4.6 Atmospheric chemical composition, toxic pollutants, and global change

This module expands global change education from climate warming to atmospheric chemistry, toxic pollutants, and environmental governance. It includes greenhouse gases, aerosols, atmospheric pollutants, toxic substances, acid deposition, pollutant transport, environmental toxicity, and ecological restoration. Its integrative role is to place human activity inside the Earth-system framework rather than outside it.

Teaching can combine lecture content with pollutant analysis, environmental event interpretation, and field practice. Students analyse how pollutants enter marine systems, how they affect ecosystems, and how pollution governance and ecological restoration contribute to sustainable development. Mangrove restoration is a useful practical case because it connects coastal ecology, carbon storage, biodiversity, disaster reduction, and public environmental education.

5. Multi-Method Teaching Reform Path

5.1 Raising questions through disaster films and recent environmental events

Disaster films and recent environmental events can open scientific questions. Disaster films present visually powerful situations involving storms, sea-level rise, polar ice change, ecological collapse, and social crisis. Recent environmental events, including marine heat waves, coral bleaching, coastal flooding, pollutant incidents, or extreme weather, bring urgency and reality into the classroom.

These materials need critical use. Teachers guide students to ask: What phenomenon is shown? What marine environmental knowledge point does it involve? Is the mechanism scientifically plausible? What is exaggerated? What data or literature can verify it? In this process, visual media become a problem-based learning resource. Problem-based learning is especially useful when students must integrate disciplinary knowledge, evidence, and self-directed inquiry around an open question (Hmelo-Silver, 2004). Students also learn how public narratives of disaster should be connected with scientific evidence.

5.2 Introducing AI and three-dimensional Earth-system observation

AI and three-dimensional Earth-system observation make complex processes easier to explore. AI supports image interpretation, data visualisation, concept mapping, scenario comparison, and simulation-based inquiry. Students may use AI-assisted tools to organise satellite images, compare model outputs, visualize ocean temperature anomalies, generate conceptual diagrams of sea-air exchange, or explore possible impacts of different marine environmental changes on global change.

The use of AI still requires teacher guidance and scientific verification. Students learn that AI-generated explanations or images are not automatically correct. They compare AI outputs with textbooks, scientific reports, monitoring data, and authoritative sources. AI then becomes not only a visualisation tool, but also a context for training critical thinking and evidence evaluation.

5.3 Embedding knowledge points and integrating interdisciplinary relationships

Knowledge points are embedded across modules so that students can follow relationships among disciplines. Each class can be organised around a core question and a set of connected knowledge points. A lesson on ocean acidification, for instance, can include atmospheric carbon dioxide, seawater carbonate chemistry, calcifying organisms, marine food webs, fisheries, and economic risk. A lesson on marine heat waves can include climate variability, ocean heat content, ecosystem stress, monitoring data, fisheries impact, and adaptation.

This design changes how knowledge points function. They are no longer isolated facts to be memorized, but nodes in an interdisciplinary network. Students construct concept maps, mechanism chains, and evidence chains. Through repeated practice, they learn to explain global change from multiple perspectives and understand the role of the ocean in connecting these perspectives.

5.4 Combining field investigation and scientific research practice

Classroom learning is connected with field investigation and scientific research practice. Students need opportunities to go outside the classroom and understand how scientific knowledge is produced. Research-vessel sampling helps them understand marine observation methods and sample collection. Marine heat-wave risk assessment links climate data with ecological and social impact. Mangrove field investigation shows the importance of ecological restoration. Pollutant analysis reveals the influence of human activities on the environment. Numerical simulation helps students estimate environmental impact risks under different scenarios.

These activities make the course more concrete and research-oriented. Students are not only receivers of knowledge; they become participants in observation, analysis, simulation, and interpretation. Research on fieldwork in higher education has shown that field experiences can positively influence students' affective engagement with learning (Boyle et al., 2007). In this course, the same principle links climate concepts with marine observation and environmental assessment, while strengthening students' willingness to serve national environmental and climate policies.

5.5 Transforming course resources into science popularisation resources

Course resources are transformed into science popularisation resources through student production. Students convert learning outcomes into public-oriented materials such as short videos, science posters, public lectures, online articles, fieldwork notes, environmental event explanations, and AI-assisted visualisations. These products explain why the ocean matters to global change, how human activities affect marine systems, and why society should actively respond to climate change.

This path gives science communication a concrete place in the course. Students simplify complex knowledge without distorting scientific meaning. They learn to communicate mechanisms, evidence, uncertainty, and responsibility. Narrative can make science more accessible to nonexpert audiences, while effective ocean communication also depends on sustained links between scientific knowledge and public engagement (Dahlstrom, 2014; Kelly et al., 2022). For the course, science popularisation turns classroom materials into open educational products.

6. Student-Centered Assessment Design

6.1 Assessment principles

Assessment is aligned with the forms of learning promoted by the course. Because teaching combines lectures, seminars, visual media, environmental-event analysis, numerical simulation, and science popularisation, a single final examination would not adequately represent the learning process.

A portfolio-based design can document how students formulate problems, connect concepts, evaluate evidence, undertake practical work, and communicate findings. Aligning assessment with capabilities that extend beyond an individual course is consistent with principles of long-term learning in higher education (Boud & Falchikov, 2006). AI-assisted inquiry and field practice may be included as optional or advanced components when appropriate conditions are available.

The core principle is student-centredness. Students are evaluated not only as receivers of course content, but as learners who construct mechanism chains, participate in field or simulation tasks, and translate professional knowledge into public-oriented explanations. This design keeps the focus of teaching reform on student learning rather than on the novelty of teaching tools.

6.2 Portfolio components and scoring method

Table 1. Student-centered Assessment Framework for the Diversified Teaching Round

Component	Weight	Operational evidence
Six-module concept map	15	A concept map linking at least three modules through one ocean-centred issue; scored for accuracy and integration.
Film or environmental-event analysis	15	A written case analysis identifying knowledge points, scientific plausibility, and supporting evidence.
Seminar presentation and discussion	15	Group presentation, attendance, and individual responses during discussion.
Numerical simulation or mechanism-chain analysis	15	Model output, calculation, or mechanism diagram interpreted in scientific terms.
Field investigation or scientific-practice report	15	Report based on available practice such as sampling, heat-wave risk assessment, mangrove observation, or pollutant analysis.
AI-assisted inquiry extension	10	Tool-use record, verification against reliable materials, and reflection on limitations.
Science-popularization product	15	Poster, short video, article, lecture outline, or visualisation scored for scientific accuracy and accessibility.

Note: If AI-assisted inquiry, numerical simulation, or field practice is not offered in a given teaching round, that component should be replaced by equivalent assessed work rather than reported as a completed activity.

The diversified teaching round can be assessed through a 100-point coursework portfolio. The scoring structure should correspond to the center of the course: understanding global change from the ocean, linking knowledge across disciplines, and turning learning into analysis, communication, and practice. Components such as AI-assisted inquiry, numerical simulation, or field practice should enter the final grade only when they have actually been implemented in that teaching round.

In this way, assessment is not a separate appendix to teaching but part of the teaching process itself. The portfolio also provides direct student-level evidence for the later comparison between different teaching rounds.

6.3 Rubric design for student learning outcomes

Rubrics describe observable learning performance.

For knowledge understanding, students explain key concepts such as climate variability, Earth climate system, ocean circulation, sea-air exchange, global carbon cycle, greenhouse gases, radiative forcing, ocean acidification, marine heat waves, polar feedback, toxic pollutants, and ecological restoration. The emphasis is not memorization, but the ability to explain why a knowledge point matters and how it connects with other knowledge points.

For interdisciplinary integration, students connect physical, chemical, biological, climatic, ecological, and social dimensions of a marine environmental issue. In a case on marine heat-wave risk, for example, they analyse ocean temperature anomalies, climate drivers, ecosystem impacts, monitoring evidence, economic risks, and adaptation measures. In a case on mangrove restoration, they analyse coastal protection, carbon storage, biodiversity, pollution control, and public education.

For numerical simulation and AI-assisted inquiry, students show that they can interpret model outputs, use AI tools responsibly, verify AI outputs, and connect visualisation with scientific evidence. They may compare AI-generated explanations with textbooks, scientific reports, monitoring data, or authoritative sources. For field practice and science popularisation, rubrics include scientific accuracy, quality of evidence, practical participation, clarity of expression, interdisciplinary connection, and social responsibility.

Through this assessment design, students become the central evidence of teaching reform.

Their maps, reports, presentations, simulations, fieldwork records, and science popularisation products show whether the course has helped them move from fragmented knowledge to integrated understanding and from professional learning to responsible communication.

7. Two-Round Teaching Comparison and Evidence

The comparison draws on questionnaire responses collected through the university course-evaluation system, supplemented by records of classroom participation and seminar activity. The two rounds were offered in the Spring and Autumn semesters of 2025. As no separate grade-based comparison was available for this graduate course, the analysis focuses on questionnaire feedback and observable classroom engagement. The first round followed a predominantly lecture-centred sequence culminating in an individual paper. In the second round, lectures were combined with disaster-film and recent-event analysis, seminars, video presentations, and science-popularisation resources.

The clearest difference between the two rounds concerned classroom participation. In the first round, observable interaction was limited because the principal student output was an individually submitted paper. In the second, all students participated in seminars, discussed relationships between marine processes and global change, and proposed activities for subsequent iterations of the course. Their suggestions informed consideration of AI-assisted learning, numerical simulation, field practice, and further development of science-popularisation resources.

Table 2 presents the evidence from the two rounds in qualitative terms. Questionnaire responses from the university course-evaluation system provide an overall view of students' perceptions, while classroom participation and students' suggestions show how they responded to the teaching activities.

Table 2. Qualitative Comparison of Two Rounds of Graduate Teaching

Aspect	Spring 2025	Autumn 2025	Basis for comparison
Main learning task	Routine lectures followed by an individual paper submission.	Lectures were combined with films, recent events, seminars, videos, and science-popularisation resources.	Course teaching records
Visible classroom participation	Participation was mainly reflected in completion and submission of the paper; in-class interaction was limited.	All students participated in the seminar activities and contributed to the discussion.	Classroom observation and seminar records
Student feedback	Student feedback was collected through questionnaires in the university course-evaluation system, while classroom interaction remained limited.	Questionnaire feedback was accompanied by active discussion and direct suggestions during seminars.	Course-evaluation questionnaires and classroom feedback
Student suggestions	Suggestions for subsequent teaching activities were not a prominent part of the course process.	Students put forward suggestions that informed the planning of AI-assisted learning, numerical simulation, field practice, and science-popularisation activities.	Seminar discussion and teacher notes
Interpretation	The round established the core content and a paper-based learning task.	The round broadened student participation and made feedback part of subsequent course design.	Comparison of teaching process and student engagement

The comparison is centred on changes in student activity. The significance of the second round lies not simply in the addition of teaching tools, but in the transition from an individual written task to collective discussion and student contributions to subsequent course design.

8. Conclusion

Marine Environment and Global Change provides a suitable context for integrating multidisciplinary teaching with the development of science-popularisation resources. Its ocean-centred perspective enables students to examine the composition and dynamics of the ocean system together with the principal drivers of global change. Marine chemical and environmental change serves as the organising thread through which human activities are connected with Earth-system responses. In this respect, the course complements physically oriented climate curricula by emphasising carbon cycling, acidification, pollutants, ecological effects, and public responsibility within a broader physical framework.

The teaching model coordinates four elements within a common sequence. Disaster films and recent environmental events generate questions; AI-assisted instruction supports visualisation, comparison, and inquiry; course materials and student outputs are developed into science-popularisation resources; and seminars and mechanism chains connect these activities across the six thematic modules. The resulting progression leads students from an observable environmental problem to interdisciplinary explanation and communication with a wider audience.

The comparison between the two rounds provides a practical basis for further development. The first round established the core content and paper-based learning task, whereas the second incorporated classroom participation and student suggestions into the teaching process. Subsequent course development will draw on this feedback when introducing AI-assisted inquiry, numerical simulation, field practice, and additional science-popularisation activities.

The model permits implementation at different levels of resource intensity. Its basic form requires lectures, locally available films or environmental events, seminar tasks, and student-produced science-popularisation materials, making it adaptable to graduate and undergraduate education as well as public outreach. AI-assisted inquiry, numerical simulation, research-vessel sampling, and field investigation require additional expertise, data, equipment, safety arrangements, and access to field sites. The present evidence is limited to two teaching rounds at a single institution and rests primarily on questionnaire feedback and qualitative classroom records. Implementation across a wider range of courses and student groups, accompanied by more systematic outcome data, is therefore required to assess the transferability of the model.

Conflict of Interest

The authors declare that they have no conflicts of interest to this work.

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