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# Reform of paleontology teaching in Xinjiang based on curricular integration of regional resources

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**Abstract:** Xinjiang University has implemented a regionally distinctive reform of its Paleontology course according to outcome-based education and the requirements of Emerging Engineering Education and First-Class Undergraduate Course development. The reforms focused on several major issues in course instruction, including insufficient integration of textbook content with the unique regional resources of Xinjiang, inadequate emphasis on geological spatiotemporal thinking, and weak linkage between classroom instruction and field practice. The course contents, teaching methods, and assessment mechanisms were systematically optimized to address the overemphasis on knowledge memorization. The reform established a "One Core, Two Wings, Four Dimensions, Three Linkages" framework, with the new curriculum including the fossils and stratigraphic sections of Xinjiang, as well as regional research findings, thereby combining theoretical instruction with practical training. Application of this framework resulted in restructuring of the course content, teaching methods, learning environment, and assessment mechanisms, emphasizing knowledge acquisition, competence development, and value cultivation. Three modules, namely, foundational theory, Xinjiang-focused topics, and field practice, were created to connect classroom instruction, laboratory studies, and fieldwork, with integration of local fossil resources throughout the teaching process and implementation of diversified, formative assessment enabling continuous improvement. This led to the transformation of information on regional resources from fragmented illustrative cases into instructional units aligned with the course objectives, tasks, and assessment, while student learning expanded from simple memorization to the articulation of identification criteria, stratigraphic correlation, and paleoenvironmental interpretation, together with strengthening task continuity across different sections of the course. These reforms demonstrate that the inclusion of relevant regional material can yield stable and lasting educational value.

## 1. Introduction

Paleontology forms a bridge between the life sciences and the earth sciences. At the university level, courses in paleontology provide a foundation for students majoring in geology and resource-exploration engineering to understand the evolution of life, stratigraphic correlation, and paleoenvironmental reconstruction. Students are required to study the morphology, classification, and temporal distribution of life forms, and must also learn to interpret geological history from specimen characteristics, stratigraphic attitude, and the depositional context. The Emerging Engineering Education initiative in China calls for reforms in engineering education and the cultivation of new talent, while proposed amendments to undergraduate courses emphasize analytical thinking, innovation, and challenge. (MEPRC, 2017; 2019). Reform of the paleontology course should therefore not be limited to adding content or information on new technology, but should instead cultivate student skills in observing evidence, synthesizing information from multiple sources, and interpreting geological data.

Current reforms of courses in paleontology and stratigraphy have explored the use of geological time as an organizing thread, competence-based training, blended online-offline instruction, virtual simulation, and the integration of values-based education (Zhang and Wang, 2016; Li et al., 2023; Wu et al., 2024; Jin et al., 2025), offering useful reference points for restructuring course objectives and updating teaching methods. A further relevant example is provided by Pimiento (2015), who showed that paleontology teaching can be made more relevant and authentic when disciplinary concepts and skills are applied to the fossil record and geological settings familiar to students, while

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research and science-communication activities are incorporated into the course design (Pimiento, 2015). However, the inclusion of regional material has been largely confined to classroom introductions and supplementary material, without being fully integrated into the course objectives, learning tasks, practical teaching, and assessments. This has led to the restriction of regional material to specific available resources and illustrative examples, with minimal integration into a stable, replicable teaching mechanism.

Xinjiang, China, covers multiple basins and orogenic belts, and includes an abundance of Phanerozoic marine and continental strata and paleontological resources. Marine fossils of the Early Paleozoic and Biostratigraphic records of the Tarim Basin, continental vertebrates from the Mesozoic, Paleobotanical remains of the Junggar-Turpan-Hami Basin, and the Carboniferous-Jurassic stratigraphic sections around Urumqi together provide authentic material for training geological spatiotemporal thinking. The presence of these resources has led Xinjiang University to focus on the Paleontology course within the Resource Exploration Engineering program and to develop the concept of "curricular integration of regional resources", examining problem diagnosis, framework design, implementation pathways, and evidence of outcomes, with the aim of providing a reference for curriculum reform at institutions with similar distinctive regional geology.

## 2. Practical problems in course teaching

### 2.1 Insufficient integration of course materials and local resources

General paleontology textbooks are required to preserve the integrity of the discipline's knowledge system, and are therefore typically organized around nationally representative taxa and classic stratigraphic horizons; this approach is followed by most instructors in their teaching. However, when classroom instruction is centered on material typical of North and South China, the fossils, strata, and paleoenvironmental data from Xinjiang appear only as isolated examples and lack consistent alignment with course objectives, classroom tasks, or assessment requirements. In general, students may memorize fossil names and ages without being able to explain the stratigraphic sections, identification criteria, or environmental significance underlying them, and would therefore similarly struggle to apply taxonomic knowledge to geological problems in their own region. The underlying issue is not a shortage of local material, but that research and outreach resources have yet to be aligned with the course objectives and converted into instructional tasks.

### 2.2 Inadequate training in geological spatiotemporal thinking

Traditional teaching tends to present the morphology, taxonomic classification, temporal distribution, and stratigraphic significance in turn; however, while this order provides a clear knowledge hierarchy, it also leads to fragmented memorization. At the same time, paleontology teaching should consider the prior conceptions of students, as identifying and addressing these conceptions can enable conceptual change and the development of a more scientifically accurate understanding (Yacobucci, 2018). Fossil identification, stratigraphic correlation, paleoenvironmental reconstruction, and biological evolution should, in principle, be organized around their relationships with time, space, and the environment. In practice, however, most students remain at the level of describing specimens, memorizing names, and reciting facts, rarely advancing from single specimens to assemblage-level patterns or from morphological description to geological interpretation. They scrape by with surface learning, in which information is memorized in a disjointed, isolated fashion, and quickly forgotten once it is no longer needed for an assignment or exam. Students are not empty vessels awaiting information, but come with preexisting knowledge, which may be incorrect. New information must be able to be integrated into this pre-existing framework or it will be discarded. To truly learn something, the student must construct his or her own personal understanding of it. Learning will not take place unless the learner is actively engaged in the process. Zhang and Wang (2016) proposed organizing the entire course around the concept of geological time, arguing that the key to teaching paleontology does not depend on the addition of more content, but rather in the construction of a spatiotemporal framework for organizing knowledge and interpreting evidence. Students leave the course with an ingrained sense of general biostratigraphy as a result of the chronological approach as well, even beyond a focused class-time treatment of biostratigraphic concepts and practice.

### 2.3 Weak field practice component

Paleontology is inherently a practice-based discipline; however, practical instruction tends to consist largely of indoor laboratory observation and identification of hand specimens. While digital models of fossils can supplement analysis of physical specimens by enabling access to rare or delicate materials, they cannot fully replace the educational value of direct observation of real fossils (Cunningham, 2021). The incorporation of field practice with classroom teaching is constrained by limited class hours, transportation, seasonal weather conditions, safety management, and site-protection requirements, leaving students with few chances to formulate questions, collect fossils, analyze environmental evidence, or develop integrated interpretations. In this respect, Xinjiang has an abundance of well-preserved fossil localities capable of supporting a full practicum ranging from prospecting to geological analysis. However, this abundance of fossil localities has yet to be fully exploited in the current teaching model.

### 2.4 Homogeneous assessment methods

In the original paleontology course model, the final written examination accounted for 70% of the course grade, with coursework and attendance making up the remaining 30%. This heavy reliance on a memorization-oriented final examination provides a poor assessment of the students' overall competence and particularly of their specimen identification and field skills, thereby only partially achieving the training objectives. Assessment reforms, therefore, cannot simply rely on adjustments of score weights, but instead require an initial identification of the intended learning outcomes, followed by the assignment of a task, an evaluation criterion, and a source of evidence to each outcome, resulting in a final alignment of the course objectives, activities, and assessment.

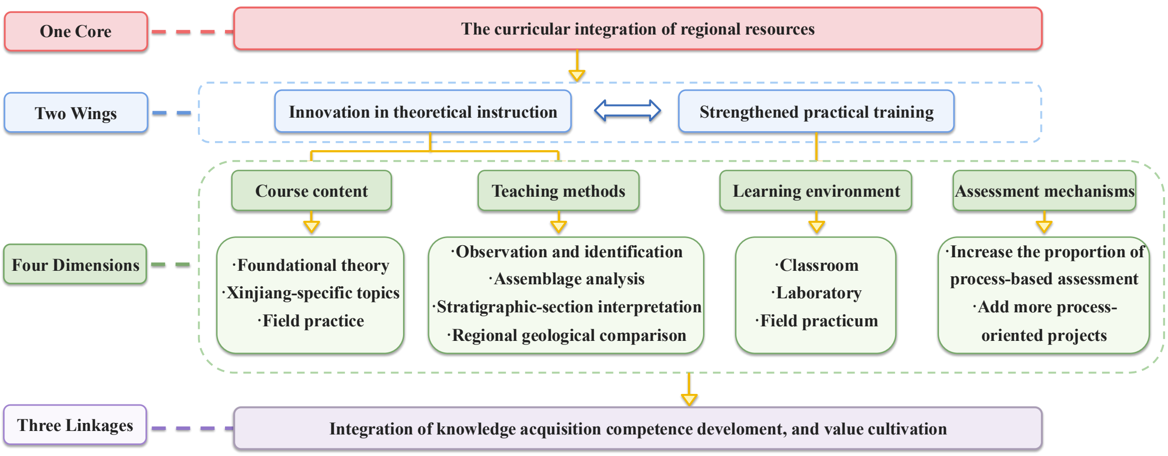


Figure 1 Curriculum reform framework

## 3. Reform objectives and overall framework

### 3.1 Redesigning the course objectives

The overarching goal of the course reform is to foster students' ability to use paleontological evidence to interpret regional geological problems, with learning outcomes organized into three mutually reinforcing dimensions, namely, knowledge, competence, and values. The knowledge dimension requires mastery of the morphology, classification, and temporal distribution of the major paleontological taxa along with the basic principles of biostratigraphy; the competence dimension requires the ability to observe and identify specimens, record stratigraphic information, analyze fossil assemblages, and interpret a variety of paleoenvironmental data; and the values dimension emphasizes scientific rigor, standardized recording, teamwork, fossil conservation, and a sense of responsibility toward the geological development of Xinjiang. Teamwork is an important aspect of fieldwork in the geological sciences. Fieldwork requires integration of a variety of skills, including communication, coordination, leadership, and peer collaboration (Nyarko and Petcovic, 2023). Therefore, teamwork should be incorporated into the course requirements for both competence development and value cultivation, and can be assessed by considering task allocation during fieldwork, process records, and team performance.

### 3.2 Developmental framework of the reformed curriculum

The proposed reform is organized around the "One Core, Two Wings, Four Dimensions, Three Linkages" framework. In this framework, the core is the curricular integration of regional resources, while the two wings are innovation in theoretical instruction and strengthened practical training. The core and the two wings are implemented across four dimensions, namely, course content, teaching methods, learning environment, and assessment mechanisms, while linking knowledge acquisition, competence development, and value cultivation (Figure 1). In terms of course content, the teaching units are reorganized around foundational theory, Xinjiang-focused topics, and field practice. Regional fossils, stratigraphic sections, and field outcrops are studied with explicit alignment to the course objectives. The teaching methods involve the implementation of a progressive sequence, comprising observation and identification of fossils, analysis of fossil assemblages, interpretation of stratigraphic sections, and comparison of geological regions. This sequence enables students to move from the recognition of individual fossils toward the interpretation of fossil assemblages, stratigraphic sections, and regional geological processes, resulting in the progressive development of their geological spatiotemporal thinking and integrative analytical ability. The design of learning tasks should accordingly move beyond the recall of isolated facts and definitions toward questions that require conceptual understanding, application, and analysis. Conceptual questions can be designed to assess students' understanding of the principal concepts underlying the course material and to engage them in comprehension, application, and analysis rather than simple factual recall. By focusing on key concepts and requiring students to explain relationships among geological phenomena, such tasks can help identify gaps in understanding while progressively developing higher-order thinking. Students direct their own learning in making these lesson plans, recognizing gaps in their own understanding and filling them in by referring back to readings and lecture notes or seeking out additional resources. The learning environment dimension introduces field practice for the first time, integrating theoretical learning, specimen observation, and field investigation across the classroom, laboratory, and field practice settings. In terms of assessment, the framework increases the proportion of formative assessment based on the incorporation of more formative projects. Evidence from student work, task records, objective-based achievement evaluations, and questionnaire feedback is used to identify areas of weakness and inform subsequent adjustments to teaching tasks.

This reform does not treat regional characteristics simply as the addition of local fossil knowledge. Instead, authentic regional geological problems are used as an organizing thread to coordinate course content, learning tasks,

Table 1 Alignment among course objectives, core tasks, learning outcomes, and assessment evidence

| Course objectives | Core tasks | Learning outcomes | Assessment evidence |
|---|---|---|---|
| Knowledge acquisition | Comparison of typical fossils; stratigraphic time positioning | Be able to describe and compare the major fossil taxa, explain their temporal distribution, and the principles of biostratigraphy. | Classroom performance, final exam basic questions |
| Competence development | Observe and identify fossil specimens; case studies; stratigraphic correlation; fieldwork | Be able to identify and document fossils, and integrate lithology, stratigraphic horizon, and fossil assemblages to conduct stratigraphic correlation and paleoenvironmental interpretation. | Observation records, identification sheets, data analysis questions, field logs, comprehensive reports |
| Value cultivation | Comply with conservation protocols; articulate evidence boundaries; collaborate to complete tasks | Be able to conduct sampling in accordance with established protocols, provide objective presentation of the evidence and limits of interpretation, and fulfill assigned responsibilities in team tasks. | Fieldwork process records, sampling records, team task-allocation records, and rubrics for task compliance and academic integrity. |

practical settings, and assessment evidence, thereby providing constructive alignment of learning objectives, instructtional activities, and assessment. The proposed mechanism integrates regional relevance, pedagogical feasibility, and the requirements of continuous improvement.

### 3.3 Designing the course implementation

A backward design approach was used in designing the course. First, the desired learning outcomes were defined in accordance with the training objectives of the program. The content and assessment criteria were then determined in line with these outcomes, with the identification of suitable Xinjiang-specific material for incorporation into the learning tasks and teaching activities. The design underwent continuous improvement based on feedback. Previous studies have demonstrated the importance of alignment among clearly defined learning objectives, teaching activities, and assessment in both the quality of the course design and accurate evaluation of student learning outcomes (Barthakur et al., 2022). Based on this foundation, the course was organized around the desired learning outcomes, with systematic alignment of the course objectives, learning tasks, and assessment evidence. Iterative refinement of the instructional content, task design, and course delivery was based on evaluation and feedback. Furthermore, the design emphasized higher-order learning in the interpretation of multiple lines of evidence, innovation in open-ended tasks, and challenging integrated learning outcomes across the different course units and learning settings.

Following the OBE emphasis on aligning objectives with continuous improvement (Jin et al., 2025), the design assigned every objective an observable task and a corresponding body of evidence. Specifically, knowledge objectives were supported by classroom performance and basic examination questions, while competence objectives were associated with specimen identification sheets, assemblage analyses, stratigraphic columns, field notes, and comprehensive reports, and values objectives required adherence to recording standards, division of labor, sampling compliance, and demonstrated research integrity. This evidence was scored against a standardized rubric mapped to the course objectives to ensure alignment of the course objectives, activities, and examinations (Table 1).

## 4 Teaching reform based on Xinjiang regional characteristics

### 4.1 Integration of regional resources into the course content

The course syllabus comprised three modules, namely, foundational theory, Xinjiang-focused topics, and field practice, of which the foundational theory module represented the core. Instructors presented information on the morphology, classification, and stratigraphic significance of the major taxa by representing geological time as the vertical axis and biological evolution and environmental change as the horizontal threads, thereby applying the framework through general teaching content while drawing on Xinjiang cases for comparison and guiding students to weigh assemblage characteristics against depositional context. The Xinjiang-focused module, in turn, was organized around representative fossil groups, key strata, and regional evolutionary history, with each topic centered on a single interpretable problem that required students to analyze stratigraphic columns, fossil photographs, and regional maps and construct a chain of evidence. Field practice was included in the introductory geological field practicum, with selection of two to three sites around Urumqi with consideration of safety, accessibility, conservation, and instructtional goals (Table 2). These sites were chosen for their relevance to teaching objectives, relatively complete evidence chains, accessible material, and clearly defined conservation requirements, leading to the translation of classroom concepts into observation tasks.

The course undergoes annual dynamic updating to incorporate recent paleontological findings from Xinjiang, such as newly discovered fossil assemblages, into the content. Students are part of a knowledge creation process

rather than consuming knowledge passively. Recent research on paleontology education has demonstrated the value of research-informed teaching by the direct involvement of undergraduate students in real-life research

Table 2 Potential sites and teaching content for paleontology fieldwork around Urumqi

| Locality | Main stratigraphic age | Representative fossils | Teaching highlights |
|---|---|---|---|
| Qijiagou (Nanshan Mining Area) | Late Carboniferous (Qijiagou Formation) | Brachiopods, corals, fusulinids, crinoids | A representative Late Carboniferous shallow-marine fossil assemblage from a terrigenous clastic–carbonate succession, with abundant and readily collectible fossils. |
| Yaomoshan (Yamalike Mountain) | Middle Permian (Lucaogou Formation) | Fishes, conchostracans, calamite plants | Lacustrine oil shale and marl preserving terrestrial and aquatic organisms. |
| Liudaowan | Middle Permian (Lucaogou Formation) | Plant fragments, fishes, amphibians, Urumqia liudaowanensis | Oil shale with fish scales; suitable for half-day short fieldwork close to the city; the type locality of Urumqia liudaowanensis. |
| Hongshan-Shuimogou | Permian-Triassic | Calamite plants, cordaite plants, bivalves | Stratigraphic sections within an urban park; ideal for "popular science on fossil plants in daily life" with non-destructive observation |
| Dongshan-Xishan (Jurassic coal measures) | Early-Middle Jurassic (Badaowan and Xishanyao Formations) | Fern plants, ginkgoalean plants, cycadalean plants, bivalves | Understanding coal-forming floral assemblages; suitable for demonstrating impression fossils and cuticle analytical techniques |

activities, such as data collection and analysis (Lautenschlager, 2024). Previous studies have suggested that traditional teaching of paleontology tends to be disconnected from recent research advances, and it is therefore important to strengthen the connection between paleontology teaching and cutting-edge research (Wang et al., 2020). As we continue lecture, textbook readings, discussion, and specimen work on each featured group, instructors add one primary literature reading relevant to the fossil group at hand. Instructors discuss classification, key genera, evolution, and geohistorical distribution, while also highlighting the connection of paleontology to mineral resource exploration and strategic resource security in China, thereby helping students see the practical relevance of what they are learning.

### 4.2 Training in geological spatiotemporal thinking

Geological spatiotemporal thinking involves the incorporation of temporal sequence, spatial position, lithological environment, and fossil evidence within a single interpretive framework. The course reform therefore adopted a progressive sequence of observation and identification, comparative analysis, and interpretation and presentation. By studying faunal and floral groups according to their chronological dominance in the Phanerozoic, students have an ingrained sense of general biostratigraphic succession at the end of the course. This sequence involved four steps, in which students first learn to observe and describe the morphology, preservation, and host rock of the fossil, followed by analysis of assemblages, in which they compare the co-occurrence of different fossils within a horizon and estimate the stratigraphic and environmental significance of specific features. In the next step, students learn to interpret sections and annotate fossil assemblages on stratigraphic columns to identify vertical variation, while in the fourth step, they learn regional correlation, using maps and correlated sections to analyze temporal and spatial relationships across localities.

The Xinjiang-focused module and field practice contribute jointly to the training of geological spatiotemporal thinking. Students first observe and identify representative fossils at different field teaching sites and relate the fossil information to specific stratigraphic horizons. This emphasis on case studies teaches students to compare fossil assemblages and lithological characteristics from different stratigraphic horizons and different localities, to conduct stratigraphic correlation using stratigraphic columns to analyze their temporal relationships and spatial differences, and to further discuss different depositional environments and their changes. Instead of supplying a single definitive conclusion, instructors ask students to record their observations, prior knowledge, and inferred conclusions in separate columns, thereby creating the habit of organizing material in terms of geological time and testing interpretations against spatial variation. In this way, "the present is the key to the past" becomes a process of evidentiary reasoning rather than a mere methodological slogan.

### 4.3 Strengthening integrated field practice

Previous studies have indicated the importance of field-based teaching in helping students connect classroom knowledge with actual geological phenomena through active learning, problem-solving, and collaborative activities in real-life settings, while enhancing learning engagement and practical skills (Jones and Washko, 2022). So, field trips are good instances to introduce topics, focus interest, and engage students. They also provide students with the basis for conducting research. Field practice was therefore included in the introductory field practicum, with one or two field teaching routes used for instruction. This involved the design of a complete training sequence covering stratigraphic measurement, fossil searching, specimen collection, and preliminary identification, to extend learning beyond the classroom and laboratory. The field practice consisted of three consecutive stages, namely, pre-field preparation, field practice, and post-field synthesis. We start the process

Table 3 Assessment schedule for paleontology course

| Assessment method | Primary basis | Assessment content | Weight |
|---|---|---|---|
| Formative assessment | Class performance | Responses to questions and participation in lectures | 10% |
| | Assignments | Completion of practice exercises on basic knowledge, identification, and comprehensive analysis | 5% |
| | Laboratory work | Reports on fossil identification | 10% |
| | Seminar participation | Responses and discussions on themed topics via the learning platform | 5% |
| | Field records and reports | Standardization and content quality of field notes and comprehensive reports | 10% |
| Summative assessment | Final Examination | Comprehensive assessment of knowledge, competencies, professional qualities, and ideological and political education objectives | 60% |

with class meetings where we read and discuss relevant background literature and practice framing testable hypotheses. We then set realistic goals for a two-day (weekend) field trip and design data collection protocols. During the pre-field stage, photographs, topographic maps, and stratigraphic profiles were used for safety instruction, guidelines on fossil protection, training in tool use, and task rehearsal. Fieldwork emphasized standardized observation and recording of evidence rather than the number of fossils collected. Accuracy and consistency in the data collection are further points that have to be considered carefully during study design. Students conduct measurements of stratigraphic attitudes, fossil searches, in situ descriptions, location recording, and preliminary identification, only allowing specimen collection when authorized. On their return from the field, students organize and identify specimens, prepare illustrations, verify data, and complete a comprehensive report. Students determine how to collect data to answer their research question, collect the data, analyze it, and present their findings. By bracketing the field trip with class time devoted to preparation and analysis, the module presents opportunities for students not only to learn more about topics in paleoecology, but also the methods and process of practicing the science. Where conditions permit, field activities should be linked to a defined interpretive question or follow-up research task, so that fossil searching, in situ observation, and standardized recording generate evidence for later assemblage analysis and paleoenvironmental interpretation rather than functioning solely as specimen-collection exercises. On this basis, field practice can be further extended from observation and identification to small-scale inquiry tasks, in which students formulate testable questions, determine appropriate procedures for data collection, and collect and record evidence during fieldwork. Subsequent data analysis, interpretation, and reporting enable students to experience a more complete process of scientific inquiry from question formulation and evidence collection to geological interpretation.

Further attention to sense of place through incorporation of cultural aspects of both situated and roadside trips may strengthen connections with landscape and result in more environmentally conscious, community-oriented geoscience graduates with stronger intrinsic motivation

### 4.4 Optimizing assessment of learning outcomes

Learning outcomes should not be assessed only on mastery of knowledge but should also consider multidimensional outcomes developed during the learning process, including cognitive, behavioral, and affective dimensions. A systematic review has shown that the assessment of learning outcomes in higher education using evidence from the cognitive, behavioral, and affective dimensions provides a more comprehensive representation of student learning (Wei et al., 2021). Accordingly, while retaining necessary summative assessment, the present course strengthened both formative assessment and performance-based assessment of student competence. Formative assessment can be used during instruction to obtain timely information about students' conceptual understanding and to identify learning difficulties before summative assessment. The weight of the formative assessment was increased from 30 to 40%, while that of the final examination was reduced from 70 to 60%. The formative assessment included evaluation of classroom performance, assignments, laboratory work, and field notes and reports (Table 3), and while the final examination retained essential foundational knowledge, its emphasis was shifted from memorization only to the incorporation of items involving fossil photographs, stratigraphic columns, and regional data that require identification, comparison, judgment, and argumentation.

The results of the evaluation constitute a closed-loop process of "objectives-tasks-evidence-feedback-improvement". Teachers not only record final grades but also use but also use various types of evidence to determine specific stages where students encounter difficulties. This output-oriented approach to problem tracing ensures anchorage of continuous improvement in concrete tasks rather than remaining at the level of course summaries. The reform of the evaluation system strengthens both the formative guidance and competence-based approaches, shifting the focus of teaching from knowledge transmission to the development of capability.

## 5. Results

### 5.1 Improvement in learning outcomes

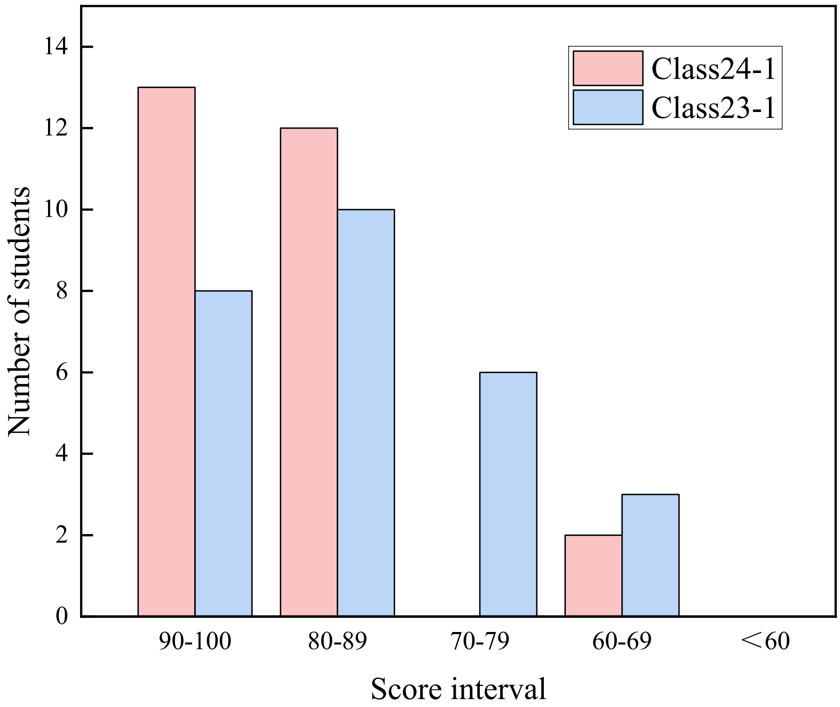


Figure 2 Comparison of student distribution across score intervals for the paleontology course of resource exploration engineering major during the 2023–2024 academic years

The reform of the course was data-driven from the outset. During the early stages, instructors analyzed course grades, assessment materials, and student feedback, which showed student weakness in transferring knowledge and analyzing complex problems. This feedback led to the incorporation of additional regional cases, strengthening of the project guidance, and improvements in formative feedback.

Learning outcomes were compared before and after reform of the course teaching. Two classes, Class 23-1 and Class 24-1, each included 27 students majoring in Resource Exploration Engineering. Both classes were taught by the same instructor and had comparable academic backgrounds and course prerequisites. Course assessments, both before and after the reform, included the same basic components, namely, the final examination, classroom performance, and laboratory work. While maintaining continuity in the overall assessment framework, the reform adjusted the weighting and content of the individual assessment components according to the course objectives, with a moderate reduction of emphasis on memorization and strengthening the assessment of fossil observation and identification, comprehensive analysis, and practical skills.

Student scores and objective achievement results from the previous two academic years were used for comparison. Both Class 23-1 and Class 24-1 included 27 students each. Before the reform, the average score of Class 23-1 was 81.52 points, while the average score of Class 24-1 after the reform was 87.56 points, an increase of 6.04 points. The score distribution also changed accordingly. The score distribution shifted toward the higher-score intervals, with more students in the high-score segment and fewer students in the low-score segment (Figure 2). The degree of objective achievement rose from 0.79 to 0.82. Course archives also showed an approximate 10% improvement in the accuracy rate of fossil identification. Classroom records further indicated increased student initiative in participating in case discussions and task presentations. These findings indicate that course scores, objective achievement, and fossil identification performance were higher in the post-reform cohort, suggesting that the teaching adjustments were associated with improved learning outcomes

### 5.2 Enrichment of learning outcomes

The course reform shifted assessment from reliance on examination scores alone. In addition to examination scripts, the course now collects case analyses, specimen observation records, fossil identification sheets, field notes, and comprehensive reports; these materials provide documentation of student learning and a basis for assessing the development of competence.

In the reformed curriculum, learning tasks are no longer confined to memorizing fossil names, but require explanation of the identification criteria and analysis of the fossil-bearing horizon, assemblage, and depositional environment, shifting the learning process from single-specimen description toward regional geological interpretation. This shift strengthens the link between fossil evidence and geological context, and enables training in geological spatiotemporal thinking. The paleontological identification event at the Geological Skills Competition offers a further, higher-order measure of this competence: participation rose from almost zero in previous years to 12 students in 2026, one of whom won first prize, with three winning second prizes and six winning third prizes. The competition requires

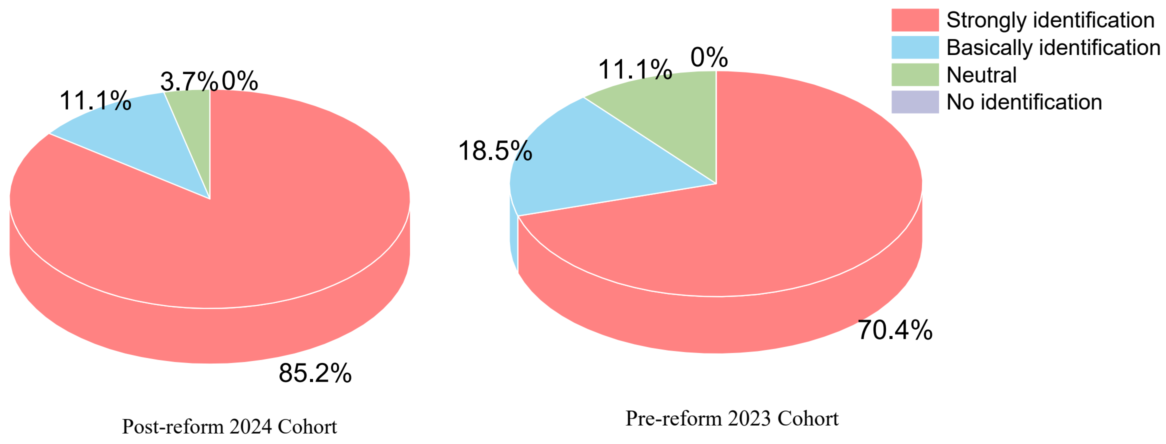


Figure 3 Comparison of students' professional identification before and after the course reform

completion of fossil observation, feature assessment, identifycation, and standardized reporting within a fixed time, and the results indicate improvements in both identification skills and overall analytical and practical capabilities, indicating the success of linking course activities with competence goals, such as practical inquiry and comprehensive analysis.

### 5.3 Strengthened course identification and professional awareness

The course incorporates both professional education and values cultivation into its teaching, using representative Xinjiang fossils and regional geological cases. The addition of fossil locality observation to the introductory geological field practicum enabled students to observe, record, identify, and analyze fossils within real-life strata, providing direct experience that strengthened the link between course content and actual regional geology.

The course collects student feedback continuously through surveys administered at the end of each offering, using the same or broadly comparable questionnaires to examine student professional identity, course satisfaction, and perceived teaching effectiveness. To compare changes before and after the reform, responses from the 2023 cohort were used as the pre-reform baseline and compared with those from the 2024 cohort after the reform. The questionnaire included three items on professional identification, seven items on course satisfaction and teaching effectiveness, and two open-ended questions. Figure 3 presents the responses to one representative item that directly reflects student professional identification. The results showed that the overall proportion of students reporting "strong identification" and "basic identification" increased from 88.9% before the reform to 96.3% after the reform. In particular, the proportion reporting "strong identification" rose from 70.4% to 85.2%, an increase of 14.8%, indicating improved professional identification (Figure 3). Analysis of the questionnaire responses and open-ended feedback also indicated a high level of recognition of Xinjiang-specific regional cases and field practice, together with a more concrete understanding of the links between paleontological knowledge and its practical application in Resource Exploration Engineering. Previous research on geoscience education has found that undergraduate students generally perceive fieldwork and training in practical skills as beneficial to both their conceptual understanding and interest in the discipline (Hoyer & Hastie, 2023). The survey results showed a similar trend, with the post-reform cohort reporting higher levels of professional identity and a more positive course learning experience.

## 6. Conclusion

The unique paleontological and stratigraphic resources of Xinjiang provide a real-life context for reform of the paleontology curriculum. The key to this reform involved the integration of these regional resources throughout course objectives, course content, learning tasks, field practice, and evidence used for assessment, thereby extending these resources from research-only applications into educational materials. The reformed Paleontology course at Xinjiang University uses these regional resources as the core of the curriculum, with theoretical instruction and strengthened practical training as its two wings, thereby advancing reform across four dimensions, namely, course content, teaching methods, learning environment, and assessment mechanisms, while linking knowledge acquisition, competence development, and value cultivation. The three modules of foundational theory, Xinjiang-focused topics, and field practice jointly support a task chain ranging from individual fossils to regional interpretation, with the field component embedded in the introductory geological field practicum, enabling students to observe, sample, record, identify, and analyze fossils at two to three fossil localities around Urumqi. Course grades, course-objective achievement, student feedback, student work, and competition performance together provide multiple sources of evidence for evaluating the outcomes of the reform, providing a curriculum with a distinct regional identity by recording learning outcomes through formative assessment. We want our students to gain knowledge and skills that reflect a solid understanding of paleontological concepts. Future analysis of its stability and verifiability requires standardization of resources, calibration of assessment, and accumulation of longitudinal evidence. This would provide earth science courses with a firmer practical foundation for the incorporation of regional resources in educating students.

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**Conflicts of interest**

The authors declare no competing interest.



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