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Exploring Pathways for Integrating Hydrogeology and Engineering Geology Professional Competencies into Geography Courses: A Case Study of Geomorphology Teaching Reform

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Abstract: With the increasing demand for interdisciplinary geography talents in fields such as integrated natural resource management and ecological environment governance, the limitations of traditional geography curricula, which are largely confined to single-disciplinary knowledge transmission, are becoming increasingly evident. Hydrogeology and engineering geology, as core disciplines that investigate the interaction between Earth surface material cycles, geological environmental evolution, and human engineering activities, exhibit strong relevance and complementarity with the professional knowledge system of geography. Taking the reform of practical teaching in the core geography course “Geomorphology” as a case study, this paper systematically analyzes the necessity and feasibility of integrating hydrogeological and engineering geological professional competencies into geography education. It identifies key problems in current practical teaching, including pronounced disciplinary barriers, fragmented and poorly articulated content, and rigid, teacher-centered practice models that constrain students’ capacity for comprehensive application. From four dimensions—reconstructing teaching objectives, optimizing and restructuring course content, innovating field- and project-based practice models, and improving diversified evaluation systems—this study proposes an integration pathway aimed at breaking traditional disciplinary boundaries. The proposed framework is intended to enhance students’ interdisciplinary problem-solving abilities, strengthen the linkage between theory and practice, and provide both theoretical reference and operational paradigms for the cultivation of high-level, application-oriented interdisciplinary geography talents.

Keywords: hydrogeology; engineering geology; geomorphology teaching reform; interdisciplinary geography education; practical teaching; curriculum integration

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1. Introduction

Geographical science encompasses mountains, rivers, settlements, and climate, studying their spatial arrangement on the Earth's surface, their mutual influences, and their slow or sudden changes [1]. This approach, simultaneously grasping both natural and human factors, highlights its comprehensiveness and practicality as defining characteristics. As global environmental changes accelerate and the impacts of human activities on the Earth's surface become increasingly pronounced, geography is steadily advancing toward integration with a broader range of disciplines, exploring intersections across various fields. Tasks such as inventorying natural resources, assessing ecological damage, and designing restoration plans for degraded environments require professionals capable of explaining foundational geographical theories while effectively employing tools such as remote sensing, data modeling, and social survey methodologies. These multidisciplinary approaches enable seamless integration of diverse techniques within a single project, fostering innovative solutions to complex challenges.

Geomorphology has long been regarded as a foundational course in geographical science, serving as a critical link between pure physical geography and applied disciplines. Historically, practical courses in geomorphology have primarily emphasized the classification of visible landforms observed in the field, often neglecting deeper inquiries into hydrogeological contexts, geotechnical engineering properties, or the dynamic interactions among various elements. Consequently, students frequently lack the ability to synthesize multidisciplinary knowledge when confronted with intricate geographical scenarios. The core competencies of hydrogeology and engineering geology, which include understanding groundwater flow, analyzing soil and rock mass characteristics, and mitigating geological hazards, significantly overlap with the research focus and educational objectives of geomorphology. Integrating these competencies into the practical aspects of geomorphology would substantially enrich classroom content, enhance students' comprehension of landform evolution, and expand their disciplinary perspectives [2]. This alignment would meet the evolving expectations for geography professionals in the modern era. By using geomorphology practical courses as a focal point, this article explores the seamless incorporation of hydrogeology and engineering geology into geography education, offering valuable insights for curriculum reform and the enhancement of talent development.

2. Necessity and Feasibility of Integrating Professional Competencies

2.1 Necessity of Integration

Adapting to the interdisciplinary trend: The rapid evolution of modern technology is driving the convergence of previously distinct knowledge domains, leading to a blurring of boundaries between geographical science and related fields such as geology and engineering. Hydrogeology and engineering geology, as dynamic branches of geology, share numerous tools and methodologies with geographical science, including observation techniques, sampling strategies, and data analysis processes. Maintaining traditional departmental divisions in this context risks perpetuating fragmented knowledge, making it challenging to construct a comprehensive understanding of complex systems [3]. Proactively dismantling these barriers and fostering collaboration between disciplines has become essential for geographical science majors to develop a more holistic perspective and align their expertise with practical, real-world applications. This integration not only enhances academic depth but also ensures that graduates are better equipped to address multifaceted challenges in their professional endeavors.

Addressing the shortage of interdisciplinary talent: As ecological civilization progresses alongside the rapid pace of urbanization, the expectations placed on geography graduates have expanded significantly. These professionals are now required to possess diverse skills that transcend the confines of a single discipline, particularly in areas such as natural resource management and large-scale engineering projects. Traditional educational programs often fragment the content of hydrogeology and engineering geology into separate chapters, resulting in a disjointed learning experience. Additionally, the limited inclusion of experimental and field-based components hinders students from forming a cohesive understanding of these subjects, leaving them underprepared and less confident in the competitive job market [4]. By reorganizing these competencies and embedding them into the curriculum, educators can create a more integrated learning environment. Incorporating case studies, hands-on training, and theoretical instruction in tandem allows students to build a robust knowledge framework, directly addressing employer demands and enhancing their readiness for interdisciplinary roles.

Taking the "Geomorphology" classroom a step further: Hydrogeological conditions and engineering geological characteristics serve as underlying forces that shape the formation and transformation of landforms. Groundwater dissolution, for instance, subtly sculpts limestone into peaks and depressions, playing a pivotal role in the development of karst landscapes. Simultaneously, factors such as rock density, fissures, and shear

strength act as critical determinants of geological events, such as landslides. Traditional "Geomorphology" instruction has often emphasized the external features of terrain while providing only a cursory exploration of the internal mechanisms driven by rock and water interactions. By integrating the specialized tools and methodologies of hydrogeology and engineering geology into the classroom, students gain the opportunity to delve deeper into the intricate processes that govern landform dynamics. This approach enables them to metaphorically "disassemble the machine box" of geomorphological systems, fostering a more profound appreciation of the interconnected elements that shape the Earth's surface and elevating the significance of the course in their academic journey [5].

2.2 Feasibility of integration

The knowledge systems of geomorphology and hydrogeology, including engineering geology, are deeply interconnected [3]. Both disciplines utilize the Earth's surface system as a central framework for research, concentrating on critical aspects such as surface morphology, the fundamental characteristics of soil and rock masses, and the dynamics of hydrological processes. Additionally, both fields prioritize the implementation of essential research methodologies, including detailed field investigations and the systematic collection and analysis of samples. This shared focus underscores their complementary nature and highlights the potential for interdisciplinary collaboration and integration.

Practical teaching in geomorphology and hydrogeology, along with engineering geology, exhibits significant overlap in its approach and execution. These disciplines are characterized by their strong emphasis on practical, field-oriented, and comprehensive activities. They share numerous similarities in fieldwork methodologies, including the use of specialized instruments and equipment. This alignment in practical techniques not only enhances the learning experience but also fosters a unified approach to addressing complex geological and environmental challenges [6].

Teaching resources in these fields are extensively shared, reflecting a high degree of integration within academic institutions [7]. Many universities with geography and geology programs utilize common field internship bases, ensuring efficient use of resources. The equipment in physical geography laboratories is often complementary to that found in hydrogeology and engineering geology laboratories, facilitating interdisciplinary learning. Furthermore, faculty members with interdisciplinary expertise provide robust support in terms of teaching, research, and the operation of shared facilities and equipment. This collaborative framework ensures a strong foundation for the integrated teaching of professional skills across these disciplines.

3. Problems existing in current practical teaching

3.1 Disciplinary barriers are obvious, and knowledge integration is insufficient

Geography and geology are distinct academic disciplines, each with relatively independent curriculum frameworks. The practical teaching content of "Geomorphology" primarily focuses on the knowledge system of geographical science, often neglecting critical aspects of hydrogeology and engineering geology. This results in a limited and compartmentalized knowledge structure for students [8]. For instance, during field observations of landslide landforms, students are typically able to describe surface morphological characteristics but lack the ability to conduct in-depth analyses of essential influencing factors, such as variations in groundwater levels or the mechanical properties of soil and rock. This limitation significantly hinders the comprehensive depth and interdisciplinary integration of practical teaching.

3.2 The teaching content is outdated and disconnected from actual needs

Many universities continue to rely on outdated syllabi in their "Geomorphology" practical courses. Although efforts are made to incorporate fieldwork into the curriculum, much of the focus remains on identifying traditional landforms such as river valleys, sand dunes, and glacial relics. However, these approaches often neglect modern and pressing

geomorphological challenges, such as the steep walls of open-pit mines, hilltops reshaped by urban development, or the significant alterations in contour lines caused by construction debris. To comprehensively analyze these evolving landscapes, it is essential to integrate knowledge from geomechanics, ecological restoration, land management, and socioeconomics. Presently, the curriculum equips students with basic tools like compasses and hammers, which are insufficient for addressing the complex and interdisciplinary demands of their future professional roles [9].

3.3 The practical training model is too simplistic and students lack initiative

Traditional practical teaching often relies on a unidirectional instructional approach characterized by "teacher explanation - student observation - on-site recording." This method primarily focuses on observation, sampling, and data processing, with minimal emphasis on designing comprehensive and engaging practical tasks. Consequently, students are placed in a passive role, with limited opportunities to independently formulate investigative plans or critically analyze problems [1]. This approach significantly hinders the development of innovative thinking and practical skills, which are essential for addressing complex, real-world challenges in a dynamic academic and professional environment.

3.4 The evaluation system is incomplete and the assessment method is too simplistic

Practical teaching evaluations often prioritize results, focusing predominantly on internship reports and field performance. This approach neglects a thorough assessment of the practical learning process, integrated skill development, and the cultivation of innovative thinking. The evaluation content tends to emphasize the mastery of foundational knowledge, while providing insufficient attention to the application of interdisciplinary concepts and the development of creative problem-solving abilities. Furthermore, the methods of evaluation are predominantly teacher-driven, with limited incorporation of diverse approaches such as student self-assessment and peer evaluation. This lack of variety hinders the ability to objectively and comprehensively reflect the overall quality and capabilities of students.

4. Path design for integrating professional skills into practical teaching

4.1 Reconstruct teaching objectives and clarify the orientation towards ability development.

Moving beyond the traditional approach of focusing solely on the transmission of isolated knowledge, a comprehensive three-in-one teaching objective system has been developed. This system integrates knowledge, ability, and quality to create a more holistic educational framework. By emphasizing the interconnectedness of these elements, the approach aims to foster a deeper understanding and application of concepts, ensuring that students are better prepared for practical challenges [10].

Knowledge objectives are centered on building a robust understanding of landform types and their evolutionary processes. To enhance this foundation, additional content has been incorporated, such as the classification and dynamics of groundwater, the engineering characteristics of soil and rock masses, and the hydrogeological and engineering geological conditions that contribute to geological disasters. This expanded curriculum constructs a cohesive knowledge system that integrates landform studies, hydrology, and engineering geology, providing students with a comprehensive perspective on these interrelated fields.

Ability objectives emphasize the development of interdisciplinary skills and practical competencies. These include the capacity to apply knowledge from multiple disciplines to analyze landform evolution mechanisms, proficiency in conducting field-based hydrogeological and engineering geological surveys, and the ability to independently design and execute comprehensive survey plans. Additionally, students are trained to utilize modern technologies, such as geographic information systems, to process and analyze data effectively, fostering innovative thinking and problem-solving capabilities [11].

Quality objectives focus on nurturing scientific thinking, fostering a rigorous and methodical approach to problem-solving, and instilling a strong sense of teamwork and social responsibility. Students are encouraged to develop a heightened awareness of environmental protection and the importance of preventing geological disasters. This holistic approach aims to cultivate not only technical expertise but also a sense of ethical responsibility and commitment to societal well-being.

4.2 Optimize course content and build an interdisciplinary knowledge system

The curriculum integrates fundamental theoretical modules to provide students with a comprehensive understanding of interconnected disciplines. When discussing classic landform types in class, essential hydrogeological and engineering geological concepts are seamlessly incorporated to enhance the learning experience. For instance, during the introduction of karst landforms, the dynamics of karst water movement within fissures and the progressive mechanisms leading to karst collapse are thoroughly explained. Similarly, when transitioning to river landforms, critical evaluation points such as the interplay between groundwater and surface water, as well as the vulnerability of river valley slopes to landslides, are emphasized. To strengthen students' interdisciplinary foundation, two additional lectures, titled "Fundamentals of Hydrogeology" and "Introduction to Engineering Geology," are strategically included in the curriculum [12]. These lectures aim to provide a deeper understanding of the theoretical principles that underpin the practical applications discussed in class, ensuring that students are well-equipped to analyze and address complex geological phenomena.

The curriculum also incorporates field practice modules to bridge theoretical knowledge with real-world applications. Initially, regional geological and geomorphological surveys are conducted, followed by the selection of the most representative practice bases. These activities are designed to transform seemingly isolated observations, sampling, and recording tasks into a cohesive and continuous task chain. For example, along a mountainous route, students are assigned to integrate "mountain topography, groundwater systems, and soil and rock stability" into a unified project. This involves sketching slope morphology, measuring spring outlets, and collecting weathered debris for laboratory analysis. By synthesizing these datasets, students deduce the gradual development of landslides or collapses. In the river section, the focus shifts to "river topography, hydrological processes, and valley engineering geological conditions." Students walk along the riverbank, documenting terrace heights, flood traces, and structural defects in bridge pier foundations on a single map. They then evaluate engineering decisions related to dam construction, water intake, and bank protection, analyzing the intrinsic connections between geomorphological evolution, water resource management, and engineering development [13]. This hands-on approach not only reinforces theoretical knowledge but also cultivates critical thinking and problem-solving skills.

The comprehensive application module extends the curriculum's scope to include practical challenges such as mine restoration and urban site selection. In the context of mine restoration, students begin by measuring acid seepage from waste rock piles and proceed to create drone-generated topographic maps. They then incorporate variables such as plant seed ratios, retaining wall heights, and drainage ditch slopes into a detailed report aimed at regenerating greenery in exposed mining pits. For urban site selection, students explore older city areas, documenting ground subsidence, tunnel cracks, and groundwater level trends over a decade. They integrate these findings with data on new subway lines, high-rise foundations, and sponge city blocks to construct models that predict potential subsidence in specific road sections. This process involves deconstructing topography, hydrology, geotechnical engineering, and urban planning knowledge into manageable components, which are then reassembled into targeted, actionable solutions. Through this experience, students gain a profound understanding that a "solution" is not merely a concluding statement in a thesis but a dynamic process of

transforming numerical data, visual representations, and field observations into practical and implementable construction plans.

4.3 Innovative practice models enhance students' active role

Project-Driven Practice: The teaching process is structured around a comprehensive practical project, ensuring each phase is interconnected, from topic selection and project initiation to scheme design, field implementation, data analysis, and the presentation of results. Students work collaboratively in groups to independently select research topics, develop detailed investigation plans, conduct field research, analyze collected data, and produce thorough practice reports. These reports are then presented and shared publicly, fostering a sense of ownership and accountability. Teachers adopt a guiding role, stepping back to allow students to take the lead, thereby promoting active engagement and critical thinking throughout the process.

Case Study-Based Practice: The teaching team designs detailed case studies based on representative engineering projects, emphasizing practical applications and interdisciplinary integration. At the start of the class, the team introduces the case studies using accessible language to illustrate how diverse fields of knowledge converge effectively [11]. During field surveys, students examine soil, rock, and water body characteristics, comparing real-world observations with pre-class materials to identify discrepancies and deepen their understanding. Upon returning to school, small group discussions are organized to refine proposed solutions, encouraging collaborative problem-solving and the natural development of interdisciplinary analytical skills.

Combining virtual and real-world practice: A virtual simulation platform was developed, encompassing modules focused on landforms, hydrogeology, and engineering geology. Dynamic visuals compress the evolution of typical landforms over millennia into a brief, comprehensible timeframe [7]. Additionally, the operational steps of field survey instruments, such as inclinometers, electrical resistivity meters, and drilling rigs, are broken down into interactive components that can be practiced repeatedly. Students engage in a "digital field" preview within their dormitories, using simulation tools to familiarize themselves with procedures and equipment. Once proficient, they transition to real-world environments, such as valleys and riverbanks, to replicate the virtual processes under actual conditions. This seamless integration of virtual and physical practice enhances the depth and breadth of practical teaching, enabling students to connect theoretical knowledge with tangible experiences.

4.4 Improve the evaluation system and strengthen the orientation of competency assessment

The evaluation content has evolved to encompass a broader range of dimensions, including knowledge, ability, and character, which are assessed concurrently. The knowledge dimension evaluates whether students can effectively comprehend and adaptively apply content across multiple disciplines. The ability dimension emphasizes practical engagement, interdisciplinary applications, and the generation of innovative ideas [2, 10]. Meanwhile, the character dimension highlights the importance of fostering a scientific mindset, collaborative teamwork, and a sense of social responsibility. This multifaceted approach ensures a holistic assessment of student competencies.

The evaluation method has shifted away from reliance on a single final examination, with process-based assessments now accounting for 60% of the overall evaluation and summative assessments comprising the remaining 40%. This balanced approach integrates both quantitative and qualitative measures, with input from teachers, students, and peers contributing to a comprehensive evaluation framework. Process-based assessments prioritize students' practical performance in real-world scenarios, the robustness of their initial planning, and the accuracy and organization of their original documentation. Summative assessments, on the other hand, focus on the analytical depth of the final report and the effectiveness of its presentation. By combining numerical scores with textual evaluations, the system ensures that assessments are thorough and reflective of students' genuine capabilities, avoiding superficial judgments and fostering a deeper understanding of their academic and practical achievements.

To ensure that evaluation outcomes are effectively utilized, schools have established a closed-loop mechanism to promptly communicate students' strengths and areas for improvement observed in the classroom. This feedback is accompanied by tailored improvement plans, which are directly integrated into subsequent teaching strategies and curriculum adjustments. Evaluation data is seamlessly incorporated into academic planning, ensuring that it serves as a dynamic reference for refining courses and practical components. Furthermore, report cards and awardee lists are now interconnected, with evaluation scores being converted into academic performance metrics and criteria for honors selection. This integration embeds supervision and guidance into the evaluation system, ensuring that its influence extends beyond documentation and actively drives continuous improvement in educational practices [5, 13].

5. A guarantee mechanism for integrating professional capabilities

5.1 Strengthen the construction of the teaching staff

Geography educators are encouraged to actively engage in specialized training programs focused on hydrogeology and engineering geology, as well as participate in academic exchanges to broaden their expertise [13]. Additionally, incorporating geology educators as part-time instructors fosters interdisciplinary collaboration. By forming cohesive teaching teams, educators can collectively explore innovative strategies and methodologies to effectively integrate diverse disciplines, thereby enhancing the overall quality and depth of interdisciplinary teaching practices.

5.2 Integrate and optimize teaching resources

Integrating field internship base resources is essential to establish a comprehensive and multifaceted internship framework encompassing areas such as geomorphology, hydrogeology, and engineering geology. Efforts should focus on increasing investments in laboratory facilities, ensuring the timely updating and supplementation of essential equipment like groundwater level measuring instruments and advanced GIS software. Additionally, the development of interdisciplinary practical teaching materials and case studies is crucial. This includes systematically collecting, organizing, and curating relevant teaching resources to enhance the quality and effectiveness of practical teaching, thereby fostering a more robust and application-oriented learning environment.

5.3 Improve the teaching management system

The syllabus and implementation plan for the practical teaching of "Geomorphology" underwent a comprehensive review, incorporating essential skills related to hydrogeology and engineering geology into the curriculum framework. The teaching objectives were articulated with precision, and assessment criteria were designed to ensure clarity and transparency. To maintain high teaching standards, strategies such as unannounced classroom observations and on-site evaluations of fieldwork activities were employed consistently throughout the semester. Observations and identified issues were systematically documented, creating a robust and traceable mechanism for monitoring teaching quality. Additionally, the institution introduced a dedicated teaching reform award to recognize and incentivize educators who excelled in implementing innovative course designs [6]. An annual ceremony was organized to celebrate these achievements, fostering a culture of excellence and ensuring that reforms were effectively translated from theoretical plans into practical classroom applications, thereby garnering both recognition and institutional support.

6. Conclusion

The professional skills in hydrogeology and engineering geology are deeply interconnected and serve as a vital complement to the broader knowledge framework of geography. Their integration into the practical teaching of geomorphology is not only a necessary adaptation to the evolving demands of the discipline but also a strategic approach to addressing the growing need for versatile and skilled professionals. Presently,

the practical teaching of geomorphology faces significant challenges, including rigid disciplinary boundaries, outdated instructional content, limited teaching models, and insufficient evaluation mechanisms. By redefining the teaching objectives to encompass a holistic "knowledge-ability-competency" framework, enhancing interdisciplinary course design, and fostering innovative and diverse practical teaching methods, these challenges can be effectively mitigated. Furthermore, the establishment of a robust support system encompassing educators, resources, and management can ensure sustainable improvements. Such reforms hold the potential to elevate the quality of education, nurture students' interdisciplinary problem-solving and innovation skills, and set a transformative precedent for the modernization of geography education and the cultivation of future-ready talent.

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References

1. E. Gondar, "College of Natural and Computational Sciences Department of Geology," 2017.
2. X. M. Chen, "Integrating GIS education with training: A project-oriented approach," *Journal of Geography*, vol. 97, no. 6, pp. 261-268, 1998.
3. H. I. Chaminé, "Water resources meet sustainability: new trends in environmental hydrogeology and groundwater engineering," *Environmental Earth Sciences*, vol. 73, no. 6, pp. 2513-2520, 2015.
4. V. Ruiz-Ortiz, S. García-López, M. Vélez-Nicolás, Á. Sánchez-Bellón, A. C. de Villar, and F. Contreras, "Learning from hydrological and hydrogeological problems in civil engineering. Study of reservoirs in Andalusia, Spain," *Engineering Geology*, vol. 282, p. 105916, 2021.
5. Y. Yao, M. Zhang, Y. Deng, Y. Dong, X. Wu, and X. Kuang, "Evaluation of environmental engineering geology issues caused by rising groundwater levels in Xi'an, China," *Engineering Geology*, vol. 294, p. 106350, 2021.
6. V. I. Ferronsky, *Nuclear geophysics: applications in hydrology, hydrogeology, engineering geology, agriculture and environmental science*. Springer, 2015.
7. Z. Sen, *Applied hydrogeology for scientists and engineers*. CRC Press, 2017.
8. A. Dassargues, *Hydrogeology: groundwater science and engineering*. CRC Press, 2018.
9. W. E. Kelly and S. Mareš, Eds., *Applied geophysics in hydrogeological and engineering practice*, vol. 44. Elsevier, 1993.
10. H. Bouwer, "Artificial recharge of groundwater: hydrogeology and engineering," *Hydrogeology Journal*, vol. 10, no. 1, pp. 121-142, 2002.
11. P. M. Santi and J. D. Higgins, "Preparing geologists for careers in engineering geology and hydrogeology," *Journal of Geoscience Education*, vol. 53, no. 5, pp. 513-521, 2005.
12. P. G. Fookes, M. H. De Freitas, and M. G. Culshaw, "Discussion of 'The first engineering geological publication in the UK?' by MG Culshaw *Quarterly Journal of Engineering Geology and Hydrogeology* 37, 227-231," *Quarterly Journal of Engineering Geology and Hydrogeology*, vol. 38, no. 1, pp. 105-108, 2005.
13. C. W. Fetter and D. Kreamer, *Applied hydrogeology*. Waveland Press, 2021.

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