Strategies and Case Studies of "Implicit Integration" of Ideological and Political Education in the Matrix Theory Course

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Abstract: Curriculum-based ideological and political education represents an important approach for higher education to fulfill its fundamental mission of fostering virtue through education. As a core public foundational course for graduate students in science and engineering fields, Matrix Theory features highly abstract concepts, rigorous logical systems, and extensive applications. Nevertheless, existing practices often encounter the challenge of disconnecting ideological and value-oriented education from professional knowledge instruction. Focusing on Matrix Theory education for graduate students in geological disciplines, this study proposes an "implicit integration" strategy for curriculum-based ideological and political education. the proposed strategy advocates embedding value-oriented objectives naturally into the course's knowledge structure, disciplinary history, and application scenarios, thereby achieving the organic integration of value guidance and intellectual development. Practical implementation shows that anchoring implicit integration in authentic geological problems can effectively bridge the gap between mathematical foundation courses and professional applications, producing an educational effect of "nurturing students through subtle and continuous influence."

Keywords: Matrix Theory; Curriculum-based Ideological and Political Education; Implicit Integration Strategy; Geological Sciences; Graduate Education

1. Introduction

The Guidelines for the Construction of Curriculum-based Ideological and Political Education in Higher Education Institutions issued by the Ministry of Education of China[1] clearly emphasize that science-related courses should strengthen the cultivation of scientific thinking approaches and scientific ethics, while enhancing students' sense of responsibility and mission in exploring the [1] unknown, pursuing truth, and advancing scientific frontiers. As a fundamental public course in graduate education for science and engineering disciplines, Matrix Theory serves as a common mathematical foundation for students in geology, petroleum engineering, geophysics, and resource exploration. the course covers essential topics including linear spaces, linear transformations, matrix decompositions, eigenvalue theory, and generalized inverse matrices, featuring both a high degree of abstraction and extensive practical applications [2] .

A natural and profound relationship exists between Matrix Theory and geological sciences. With the development of modern geoscience, research approaches have gradually shifted from qualitative descriptions to quantitative analyses. Key geological investigations, including stress–strain analysis of tectonic structures, seismic wave propagation and imaging, and geophysical inversion and interpretation, fundamentally rely on matrices and linear algebraic methods. As highlighted in Structural Geology Algorithms[3] , structural geology increasingly requires linear algebra techniques to systematically analyze vector and tensor problems, providing a solid theoretical basis for incorporating authentic geological problems into Matrix Theory instruction. Nevertheless, current Matrix Theory education largely remains centered on theoretical derivations, with practical applications serving only as supplementary illustrations. Such a teaching paradigm neither adequately addresses the disciplinary needs of graduate students in geology-related fields nor fully explores the rich value-oriented educational resources arising from the integration of matrix theory and geoscience practice.

Previous studies have demonstrated that geoscience-related disciplines possess unique advantages for integrating ideological and political education into professional teaching. the “Three Honors” spirit of geological workers—taking pride in devotion to geological exploration, perseverance in challenging working conditions, and contributing to national resource discovery—the scientific commitment exemplified by Li Siguang in challenging the assertion of “China as an oil-poor country, ” and the philosophical perspectives and scientific spirit cultivated through field geological practices all provide valuable resources for curriculum-based ideological and political education [4] . Nevertheless, existing implementations have primarily concentrated on specialized disciplinary courses and field-based practical training[5-8] . In contrast, the integration of ideological and political education into graduate-level public mathematics courses remains relatively insufficient, lacking a systematic theoretical framework and a replicable pedagogical model[9] .

This study focuses on Matrix Theory education for graduate students in geological disciplines and proposes an implicit integration strategy for curriculum-based ideological and political education. A systematic mechanism for deeply embedding value-oriented educational elements is constructed through three dimensions: knowledge logic, disciplinary history, and frontier applications. Taking “matrix eigenvalue decomposition and geological stress tensor analysis” as a representative teaching case, this study presents a complete instructional design framework and aims to provide a transferable pedagogical model for integrating ideological and political education into graduate-level mathematics courses in geoscience-related fields.

2. Construction of the Target System for Ideological and Political Education in the Matrix Theory Course

Curriculum-based ideological and political education should not be treated as an “external addition” beyond the objectives of a course, but should be integrated into the curriculum objective system as an essential component. Based on the training goals and professional needs of geological graduate students, this study establishes the teaching objectives of ideological and political education in the Matrix Theory course from three dimensions.

2.1 Knowledge Objective Dimension

Students are expected to systematically acquire the core theories and algorithms of linear spaces and linear transformations, eigenvalues and eigenvectors, various matrix decompositions (including LU decomposition, QR decomposition, singular value decomposition, and eigenvalue decomposition), and generalized inverse matrices[3] . Meanwhile, they should understand the geological counterparts of these mathematical tools, such as stress tensors, strain tensors, and seismic wave propagation matrices. This dimension provides the fundamental knowledge foundation for integrating ideological and political education into the course.

2.2 Ability Objective Dimension

This dimension aims to develop students’ abilities in mathematical abstraction, logical reasoning, and mathematical modeling by transforming geological problems into matrix-based models. In particular, students are expected to recognize matrix structures embedded in geological data (e. g., Toeplitz matrices in seismic records and ill-conditioned matrices in geophysical inversion), and to select appropriate matrix methods for analysis and solution. This dimension represents the “competence-oriented outcome” of curriculum-based ideological and political education.

2.3 Value Objective Dimension

This dimension is developed from three specific perspectives. First, the cultivation of scientific spirit and dialectical thinking. Through the philosophical interpretations of stress–strain tensor transformations in matrix theory, which reflect the law of unity of opposites, and the philosophical meaning of matrix decompositions in revealing the relationship between “phenomena and essence, ” students are guided to develop a scientific worldview and methodology. Second, the enhancement of cultural confidence and scientific ethos. By adopting a “dual-line narrative” approach that combines Li Siguang’s contribution to geomechanics, particularly the concept of stress field matrix analysis, with major achievements in Chinese geoscience such as the continental oil-generation theory, students’ national pride and commitment to scientific rigor are fostered. Third, the cultivation of patriotic responsibility and a sense of mission. Through case studies related to national strategic needs, including earthquake monitoring, energy exploration, and geological disaster prevention and control, students are encouraged to recognize how matrix theory contributes to addressing major national challenges.

3. Three Core Paths of Implicit Integration

The fundamental principle of "implicit integration" is that ideological and political education objectives are inherently contained in the knowledge structure, disciplinary history, and application contexts of the course. Through careful instructional design, teachers aim to "activate" these values rather than simply "embed" them externally, allowing students to internalize value orientations naturally in the process of acquiring and applying knowledge. In the context of geological disciplines, the implicit integration strategy exhibits distinctive disciplinary compatibility.

3.1 Integration through Knowledge Logic: Dialectical Philosophy and Geological Thinking in Matrix Theory

The knowledge framework of Matrix Theory exhibits a profound intrinsic congruence with dialectical materialist philosophy, which is particularly manifested in the context of geological disciplines.

The Dialectical Unity of Opposites Reflected in Stress–Strain Tensors. In geomechanics, stress and strain tensors serve as essential mathematical tools for characterizing the mechanical state and deformation behavior of rocks. the eigenvalues (principal stresses) and eigenvectors (principal stress directions) of stress tensors reveal the key characteristics of the internal stress state of rock masses. During the teaching of eigenvalue decomposition, instructors can naturally demonstrate that compression in one direction within a rock mass is often accompanied by tension in the perpendicular direction. This provides a vivid example of the dialectical principle that "opposite aspects coexist within a unified whole" in geological processes. Through learning eigenvalue decomposition, students not only acquire mathematical knowledge but also develop dialectical thinking skills.

The Relationship between "Phenomena and Essence" Revealed by Matrix Decomposition. the central objective of geophysical inversion is to recover the distribution of subsurface physical parameters from surface observations, such as seismic travel-time data and gravity anomalies. This process typically requires solving ill-posed linear systems or applying matrix decomposition techniques. the essential idea of matrix decomposition, particularly singular value decomposition (SVD), is to transform a seemingly complex observation matrix into the product of several simpler factor matrices with clear structural meanings. This mathematical process provides an analogy for the philosophical idea of "penetrating phenomena to uncover essence. " Teachers can further guide students to recognize that a fundamental mission of geoscience is to extract the underlying structures of the Earth's interior from complicated surface observations, reflecting a universal methodology of scientific inquiry.

The Manifestation of the Law of Quantitative Change Leading to Qualitative Change in Geological Processes. the evolution of fault activity, characterized by the gradual accumulation of stress followed by its sudden release during an earthquake, represents a typical natural example of quantitative change resulting in qualitative transformation. Mathematical tools used to describe such processes, such as matrix powers for modeling the cumulative effects of stress evolution, provide an epistemological bridge connecting mathematical methods with geological principles.

3.2 Integration through Disciplinary History: Li Siguang's Spirit and the "Dual-Line Narrative"

The convergence of the disciplinary histories of Matrix Theory and geological sciences provides distinctive narrative resources for integrating ideological and political education into the curriculum. Based on this perspective, this study proposes a "dual-line narrative" strategy.

The First Narrative Line: Li Siguang and Matrix-Based Thinking in Geomechanics. the methodological foundation of Li Siguang's development of geomechanics was the integration of geological structural observations with mechanical analysis, using systematic stress-field analysis to reveal the laws governing crustal movements. Although modern matrix notation had not yet been widely adopted, the mathematical essence of core geomechanical concepts, including "structural systems" and "stress fields, " is closely associated with matrix and tensor analysis. When introducing concepts such as eigenvalue decomposition and tensor transformations, instructors can incorporate Li Siguang's scientific achievements, including his challenge to the foreign claim of “China’s oil-poor status” and his application of geomechanical theories in guiding major discoveries such as the Daqing Oilfield. Such a narrative helps strengthen students’ professional confidence, scientific spirit, and commitment to contributing to national development.

The Second Narrative Line: From the Continental Oil-Generation Theory to Contemporary Energy Strategies. the breakthroughs achieved by Chinese geologists in developing the continental oil-generation theory, which overturned the assertion of “China’s oil-poor status, ” represent a landmark achievement in scientific self-reliance and innovation. the educational significance of this narrative is to help students recognize the long-term evolutionary relationship among “fundamental research, technological breakthroughs, and national strategic development. ” When introducing the application of generalized inverse matrices in geophysical inversion, instructors can integrate such historical cases into the teaching process. By comparing the achievements of earlier Chinese geologists, who relied primarily on theoretical insight in the absence of advanced computational tools, with modern approaches that employ matrix computation to efficiently address geological challenges, students can appreciate both the historical depth of scientific development and their contemporary responsibility to contribute to national needs.

3.3 Integration through Cutting-Edge Applications: Cultivating a Sense of Mission through Cases Driven by National Strategic Needs

As a fundamental mathematical tool for contemporary quantitative geoscience research, Matrix Theory provides abundant real-world application contexts, and its frontier applications naturally serve as effective carriers for integrating ideological and political education into the curriculum.

Case 1: Seismic Tomography and Generalized Inverse Matrices. Seismic tomography is a key technique for reconstructing the velocity structure of the Earth’s interior from surface seismic observations. Its mathematical foundation lies in solving large-scale ill-posed linear inverse problems, where generalized inverse matrices provide essential computational tools. Since seismic monitoring plays a critical role in geological hazard early warning and public safety, this application case can be incorporated into the teaching of generalized inverse matrices. By discussing the connection between numerical accuracy and the protection of human lives, instructors can guide students to develop a rigorous scientific attitude and a strong sense of professional responsibility.

Case 2: Shale Gas Reservoir Evaluation and Tensor Decomposition. the exploration of unconventional energy resources, such as shale gas, represents a significant component of national energy strategies. In reservoir characterization and evaluation, the analysis of permeability tensors and pore structures essentially involves the decomposition and feature extraction of high-dimensional data tensors. This case can be incorporated into the teaching of tensor-related matrix methods to help students recognize that mathematical tools not only support scientific research but also play a direct role in safeguarding national energy security.

Case 3: Geological Hazard Monitoring and Low-Rank Matrix Recovery. Remote sensing technologies, such as InSAR (Interferometric Synthetic Aperture Radar), provide important approaches for monitoring geological hazards, including landslides and ground subsidence. the observational data matrices obtained from these technologies usually contain significant noise and redundant information. Low-rank matrix recovery methods can effectively extract underlying deformation signals from noisy measurements and reconstruct reliable surface deformation patterns, thereby directly contributing to geological disaster prevention and mitigation. By introducing this case, instructors can guide students to recognize that mathematical theories and methods can serve the protection of human lives and property, fostering a sense of social responsibility and professional commitment.

4. Teaching Example: Eigenvalue Decomposition of Matrices and Analysis of Geological Stress Tensors

This section adopts “matrix eigenvalue decomposition, ” a core topic in Matrix Theory, as a teaching example and integrates it with the geological application scenario of stress tensors. A four-stage instructional design framework, including “scenario-based introduction, problem-driven learning, knowledge exploration, and value enhancement, ” is presented to demonstrate the implicit integration of ideological and political education into professional knowledge instruction.

4.1 Contextual Introduction (Approximately 5 Minutes)

At the beginning of the class, the instructor presents an experimental image showing rock fracture under confining pressure, together with a seismic waveform record. Students are encouraged to consider the questions: “Why does rock fracture in a particular direction? How can the processes of compression and extension within the Earth’s crust be quantitatively characterized?” These questions naturally introduce a powerful mathematical tool—eigenvalue decomposition. Through this scenario-based introduction, students’ attention is shifted from abstract mathematical concepts to practical geological problems.

4.2 Problem-Driven Learning (Approximately 8 Minutes)

Two gradually deepening questions are introduced to guide students’ thinking. First, given a three-dimensional stress tensor (a 3×3 symmetric matrix), how can the principal directions of the stress state be identified? Second, why do rocks preferentially fracture along certain “weak planes, ” and how is this phenomenon related to eigenvalues and eigenvectors? These questions directly reveal the core idea of eigenvalue decomposition: identifying the “invariant directions” of a matrix transformation. the problem-driven stage aims to stimulate students’ curiosity and motivate them to explore mathematical concepts through the perspective of geological problems.

4.3 Knowledge Exploration (Approximately 30 Minutes)

A systematic explanation is provided of the definitions, computational approaches, and geometric interpretations of eigenvalues and eigenvectors, as well as the special properties of symmetric matrix diagonalization. Throughout the teaching process, two implicit ideological and political education threads are incorporated:

Knowledge Logic Integration: When explaining how eigenvalue decomposition transforms a general stress state into purely compressive or purely tensile states along principal directions, instructors can highlight the scientific methodology of “reducing complexity and identifying the dominant factors. ” the identification of principal stress directions by geologists and the determination of structural weak planes by engineers are essentially manifestations of the same mathematical principle in different disciplines. This approach helps students develop interdisciplinary perspectives and recognize the universality of mathematical thinking.

Disciplinary History Integration: During the teaching process, instructors briefly introduce how Li Siguang employed mechanical analysis methods to determine the orientation of tectonic stress fields in eastern China and applied these insights to guide petroleum exploration. By presenting visual representations of “tectonic systems” in geomechanics, instructors can help students intuitively perceive the relationship between mathematical abstraction and geological phenomena. This historical narrative not only enriches students’ understanding of the disciplinary development of geomechanics but also demonstrates the practical significance of mathematical methods in solving geological problems.

4.4 Value Enhancement (Approximately 7 Minutes)

Taking seismic tomography as an extended application case, instructors demonstrate how eigenvalue decomposition can be employed to extract information about the Earth’s deep structures from seismic observations. Students are subsequently guided to reflect on two deeper questions. First, why is earthquake prediction inherently challenging? From a mathematical perspective, geophysical inversion problems are often ill-posed due to the instability of the underlying systems, and this fundamental uncertainty determines the limitations of prediction. This raises an important question: how should the boundaries of scientific knowledge shape our understanding and interaction with nature? Second, China continues to face critical technological challenges in fields such as seismic monitoring and energy exploration. A solid foundation in fundamental mathematical tools is essential for addressing these challenges. As graduate students in geological sciences, students are encouraged to consider a fundamental question: why should they learn Matrix Theory, and whom should their knowledge ultimately serve? the purpose of this discussion is not to seek a predetermined “standard answer, ” but to inspire critical thinking and a deeper sense of responsibility.

5. Implementation Points and Effect Evaluation

5.1 Key Points of Implementation

Precise Selection of Geological Application Contexts. the effectiveness of implicit integration largely depends on the appropriate matching between teaching cases and corresponding mathematical concepts. For example, stress tensors can be associated with eigenvalue decomposition, seismic inversion with generalized inverse matrices, and remote sensing data analysis with low-rank approximation techniques. To achieve effective integration, instructors should establish a three-dimensional mapping framework of “Matrix Theory concepts–geological application scenarios–ideological and political education elements, ” ensuring that ideological and value-oriented elements are incorporated naturally and purposefully into professional knowledge instruction.

Appropriate Balance in Disciplinary Historical Narratives. Curriculum-based ideological and political education should never overshadow the core objectives of professional knowledge instruction. Historical resources, such as Li Siguang’s scientific spirit and the development of the continental oil-generation theory, should be introduced in a concise and purposeful manner. At critical teaching points, brief historical narratives can effectively stimulate students’ value reflections, while avoiding lengthy historical discussions that may distract from the main content of Matrix Theory.

Interdisciplinary Collaboration. the development of ideological and political education within Matrix Theory courses for geological disciplines requires deep cooperation between mathematics educators and geological science specialists. Mathematics educators contribute the theoretical framework and knowledge logic of Matrix Theory, whereas geological experts provide authentic application cases and frontier information from the discipline. Through interdisciplinary collaboration, the two sides can jointly design teaching cases and instructional frameworks that effectively integrate mathematical knowledge with geological applications.

5.2 Framework for Evaluating Teaching Effectiveness

The effectiveness of implicit integration of ideological and political education should not be assessed merely through questionnaire surveys and satisfaction ratings. Instead, a diversified evaluation framework is recommended, including the following approaches:

Critical Thinking Performance in Classroom Discussions: Students’ classroom discussions are evaluated by examining whether they can analyze geological problems from the perspective of Matrix Theory and whether their expressed viewpoints reflect scientific thinking, critical awareness, and problem-oriented inquiry.

Value-Oriented Expression in Case Analysis Reports: In final case analysis reports, students’ ability to consciously connect Matrix Theory methods with emerging needs in geological applications is evaluated, particularly whether they can recognize the practical value and broader significance of mathematical tools in addressing frontier geological challenges.

Changes in Professional Identity and Recognition: By comparing students’ perceptions before and after the course, instructors evaluate the extent to which students develop a deeper understanding of the relevance and value of Matrix Theory to their own professional fields.

6. Conclusion

The fundamental challenge of curriculum-based ideological and political education is to integrate value-oriented guidance into professional knowledge systems in a deeply embedded manner. This paper focuses on Matrix Theory education for graduate students in geological disciplines and proposes an “implicit integration” strategy for implementing curriculum-based ideological and political education. the particular suitability of this strategy in the geoscience context arises from the intrinsic epistemological connection between Matrix Theory and geological sciences. Both disciplines share a common scientific methodology: understanding essential mechanisms from complex phenomena and extracting critical structures from complicated systems. Moreover, they jointly contribute to major national strategic objectives, including energy security, geological disaster prevention, and sustainable development. From the eigenvalue decomposition of stress tensors to generalized inverse matrices in seismic inversion, from Li Siguang's contributions to geomechanics to contemporary shale gas reservoir evaluation, the intersection between matrix theory and geological practice provides rich resources for value-oriented education. the transformation of these resources from external disciplinary references into internal components of curriculum content represents the fundamental significance of implicit integration. It also offers a practical approach for graduate-level public mathematics courses to respond to the essential educational mission of "cultivating talents for whom and for what purpose."

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