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The Thinking and Exploration of the Ideological and Political Teaching of Linear Algebra

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Abstract: Curriculum ideology and politics is the key to carry out the mission of educating people in colleges and universities in the new era. On the problem of integrating the linear algebra course into the ideological and political education, it was expounded from four aspects: the necessity of integrating the course ideology and politics into the teaching of linear algebra, exploring curriculum ideological and political elements, the case design of integrating the course ideology and politics teaching, and the expected effect of integrating linear algebra courses into ideological and political education in the curriculum, in order to have the reference and help function to the educator.

Keywords: Linear algebra; Curriculum ideological and political education; Ideological and political elements; Design of teaching cases

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1. Introduction

Cultivating new-era individuals capable of shouldering the responsibility of national rejuvenation is the core mission of higher education. In 2004, the "Opinions on Further Strengthening and Improving Ideological and Political Education for College Students" issued by the Central Committee of the Communist Party of China and the State Council emphasized the importance of strengthening and improving ideological and political education for college students from the strategic height of ensuring the succession of people for the cause of socialism with Chinese characteristics, thereby promoting the reform and exploration of ideological and political education in schools [1]. Shanghai took the lead in practice and proposed the concept of transforming from "ideological and political courses" to "ideological and political education in all courses" in comprehensive education reform in 2014 [2-4]. To fully implement this requirement, the Ministry of Education issued the "Guidelines for the Construction of Ideological and Political Education in College Courses" in May 2020, systematically proposing to focus on the "main force" of the teaching staff, the "main battlefield" of course construction, and the "main channel" main channel' of classroom teaching to build a comprehensive and all-round education pattern [5]. As an educational concept of the new era, course based ideological and political

education fundamentally responds to the major theoretical and practical issues of "for whom to cultivate people, what kind of people to cultivate, and how to cultivate people", and is a key measure to improve the quality of talent cultivation in colleges and universities [6].

Linear algebra is an important component of classical higher mathematics (including mathematical analysis, algebra, and geometry) and is a discipline that studies the linear relationships between variables. Its core content includes determinants, matrices and their operations, systems of linear equations, linear dependence of vector groups, similar matrices, and quadratic forms [7]. It is an important compulsory basic theoretical course for non-mathematics science and engineering, economics, and management majors in higher education institutions, with high abstraction and logic, and it has wide applications in natural science, engineering technology, economics, and management [8]. The learning of this course aims to enable students to master basic theories and knowledge and significantly enhance their abstract thinking, logical reasoning, and mathematical modeling abilities to solve practical problems.

Deeply integrating ideological and political education into the teaching of linear algebra carries the dual mission of fulfilling the fundamental task of cultivating virtue, fostering talent, and responding to the challenges of the times, which is profoundly necessary and urgent. On the one hand, "cultivating virtue and fostering talent" is the fundamental task of education, and "cultivating people for the Party and talents for the country" is the noble mission of colleges and universities [9]. As a core basic course in science and engineering, teaching linear algebra must serve the goal of cultivating qualified socialist builders and successors. This course contains rich ideological and political elements (such as the "craftsman spirit" and "patriotism" reflected in "matrix multiplication", and the "cultural confidence" and "national pride" contained in "solving systems of linear equations"), providing a natural carrier for value guidance. It is urgent to break through the limitations of traditional teaching that focuses on imparting knowledge and skills while neglecting value shaping and quality cultivation, and organically integrating elements such as patriotism, scientific spirit, and cultural confidence in knowledge imparting and ability cultivation, guiding students to integrate their personal ideals into the overall development of the country and grow into idealistic, responsible, and capable new era individuals. On the other hand, the prosperity of the country depends on the youth, the strength of the country depends on the youth [10], and their value shaping is directly related to the future of the country [11]. In the current complex and diverse Internet information environment, information of varying quality and even conflicting with mainstream values poses a serious challenge to young college students who are in the "critical period of growth" [12]. It is urgent to help them establish correct worldviews, outlooks on life, and values. The teaching of linear algebra is the key approach for addressing this challenge. By integrating teaching content (such as "orthogonal transformation of quadratic forms" or "diagonalization of real symmetric matrices", "inertia theorem" [13]), and timely introduction of exemplary stories of scientists, such as Chen Jingrun's selfless dedication and patriotism, and mathematicians, such as Gauss's innovative spirit and rigorous academic attitude, it can effectively cultivate students' scientific spirit, research will, innovative consciousness, pragmatic attitude, and the quality of not fearing difficulties [14]. While imparting abstract mathematical knowledge, it can also strengthen their ideological foundation and guide them to form a positive and healthy attitude towards life and value pursuit.

2. Exploration of ideological and political elements in linear algebra courses

The key entry points and focus on integrating ideological and political education into the teaching of linear algebra courses involve embedding ideological and political elements within the course's top-level design,

teaching content, and teaching cases [15]. Concerning the educational function of the linear algebra course, instructors can conduct an in-depth exploration of the ideological and political elements within the course, such as a sense of responsibility, mission, socialist core values, and cultural confidence. This exploration can be carried out from multiple aspects: the academic major to which the linear algebra course pertains or for which it provides support, exemplary deeds of scientists or role models associated with the course, materialist dialectics embodied in the course content, and outstanding traditional Chinese culture. These elements should be subtly integrated into the course teaching process, thereby internalizing them as the spiritual pursuits of young college students and externalizing them as conscious behaviors.

2.1. Explore the elements of ideological and political education in the linear algebra course from the disciplines it serves

As a fundamental course for various disciplines such as science, engineering, agriculture, medicine, economics, and management, the ideological and political construction of linear algebra should be closely integrated with the core requirements of the majors it serves. By delving into the profound connections between the course theory and professional practices, students can be guided to recognize the value of the discipline, thereby establishing a sense of mission in learning while acquiring knowledge. Taking computer related and chemistry related majors as examples, the integration of ideological and political education in the course follows distinct paths.

In the case of computer - related majors, it is possible to achieve the dual objectives of ability cultivation and spiritual cultivation by relying on the characteristics of programming design. During the teaching of solving systems of linear equations

$$\begin{cases} a_{11}x_1 + a_{12}x_2 + \cdots + a_{1n}x_n = b_1 \\ a_{21}x_1 + a_{22}x_2 + \cdots + a_{2n}x_n = b_2 \\ \qquad\qquad \vdots \\ a_{n1}x_1 + a_{n2}x_2 + \cdots + a_{nn}x_n = b_n \end{cases}$$

by analyzing the principle of transforming the augmented matrix into its row-reduced echelon form through row operations (including determining the existence of solutions using the matrix rank, identifying free variables, and constructing general solutions), students can be led to translate mathematical principles into algorithmic practices. For example, after explaining the solution of non-homogeneous systems of equations, an extracurricular assignment like “Implement the solution of homogeneous systems of equations using C++ programming” can be assigned. This encourages students to convert abstract mathematical logic into executable code. This process not only enhances students’ engineering practice capabilities but also fosters the spirit of craftsmanship through the precision and rigor required in algorithm design. Moreover, it deepens students’ sense of innovation through independent exploration.

For chemistry-related majors, the emphasis is on revealing the discipline-supportive value of mathematical tools. Using the balancing of chemical equations as an entry point, educators can guide students in establishing a homogeneous linear equation system model based on the principle of atomic conservation. For example, consider a particular chemical reaction. By applying the law of element conservation, the equation system can be formulated as below.

$$\begin{cases} x_1 - x_3 = 0 \\ x_1 + 2x_2 - 2x_4 = 0 \\ x_1 + 4x_2 - 4x_3 - x_4 = 0 \\ x_2 - x_3 = 0 \end{cases}$$

By solving the fundamental solution of this equation system, we can obtain the balancing coefficients ($x_1 = 2, x_2 = 1, x_3 = 1, x_4 = 2$). This enables precise balancing of the chemical equation

$$2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O.$$

This process not only underscores the fundamental role of mathematical modeling in scientific research, but also fosters students' interdisciplinary thinking and a scientific attitude of truth-seeking through the rigorous construction of the equations and the verification of the uniqueness of the solutions.

The practices of these two types of majors illustrate that integrating ideological and political education into courses should be firmly grounded in the unique characteristics of each major. In the computer science domain, the focus should be on integrating algorithm implementations with engineering ethics. In the chemistry domain, it is essential to emphasize the connection between model construction and the scientific spirit. Ultimately, through value reconstruction of knowledge application scenarios, a synergistic elevation of both ability cultivation and value orientation can be achieved.

2.2. Exploring the ideological and political elements in the course from the typical deeds of scientists or model figures involved in linear algebra

The linear algebra course can be deeply integrated with the deeds of scientists to fulfill the objectives of ideological and political education. In 1950, Hua Luogeng relinquished his teaching position in the United States and returned to China to advance matrix theory. His patriotic sentiments can be utilized during the teaching of eigenvalues to inspire students to align their personal development with national imperatives. Cayley's two-decade-long unwavering exploration in founding matrix theory, when incorporated into the teaching of matrix operations, can cultivate students' confidence in theories and an innovative spirit.

Chen Shengshen's establishment of the Nankai Institute of Mathematics conveys an open and inclusive academic ideology through the theory of vector spaces. Grassmann's experience of adhering to the truth for three decades, despite his overlooked concept of linear independence, can be expounded upon in the analysis of vector-group correlations to illustrate academic tenacity.

The contemporary practices of Chinese scientists have even greater educational appeal. Guan Zhaozhi's application of matrix theory to the control systems of the "Two Bombs, One Satellite" project can be highlighted during the teaching of solving systems of linear equations to exemplify the spirit of dedicating oneself to the nation through science and technology. Zhang Yitang's journey of using matrix construction to overcome difficult problems in number theory can be employed in the teaching of matrix rank to impart the academic quality of focus and perseverance.

These cases form a comprehensive ideological and political resource system that integrates the Chinese and international elements. From Hua Luogeng's academic adage "Genius is built on accumulation" to Cayley's perseverance in the face of doubts about "useless abstractions", they collectively reveal the core value of basic

research.

A systematic approach is essential to the implementation of teaching. For example, the case of Hua Luogeng's return to China can be introduced at the teaching node of eigenvalues, Cayley's exploration journey can be analyzed during the section on matrix operations, and Guan Zhaozhi's practical spirit can be demonstrated through the application of linear systems. Through special columns such as "Enlightenment from Scientific Spirit", seminars on the development history of matrices, and case studies of scientific ethics, abstract mathematical concepts can be transformed into carriers of value dissemination. Ultimately, organic integration of knowledge dissemination and value guidance can be achieved. This enables the cultivation of patriotism within the context of vector spaces and the nurturing of an innovative character from matrix transformations, thereby attaining the fundamental goals of moral cultivation and student development.

2.3. Extracting ideological and political elements related to dialectical materialism from the teaching content of the linear algebra course

The knowledge system of linear algebra is rich in dialectical, materialist thought. Its core concepts and theories profoundly reflect philosophical laws, such as the unity of opposites and the law of quantitative change, leading to qualitative change. In matrix operations, the associative and distributive laws of addition and multiplication demonstrate the universal unity of operational rules, while the non-commutativity of multiplication (e.g., $AB \neq BA$) reveals the particularity of contradictions, illustrating the law of the unity of opposites–mathematical objects maintain a dynamic balance in the movement of contradictions.

Similar transformations ($P^{-1}AP = B$) further embody the dialectical relationship of "change and constancy": the form of the matrix can change, but essential attributes such as eigenvalues and rank remain unchanged, echoing the unity of external form and internal law in the development of things. The law of quantitative change leading to qualitative change is prominently manifested in the evolution of the matrix rank: elementary row operations of addition maintain the rank (accumulation of quantitative change), but when row vectors are linearly dependent, a sudden drop in rank (e.g., $\begin{bmatrix}1 & 2\\ 2 & 4\end{bmatrix} \xrightarrow{\text{Row transformation}} \begin{bmatrix}1 & 2\\ 0 & 0\end{bmatrix}$ from rank 2 to 1) marks a qualitative change. The critical effect of eigenvalues also supports this law: the positive definiteness of a real symmetric matrix undergoes a fundamental transformation when eigenvalues cross zero, thereby revealing the dialectical rule of property transformation at critical points.

The profound value of ideological and political education in the curriculum lies in guiding students to grasp dialectical laws through their mathematical forms. The least squares method, which shifts from the theoretical insolubility of the contradictory equation system AX = b to the construction of the practical optimal solution $\min\|AX = b\|_2$, embodies the materialist view of practice "theoretical contradiction → practical unity". The axiomatic system of linear algebra (the eight axioms of vector spaces) demonstrates the mathematical manifestation of dialectical materialism, abstracting from specific linear equations to universal spatial structures, and guiding new practices such as quantum mechanics and data science, completing the dialectical cycle of "practice → theory → practice". In teaching, philosophical speculation can be triggered through cases of contradictions in matrix operations (e.g., designing counterexamples where the sum of invertible matrices is not invertible), and the historical evolution of Gaussian elimination from "The Nine Chapters on the Mathematical Art" to numerical computation can be combined to showcase the process of negation of negation in cognition. Ultimately, students can master mathematical tools while developing dialectical thinking and scientific worldviews.

2.4. Extracting ideological and political elements of China's outstanding traditional culture from the perspective of mathematical culture

The teaching of linear algebra can be deeply integrated into traditional Chinese mathematical wisdom to strengthen national confidence through cultural inheritance. The "method of equations" in the ancient Chinese mathematical classic "The Nine Chapters on the Mathematical Art" already contains the core ideas of modern linear algebra: its "direct subtraction method" solves systems of linear equations by interchanging rows and columns, which is essentially the prototype of elementary row operations on matrices. Taking the problem in Chapter 8 "Equations" as an example: "There are 3 bundles of upper grain, 2 bundles of middle grain, 1 bundle of lower grain, yielding 39 dou...", the five-variable equation system is gradually solved through "multiplying through" and "direct subtraction", which shares the same origin as the Gaussian elimination method but predates it by over a thousand years. The advanced nature of algorithmic thinking highlights the mathematical creativity of the Chinese nation. By recreating the elimination process from "The Nine Chapters" in teaching (as illustrated in **Figure 1**), students can intuitively appreciate the systematic thinking and practical wisdom of Chinese mathematics, dispelling the misconception that ancient China had only fragmented mathematical achievements.

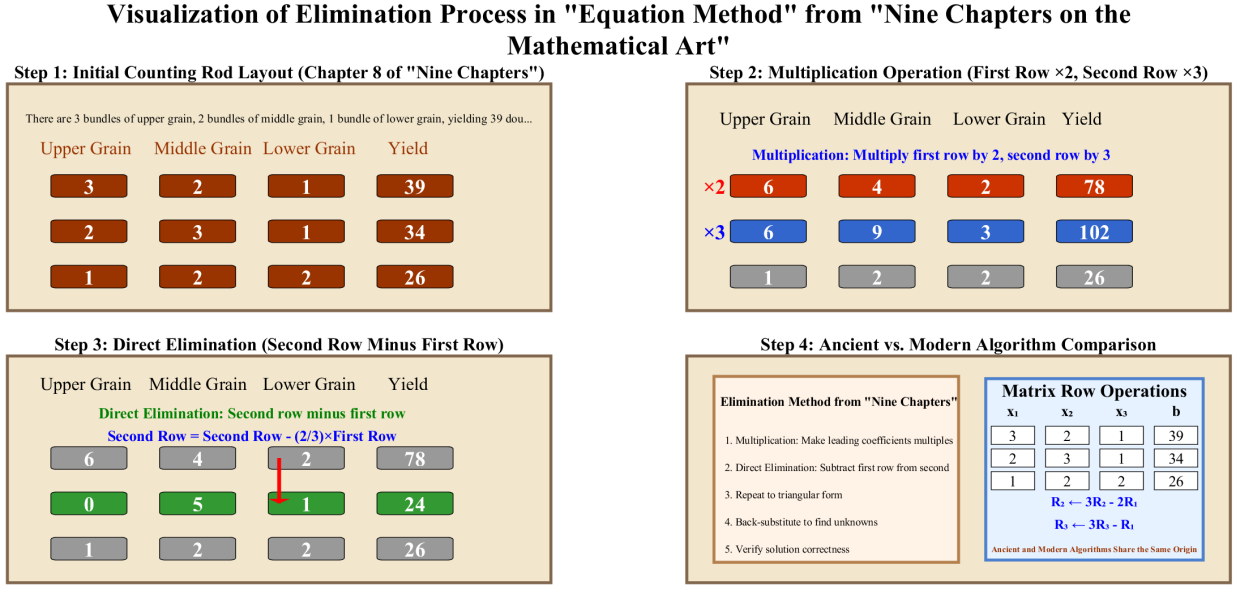

Figure 1. Core Algorithm Concept: The "Multiplication and Direct Elimination" method of the Han Dynasty is mathematically equivalent to modern row operations.

The achievements of mathematicians in the Song and Yuan dynasties represent the peak of abstraction and proceduralization. Qin Jiushao's "Mathematical Treatise in Nine Sections" pioneered the algorithm for solving systems of congruences with the "Great Invention Method", whose three steps of "finding the constant", "finding the multiplier", and "finding the total" essentially construct the inverse matrix modulo to solve linear congruence systems, leading the way for Euler by 554 years. Li Ye's "Sea Mirror of Circle Measurements" used the "Heavenly Element Method" (setting unknowns to establish equations) to derive geometric relationships, laying the foundation for the symbolic thinking of linear algebra. Zhu Shijie's "Jade Mirror of the Four Unknowns" extended the Heavenly Element Method to systems of high-order equations with four unknowns, and its "elimination method" of successive elimination is in line with the logic of reducing dimensions in modern linear spaces. These cases reveal that mathematicians in the Song and Yuan periods had already

constructed a systematic algebraic theoretical framework, which was not lost due to a lack of wisdom, but rather due to cultural environmental constraints. In teaching, programming practices such as solving systems of congruences using the "Great Invention Method" (such as solving the "Unknown Quantity" problem in "Sunzi's Mathematical Manual") can be designed to enable students to experience the inheritance of algorithms and cultural resilience.

The deeper value of traditional mathematical culture lies in the inspiration it provides for thinking paradigms and a humanistic spirit. The binary thinking of "Taiji generating the two trigrams" in "The Book of Changes" can be associated with the eigenvalue decomposition of matrices (a symmetric matrix can be expressed as $A= Q\Lambda Q^T$, where is a diagonal matrix composed of eigenvalues), revealing the dialectical view of simplicity and complexity. The deductive proof of the Pythagorean theorem in "The Arithmetical Classic of the Gnomon and the Circular Paths of Heaven" reflects a logical rigor comparable to Euclidean geometry. Zu Chongzhi's calculation of π, "the true value lies between the excess and deficiency limits", embodies the scientific spirit of error control. These ideas can be integrated into the teaching of linear algebra: interpreting the "balance of yin and yang" in orthogonal transformations as a symmetrical aesthetic, and comparing Liu Hui's "circle-cutting method" in the teaching of vector norms. Through dialogue between the past and the present, students can understand the unique gene of the integration of mathematics and science in Chinese culture, cultivate broad-mindedness for mutual learning among civilizations, and be inspired to take on the mission of promoting Chinese-style scientific and technological innovation through original research.

3. Teaching case design of ideological and political education in linear algebra

Taking the two sections of "Properties of Determinants" and "Concept of Matrix" in "Linear Algebra" as examples, this paper introduces the teaching design of ideological and political education from four aspects, namely the student analysis, teaching objectives, key and difficult points, and teaching process. It aims to play the role of teachers in nurturing students and implementing the tasks of fostering virtue and cultivating talent in teaching practice.

3.1. Properties of determinants case integration method

The teaching design of this lesson can be divided into the following six steps.

3.1.1. Introduces a case that introduces this topic

Calculating a determinant of order n completely, according to the definition, requires $n!\sum_{i=1}^{n-1}\frac{1}{i!}$ multiplication operations, respectively. Therefore, calculating a 30th-order determinant requires approximately 4.6×10^{32} multiplication operations. The peak computing speed of China's Sunway TaihuLight supercomputer is 1.25×10^{17} times/second. Even at the peak speed, it would take approximately 100 million years to calculate a 30th-order determinant using Sunway TaihuLight in practical applications. In 2016, the International Supercomputing Conference (ISC) in Frankfurt, Germany, announced that Sunway TaihuLight ranked first. In 2020, the Top500 list of global supercomputers was released, and Sunway TaihuLight ranked fourth. This can enhance students' national pride and inspire them that, for China to be strong and for the Chinese people to live well, there must be strong science and technology, thereby motivating students to study scientific knowledge diligently and contribute to the development of the country.

3.1.2. Raise the question

In the era of big data, calculating determinants according to the definition is impractical. How should they be calculated? This stimulates students' curiosity and motivation for further exploration.

3.1.3. Explain and prove the six properties of determinants

Through the explanation of the properties and proof process of determinants, students can master the recursive method of mathematical proof, train their logical reasoning ability, and combine the abstract with concrete to improve their abstract thinking ability.

3.1.4. Transforming determinants into upper triangular form for efficient calculation

Use the above six properties to provide a method for simplifying the calculation of determinants; that is, to transform the determinant into an upper triangular determinant.

3.1.5. Reinforcing determinant calculation through guided examples and practice

Explain typical examples and require students to perform the exercises themselves to improve their calculation ability and help young college students establish the principle of doing things according to rules and requirements.

3.1.6. Reinforcement practice and performance-based learning to enhance determinant mastery

Send reinforcement practice homework through the APP and ask some students to perform on the blackboard to cultivate their comprehensive thinking ability. Students at different levels can improve, and everyone can gain something.

(1) Concept of Matrix–Case Integration Method. The teaching design of this lesson can be divided into the following six steps: (1) Introduce the topic through the lemma of "interesting logic problems" to enable students to feel the truth that mathematics originates from life and serves life.

(2) Based on the understanding of the knowledge in the introductory example, provide the concept of a matrix: a rectangular number table with m rows and n columns formed by $m \times n$ numbers $a_{ij}(i=1,2,...,m,j=1,2,...,n)$.

(3) Example analysis: $A=\begin{pmatrix} 1 & 9 & 4 & 9 & 1 & 0 & 0 & 1 \\ 2 & 0 & 0 & 2 & 0 & 8 & 2 & 0 \\ 2 & 0 & 2 & 1 & 0 & 7 & 0 & 1 \end{pmatrix}$. Analyze the elements of matrix A and the practical significance of the elements together with the students. For example: The first row: October 1, 1994–The founding of New China; The second row: August 20, 2002–This is the first International Congress of Mathematicians in the 21st century and also the first International Congress of Mathematicians held in a developing country in history; and the third row: July 1, 2021–The 100th anniversary of the founding of the Communist Party of China. Through this, guide students to work hard, study diligently, and contribute to further improvement of the country's mathematics development level.

(4) Application of matrices: Applications in linear equations and in the aerospace field. By introducing practical application examples of matrices in various fields, students' interdisciplinary perspectives can be broadened and their sense of social responsibility and innovation awareness cultivated.

(5) Several special matrices: zero matrix, row matrix, column matrix, square matrix, diagonal matrix, identity matrix, upper triangular matrix, and lower triangular matrix.

(6) Through extended homework, help students better understand and remember important moments in Chinese history and further sublimate students' feelings of patriotism and family. Select some important historical events in China and their corresponding dates, arrange them in a certain classification and order, and write a matrix with dates of special significance in history as elements.

4. Retrospect and prospect

As one of the core courses covering various disciplines, such as science, engineering, agriculture, medicine, and economic management, linear algebra is usually offered in the freshman year. During this period, young college students are in a stage where their thinking and consciousness gradually matures. This stage is crucial not only for laying a solid foundation for professional learning but also for the formation of their outlook on life and values [15].

Educators should guide young college students to establish correct values through ideological and political education, and course-based ideological and political education. Therefore, integrating course-based ideological and political education into teaching is particularly important at this time. Against the backdrop of the comprehensive implementation of course-based ideological and political education; to fulfill the fundamental task of moral education and talent cultivation, educators should organically incorporate course-based ideological and political education into course teaching, achieving a balance between knowledge imparting and value guidance. In this way, the goal of "moving in the same direction and forming synergy" can be realized.

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