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Practical Exploration of Self-Directed Learning Methods in Linear Algebra Course Teaching

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Abstract

This paper expounds the connotation and characteristics of the self-directed learning method. Combined with the characteristics of the Linear Algebra course and with the help of digital and intelligent technology, a teaching practice plan based on the self-directed learning method is designed, including the creation of hierarchical goals, the construction of online resources, the tracking of learning processes, the joint construction of teaching cases, the introduction of AI teaching assistants, and the implementation of multi-dimensional evaluation. The practical results show that this method can effectively improve students' learning autonomy, enhance their thinking ability and strengthen their ability to apply knowledge, providing a useful reference for the teaching reform of the Linear Algebra course.

Keywords

Self-Directed Learning

Linear Algebra

Teaching Practice

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1. Current Situation of Linear Algebra Course Teaching

In the higher education system, Linear Algebra, as a core public basic course, is not only an important branch of mathematics but also a fundamental tool in many fields such as physics, engineering, computer science, and economics. However, the course itself has prominent characteristics like abstract concepts, strong theoretical nature, and complex calculations, which pose considerable challenges to teaching. For a long time, the traditional teaching mode of Linear Algebra has been teacher-centered. Teachers impart knowledge to students through blackboard writing or PPT demonstrations, leaving students with few opportunities for active thinking and exploration, making it difficult for them to truly understand and master the core concepts and methods of Linear Algebra. Many students merely memorize formulas and problem-solving steps mechanically during the learning process and fail to connect the learned knowledge with practical applications, resulting in poor learning outcomes.

The self-directed learning method emphasizes the subjectivity and initiative of learners in the learning process, which can effectively stimulate learners' interest

in learning and their potential. Introducing the self-directed learning method into the teaching of the Linear Algebra course, supplemented by the support of digital and intelligent technology, is expected to break the constraints of the traditional teaching mode, enhance students' dominant position in the learning process, and improve the teaching situation of the Linear Algebra course in application-oriented undergraduate universities. Based on this, this paper conducts a practical exploration of the self-directed learning method in the teaching of the Linear Algebra course, aiming to provide useful references for the teaching reform of the Linear Algebra course.

2. Overview of the Self-Directed Learning Method

2.1. Connotation of Self-Directed Learning

The concept of self-directed learning was first proposed by Malcolm Knowles, an American adult educator. After years of development and improvement, it has formed a relatively mature theoretical system. In the context of modern education, self-directed learning refers to a learning method in which learners, on the basis of clarifying their own learning needs and goals, take the initiative to formulate learning plans, select appropriate learning resources and methods, independently monitor the learning process, and evaluate and reflect on the learning results.

In the process of self-directed learning, learners are no longer passive recipients of knowledge but active participants and leaders of learning activities. They can flexibly adjust the learning pace and content according to their own knowledge foundation, learning ability, and interests, so as to better meet their own learning needs. For example, when learning the concept of matrices in Linear Algebra, some students may choose to first watch micro-lecture videos to gain a preliminary understanding of the definition and basic properties of matrices, and then consolidate the learned knowledge by doing exercises; while others may first read the relevant content in textbooks and then consult online learning resources or ask teachers and classmates for help when encountering unclear points. This personalized learning method can give full play to the subjective initiative of learners and improve learning efficiency and quality.

2.2. Characteristics of Self-Directed Learning

2.2.1. Subject Autonomy

In self-directed learning, students are the subjects of learning and have full autonomy. From the setting of learning goals to the selection of learning resources, and from the implementation of learning plans to the arrangement of learning progress, all are determined by students themselves. This autonomy enables students to participate more actively in the learning process and give full play to their subjective initiative.

2.2.2. Reflective Initiative

Reflection is an important part of self-directed learning. During the learning process, students can continuously reflect on and summarize their own learning behaviors, methods, and results. Through reflection, students can promptly identify the problems and shortcomings existing in the learning process, analyze the causes of the problems, and take corresponding measures to improve.

3. Practical Design of the Self-Directed Learning Method in the Linear Algebra Course

To address the problems existing in the traditional teaching of the Linear Algebra course, the course teaching team has conducted in-depth research on the self-directed learning theory, fully combined the advantages of digital and intelligent technology, and designed a teaching practice plan for the Linear Algebra course from multiple aspects. The specific measures are as follows:

3.1. Create Hierarchical Goals to Provide Learning Guidance

Learning goals are the direction and driving force for students' learning. Scientific and reasonable learning goals can guide students to carry out learning activities in a targeted manner. On the basis of fully investigating the syllabus of the Linear Algebra course and the talent training goals, and combining with the actual learning situation of students, the course team divides the learning goals into three levels: basic goals, advanced goals, and extended goals, providing students with clear learning

guidance.

Basic Goals: Basic goals are mainly for all students, aiming to ensure that students master the basic concepts, theorems, and calculation methods of Linear Algebra. Specifically, they include: understanding the definitions and properties of basic concepts such as matrices, determinants, vectors, and linear equations; mastering the operation methods of matrices, including addition, subtraction, multiplication, transposition, and inverse matrices; being able to calculate the value of determinants using the properties and expansion rules of determinants; and proficiently mastering the solution methods of linear equations, including Gaussian elimination, Cramer's rule, etc.

Advanced Goals: Advanced goals are mainly for students with a good foundation and strong learning ability. On the basis of mastering the basic goals, students are required to further understand the internal connections between concepts and theorems and be able to use the learned knowledge to solve simple practical problems. Specifically, they include: deeply understanding the logical relationships between concepts and theorems such as the linear dependence of vectors and the structure of solutions to linear equations; being able to use the knowledge of Linear Algebra to solve some simple practical problems, such as stress analysis in engineering and input-output analysis in economics; and learning to use mathematical software (such as Matlab, Python, etc.) for the calculation and analysis of Linear Algebra.

Extended Goals: Extended goals are mainly for students who have a strong interest in Linear Algebra and hope to conduct in-depth learning and research. Students are required to be able to deeply explore the application of Linear Algebra in professional fields and carry out innovative thinking and research. Specifically, they include: understanding the cutting-edge applications of Linear Algebra in fields such as computer graphics, machine learning, and cryptography; being able to read relevant academic papers and understand the latest research results in the field of Linear Algebra; and trying to use the knowledge and methods of Linear Algebra to solve some challenging practical problems or carry out innovative research projects.

Through the setting of such hierarchical learning goals, students can independently select learning goals suitable for themselves according to their own knowledge foundation, learning ability, and interests, clarify their learning direction, and thus carry out learning activities in a more targeted manner.

3.2. Build Online Resources to Lay the Foundation for Learning

Abundant learning resources are an important guarantee for students to carry out self-directed learning. The course team makes full use of digital and intelligent technology to construct a multi-dimensional online knowledge system including knowledge graphs, ideological and political graphs, problem graphs, and goal graphs, providing students with accurate and diverse learning resources for self-directed learning.

Knowledge Graph: The knowledge graph displays the knowledge structure of the Linear Algebra course and the internal connections between knowledge points in a visual way. Through the knowledge graph, students can intuitively understand the overall framework of the Linear Algebra course, clarify the position and importance of each knowledge point, and the interrelationships between knowledge points.

Ideological and Political Graph: The ideological and political graph organically combines the knowledge points in the Linear Algebra course with ideological and political elements, exploring the ideological and political contents contained in the Linear Algebra course, such as the spirit of science, the awareness of innovation, and the feelings of patriotism.

Problem Graph: The problem graph collects common problems and typical examples in the Linear Algebra course, classifying and organizing them according to knowledge points and difficulty levels. Each problem is accompanied by detailed problem-solving ideas and methods, as well as links to relevant knowledge points.

Goal Graph: Corresponding to the hierarchical learning goals created earlier, the goal graph lists in detail the knowledge points, learning requirements, learning resources, and assessment methods corresponding to each learning goal.

Up to now, the course team has built 80 core knowledge points, 537 associated test questions, and 890 associated learning resources on the online learning

platform, providing contents including micro-lecture videos, teaching courseware, unit tests, and extended resources. These online resources cover all aspects of the Linear Algebra course and meet the learning needs of students at different levels. The online learning platform has been in full operation for 4 semesters, with more than 9 universities and 2,480 students participating in the course learning, and the number of visits has reached 3.85 million. Students can independently select learning resources, formulate learning plans, and carry out personalized independent learning according to their own knowledge background, thinking characteristics, and learning needs.

3.3. Track the Learning Process and Generate Learning Paths

In order to guide students to develop self-directed learning habits and ensure that students can carry out learning activities in accordance with the established learning goals and plans, the course team has taken a series of measures to track the students' learning process and generate personalized learning paths for them.

Firstly, guide students to formulate learning plans. At the beginning of the course, the course team guides the enrolled students to formulate learning plans including knowledge points to be learned, learning schedule, selection of learning resources, learning tasks, and goals according to their own learning goals and time arrangements. Secondly, use the online learning platform to record learning data. The online learning platform has powerful data analysis functions, which can record the students' learning progress and knowledge mastery throughout the process. These data can not only reflect the students' learning attitude and efforts but also accurately evaluate the students' mastery of each knowledge point. Thirdly, generate personalized learning paths. Based on the students' learning plans and learning data, the online learning platform uses big data analysis and artificial intelligence technology to generate personalized learning paths for students. Finally, optimize and adjust teaching strategies. By regularly analyzing the students' learning data and learning paths, the course team can keep abreast of the students' learning situation and needs in real-time and adjust the teaching strategies and contents in a timely manner.

3.4. Jointly Build Teaching Cases to Drive Application Practice

The abstract nature of Linear Algebra often makes it difficult for students to connect theoretical knowledge with real life, resulting in weak knowledge application ability. To solve this problem, the course team innovatively proposes a "teacher-student joint construction of teaching cases" model, allowing students to transform from "passive acceptance of cases" to "active creation of cases". In the process of case exploration and construction, students can deepen their understanding of abstract knowledge and improve their ability to apply knowledge.

Firstly, guide case topic selection. Before the start of teaching each chapter, teachers will put forward several case topic directions related to real life and professional fields based on the core knowledge points of the chapter. At the same time, students are encouraged to independently select topics based on their own professional backgrounds or life interests. Secondly, collect case materials. After determining the topic, students, individually or in groups (2-3 people), collect case-related materials by consulting academic papers, industry reports, enterprise practice cases, or conducting field investigations and data collection. Thirdly, construct case models. On the basis of collecting sufficient materials, students need to transform practical problems into Linear Algebra models, clarify the variable definitions and constraint conditions in the models, and figure out how to use relevant knowledge points to solve the problems. Finally, display and optimize case results. After completing the first draft of the case, students need to submit the case report (including the background of the topic selection, source of materials, model construction process, solution steps, application effect analysis, etc.) through the online platform and display the case in class to share their exploration process and experience. Other students and teachers will comment on the case and put forward modification suggestions. Students will revise and improve the case according to the comments, and finally form a mature teaching case, which will be included in the course case library.

Through the teacher-student joint construction of teaching cases, students not only deepen their understanding of the abstract knowledge of Linear

Algebra but also cultivate their ability to apply knowledge and innovative thinking. Up to now, the course case library has collected 128 cases independently constructed by students, covering multiple fields such as computer science, engineering, economics, and medicine. Among them, excellent cases such as "Simplified Model of Face Recognition Based on Matrix Transformation" and "Application of Linear Equations in the Optimization of Logistics Distribution Paths" have been used for classroom teaching demonstrations and become examples for other students to learn from.

3.5. Introduce AI Teaching Assistants to Empower Learning Support

To solve the problem in traditional teaching that "teachers have limited energy and cannot meet the real-time and personalized learning needs of all students", the course team has introduced an AI teaching assistant system to provide students with full-time and interactive learning support, and built a learning closed loop of "independent learning - real-time Q&A - self-assessment" to help the effective implementation of self-directed learning.

The AI teaching assistant has natural language understanding ability, which can quickly respond to students' questions and answer questions such as concept doubts and problem-solving confusion in the learning of Linear Algebra. Based on the students' learning data (such as the mastery rate of knowledge points, learning progress, types of wrong questions, etc.), the AI teaching assistant will recommend personalized learning resources to students. The AI teaching assistant supports students to independently initiate evaluation activities such as unit tests, chapter tests, and mock exams, and the system will generate personalized test papers according to the students' learning progress and mastery of knowledge points. In addition, for complex questions raised by students or questions that the AI teaching assistant cannot answer in a timely manner, the system will automatically transfer the questions to the course teachers. After the teachers answer the questions, they will feed back to the students, ensuring the accuracy and completeness of the Q&A.

Since the introduction of the AI teaching assistant, students' learning efficiency and learning experience have been significantly improved. Data shows that the average response time for students to ask questions through the AI teaching assistant is less than 3 minutes. Compared with the traditional mode of "asking questions after class - teachers answering in the next class", the Q&A efficiency has increased by more than 90%; 85% of students said that the learning resources recommended by the AI teaching assistant "meet their personal learning needs" and help them quickly make up for their knowledge gaps.

3.6. Implement Multi-Dimensional Evaluation to Provide Learning Feedback

The traditional teaching of Linear Algebra mostly adopts a single evaluation method of "final exam + usual homework", which is difficult to fully reflect the students' learning process and comprehensive quality. To meet the needs of self-directed learning, the course team, based on big data analysis, has constructed a multi-dimensional evaluation system combining "process evaluation + summative evaluation", evaluating students' learning results from multiple dimensions and providing students with timely and comprehensive learning feedback.

The course team provides students with real-time evaluation feedback through the online learning platform. Students can check their process evaluation scores, performance in various dimensions, and teachers' comments and suggestions at any time; after the summative evaluation, the system will generate a personalized exam analysis report, pointing out the students' weak knowledge links and recommending targeted review resources.

4. Practical Results and Analysis

In the early stage of practicing the self-directed learning method, some students, who were accustomed to traditional passive learning, felt unadaptable when facing independent learning tasks and knowledge exploration, resulting in slow learning progress or the emergence of a sense of fear of difficulties. With the continuous guidance of the course team, students gradually adapted and adjusted their learning strategies, actively communicated their learning experience, selected appropriate learning materials according to their own shortcomings, and explored their personal learning paths. The analysis of the practical results over 4 semesters shows that the overall

teaching effect has been continuously improved.

4.1. Improvement of Learning Enthusiasm

Through data monitoring, the course team found that at the beginning of the semester, the average daily number of visits to the online resource platform was about 60. With the deepening of teaching practice, the number of visits continued to increase, reaching about 150 per day in the 8th week, and then remained stable at 130-150 per day until the end of the semester. At the same time, the "three rates" (attendance rate, head-up rate, and front-row seating rate) in the classroom have increased significantly, and the frequency of active questioning and participation in discussions has also increased significantly, from 2-3 times per class to 8-10 times. In group cooperation projects, students can also carry out active learning behaviors such as independent planning, project decomposition, and task assignment. These data changes indicate that students have gradually adapted to the self-directed learning method, and their learning enthusiasm and initiative have been continuously improved.

4.2. Improvement of Comprehensive Quality

By independently exploring textbooks, online resources, and conducting after-class extended learning, students have a deeper understanding of the concepts of Linear Algebra. In the final exam, even though the proportion of subjective questions has increased, the students' scores have still improved significantly. At the same time, students' ability to apply knowledge has been significantly enhanced. For example, the number of awards in the National College Students' Mathematics Competition in 2023 has increased by 60% compared with that in 2022, and the number of awards in the National Undergraduate Mathematical Modeling Competition has increased by 90%. In addition, students who are preparing for the postgraduate entrance examination have significantly enhanced the agility and logic of their problem-solving thinking for Linear Algebra questions by independently planning their learning paths and making rational use of online resources. Their average score has increased by 10-15 points, laying a solid foundation for their postgraduate studies.

5. Conclusions and Prospects

This practice of applying the self-directed learning method in the teaching of the Linear Algebra course closely aligns with the course characteristics of Linear Algebra, such as "abstract concepts, rigorous theories, and wide applications". Supported by digital and intelligent technology, a teaching plan was designed from six dimensions: "establishment of hierarchical goals, construction of online resources, tracking of learning processes, joint construction of teaching cases, introduction of AI teaching assistants, and implementation of multi-dimensional evaluation". This effectively addresses the shortcomings of the traditional teaching mode and achieves remarkable teaching results. The teaching reform practice of the self-directed learning method shows that this method effectively compensates for the shortcomings of the traditional teaching mode and greatly stimulates students' enthusiasm for independent exploration of knowledge. However, there are still some problems in the practice process, such as insufficient self-management ability of some students and inadequate utilization of learning resources. In the future, it is necessary to further optimize the teaching practice plan, strengthen the cultivation of students' self-management ability, and improve the integration and recommendation mechanism of learning resources. This will better exert the role of the self-directed learning method in the teaching of the Linear Algebra course and promote the in-depth development of the teaching reform of the Linear Algebra course.

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