The exploration of project-based teaching in *Mechanical Principles Course Design* based on the progressive learning theory

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Abstract. Engineering course design classes generally have long hours, diverse content, and strong integration. These characteristics can lead to issues such as students being unclear about learning objectives, lacking initial motivation, and blindly rushing to complete tasks later on. This paper aims to analyze the staged learning characteristics of students in project-based teaching practices by constructing a progressive learning model for the Mechanical Principles Course Design (MPCD), providing references and basis for implementing project-based teaching in undergraduate practical courses. This attempt to transform the course design from the traditional individual centered teaching mode to a group cooperative learning mode successfully solved the integration problem of teamwork skills and professional training. At the same time, we have effectively applied the theory of progressive learning to practical courses, improved teaching effectiveness, and established a project-based MPCD teaching framework, developing relevant implementation documents and evaluation standards.

Keywords: project-based teaching, theory of progressive learning, reform of higher education institutions.

1 Introduction

The MPCD is a crucial component in the curriculum development for the automobile engineering program, designed to meet student training needs and align with the goals of cultivating applied talents [1-4]. This course aims to apply the gear rack transmission mechanism and steering trapezoidal principle from the mechanical principles course to the design of automotive steering systems. Through hands-on disassembly, determining and optimizing steering solutions, designing transmission mechanisms, and 3D modeling, students gain a thorough understanding of mechanical transmission and the principles and structures of automotive steering. It integrates foundational theoretical courses with mandatory specialized theoretical courses, serving as a comprehensive practical course and laying the groundwork for the graduation project. The course teaching has revealed several issues, including:

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Firstly, the topics are singular and disconnected from actual production in the industry. In traditional teaching methods, the teacher proposes topics, and students choose and complete them independently. To prevent similarities in design results, parameters for each student's topic are modified. However, due to the large number of students, this differentiation of design parameters may lead to discrepancies between the parameters and those of actual automotive steering systems, detaching them from real production issues.

Secondly, passive completion and even plagiarism are prevalent. The traditional course design teaching model involves teachers overseeing students as they complete tasks, leading to unclear learning objectives and difficulty in motivating students to engage in active learning. This often results in initial lack of motivation and later blind, low-quality work. In situations where students feel unable to meet expectations, they may resort to directly copying and pasting assignments from other classmates.

Finally, there is a lack of effective management of the learning process. Course design is a highly integrative teaching component, but due to some students having weak foundations and limited ability to apply knowledge comprehensively, it is difficult to achieve real-time process management with traditional teaching models. This leads to significant inconsistencies in the learning progress among the entire class.

2 Progressive Learning and Project-Based Teaching Model

2.1 Design of the Project-Based Teaching Model for MPCD

From the above situation analysis, it is clear that the knowledge goals, ability goals, and quality goals of the course correspond to progressive learning, which is a gradual process of knowledge acquisition, ability development, and cultivation of qualities [5, 6]. This progressive characteristic aligns with the learning objectives of the syllabus and the requirements for undergraduate graduation [7-10]. Therefore, based on the learning objectives outlined in the syllabus and the course task arrangement, a course progressive learning model can be constructed. This model takes the MPCD as the project and is divided into four stages, comprising a total of 16 modules, as shown in Fig. 1A.

In the progression of the project, Stage 1 requires students to read the task assignment and apply their foundational knowledge to understand the working principles and structural components of the project subject—the steering system. The four modules in stage 1 ask students to engage in hands-on disassembly and comprehension of the working principles using their foundational knowledge and knowledge from related fields. This stage represents an attempt to apply the understanding of basic concepts in practical operations.

Stage 2 requires students to apply their knowledge of mechanical principles to derive formulas for the steering trapezoid and create sketches based on the results. They then conduct simulations according to the requirements for the minimum turning radius to obtain the optimal steering trapezoid parameters.

Stage 3 requires students to use CATIA tools to create 3D models and 2D drawings based on the parameters obtained in the previous stage. Stages 2 and 3 build on the foundational understanding from Stage 1, aiming to cultivate students' development and design abilities while promoting the integration and accumulation of professional theoretical knowledge and practical experience. This stage is a continuous deepening of core competencies and key qualities. The learning objective in this process is not merely to achieve a single drawing as the final result, but to guide students to treat the course design as a project, implementing a spiral approach to quality management.

Stage 4 involves the writing of the documentation and the defense, which is a crucial part of summarizing and presenting the entire project. It guides students to reflect on and summarize the project development, laying the groundwork for the next stage of learning and accumulating experience. Additionally, the writing of the documentation helps students establish a solid research foundation and writing skills throughout the research process, setting the stage for their later thesis writing.

The entire model encompasses knowledge cognition, design capability training, team communication and collaboration, as well as the enhancement of thesis writing skills.

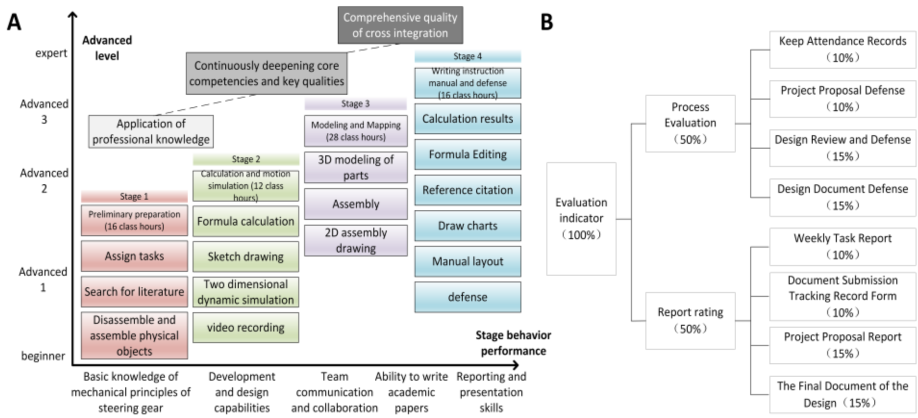

Fig. 1. A, Advanced model diagram for MPCD learning. B, Course Scoring Criteria for MPCD.

2.2 Course Evaluation Criteria

Based on the objectives set for the course, a detailed assessment method is employed that emphasizes students' level of participation and performance throughout the entire process, as illustrated in the Fig. 1B.

3 Outcomes

Using the progressive learning model as an analytical and explanatory theoretical framework for undergraduate project-based teaching practices can positively maintain the normal progression of project-based teaching. Strict process management ensures the project's progress and quality, creating a favorable work environment for students to collaborate on completing tasks. Additionally, employing the progressive learning model as a criterion for evaluating stage outcomes enhances the effective real-time management of course design and improves teaching quality.

3.1 Students' Self-Evaluation of the Project is Positive

From the perspective of teaching evaluation, the effects of the course reform can be reflected. The teaching evaluation consists of two parts: data from the university's academic affairs office regarding teaching supervision, and student evaluations collected online. Both evaluation categories received excellent ratings.

Additionally, to assess the practical effectiveness of project-based teaching based on progression theory, a survey on the effectiveness of the MPCD project-based learning was distributed in class. A total of 34 questionnaires were distributed and returned, all of which were valid.

The survey primarily investigates teaching effectiveness from three aspects:

Understanding students' subjective judgments on the effectiveness of project-based learning: The survey results indicate that most students believe the advocacy for group-based learning significantly aids their course studies. This is mainly reflected in their view that group-based learning allows for complementary strengths, enhances collaboration skills, promotes information and resource sharing, and facilitates communication among peers. Additionally, most students acknowledge that the staged learning and assessment approach used in this course greatly benefits their learning experience. Many students expressed that staged learning and assessment help create a sense of task pressure that motivates their learning, allowing them to better understand the tasks for each stage and thus increasing their engagement and timely completion of assignments.

Understanding the impact of project-based learning on students' skill development: The survey results show that 97% of students are clear about the learning tasks and assessment criteria for each stage of the course. They can provide suggestions for adjusting the class schedule based on their experiences in completing tasks for each stage.

Understanding the influence of project-based learning grounded in progressive learning theory on students' career planning (Fig. 2): Among the respondents, 97% believe that learning in this course will be beneficial for their future employment. Specifically, 76% think it enhances their knowledge of automotive structures and principles; 85% feel their software application and modeling skills have improved; 32% believe their project management skills have developed; and 44% report having trained their Word and PowerPoint editing abilities. Students have also started to form initial ideas about their future job positions. Some believe they could be suitable for engineering design roles, while others discovered their organizational abilities during the project-based learning process and are considering management positions. Moreover, 76% of students suggested designing course topics that align with actual business needs, providing an important insight for curriculum reform: students have a strong desire to understand the real demands of enterprises. Collaborating with businesses in teaching could deepen students' understanding of enterprise projects, thereby enhancing their motivation to learn.

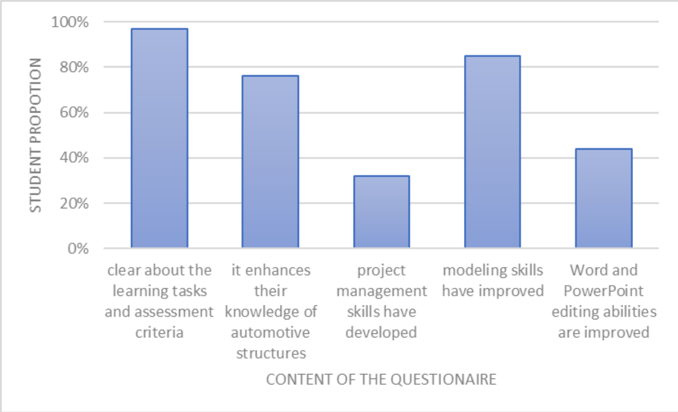

Fig. 2. Results of the questionaire

3.2 Promoted and Applied in Other Practical Courses

Taking MPCD as an example, the project-based teaching reform not only ignited students' enthusiasm for learning but also achieved the desired outcomes. Students showed positive feedback regarding their overall project completion, personal gains, and future plans, indicating significant progress. Through systematic training, they became familiar with the learning process of practical courses and developed the ability to solve problems independently, with clear learning objectives, reasonable task distribution, and timely, high-quality submissions. This deep engagement facilitated a more thorough understanding of the knowledge. Therefore, the evaluation system and theoretical model of this course can be effectively applied to other practical courses. Currently, courses such as Mechanical Design Course Design and Automotive Structure Design have adopted this teaching model, and instructors have provided positive feedback, believing that this reform enhances teaching quality and students' overall capabilities.

4 Conclusion

The project-based teaching reform grounded in progressive learning theory has significantly increased students' interest in learning and, through rigorous process management, ensured the progress and quality of projects. This model helps students clarify their learning tasks and objectives at each stage, enhancing their intrinsic motivation and transforming their mindset from *I don't know what to learn* to *I want to complete the project with my group members*. This shift provides students with a broad platform to showcase and enhance their individual abilities, fully tapping into their creativity and initiative.

After a year of practice, we have accumulated valuable experience in promoting higher engineering education concepts and the project-based design model: Transitioning from a traditional individual-focused teaching model to a group collaboration learning model, successfully addressing the integration of teamwork skills and professional training; Effectively applying progressive learning theory to practical courses, enhancing teaching effectiveness; Establishing a project-based MPCD teaching framework based on progressive learning theory and developing related implementation documents and evaluation standards, laying a solid foundation for further promotion of this model. These experiences not only enrich the teaching content but also promote the overall development of students.

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