A New Approach to Teaching — “Q-step” Teaching Method

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Abstract. Aiming at the issue of how to cultivate and strengthen the question analysis ability of engineering majors in higher education institutions, this paper innovatively puts forward a new teaching method called the “Q-step” teaching method. This method is guided by questions, taking the teaching content as the carrier to teach students the typical questions analysis ideas of "survey - analysis - experiment - perfect", and provides practical innovative new approach to improve the teaching effect of engineering courses. Taking the course "Principles of optoelectronic Imaging" as an example, the specific application of this method is explained in detail. It has been verified through teaching practice that the “Q-step” teaching method has good teaching effects and provides a new approach to achieving course learning outcomes and formative assessment.

Keywords: Engineering thinking, Teaching method innovation, “Q-step” teaching method.

1 Introduction

Network and computing technology is quite import to technological revolution and industrial transformation. In the "new engineering" reform system laid out by the Ministry of Education, "paying attention to the interdisciplinary and cultivating students' cross-disciplinary integration capabilities through question-oriented, interdisciplinary cooperative learning" is clearly listed as a key to the reform and development of new engineering [1-2]. How to cultivate students' engineering thinking so that they can deal with unknown and changing practical issues in the future has become a teaching main point for many courses. Therefore, this paper proposes a new approach - “Q-step” teaching method, which can effectively cultivate and improve students’ question analysis abilities. Taking the course "Principles of Optoelectronic Imaging" as an example to carry out practical exploration and innovate new methods to improve the teaching effectiveness of interdisciplinary courses.

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2 Core Idea of the "Q-step" Teaching Method

Question-driven teaching methodology has become a mainstream and widely applied approach [3-6], as it not only stimulates students' interests but also facilitates the effective introduce of teaching content, thereby guiding students to learn. However, if the students are not given sufficient time to think after the question is presented, the subsequent theoretical knowledge is directly imparted, it may not fully engage students' initiative. In order to better "learning-oriented" and enthuse the students, this paper proposes the "Q-step" teaching method. This method mainly comes from the constructivist concept[7] in the current teaching field, advocating for students to engage in self-directed learning in the environment provided by teachers, and ultimately explore to obtain answers. "Q-step" teaching method uses questions as a guide and incorporates the question analysis approach of "survey - theory analysis - experiment - perfect" into the teaching content, aiming to empower students to achieve "teaching a man how to fish", as shown in Figure 1.

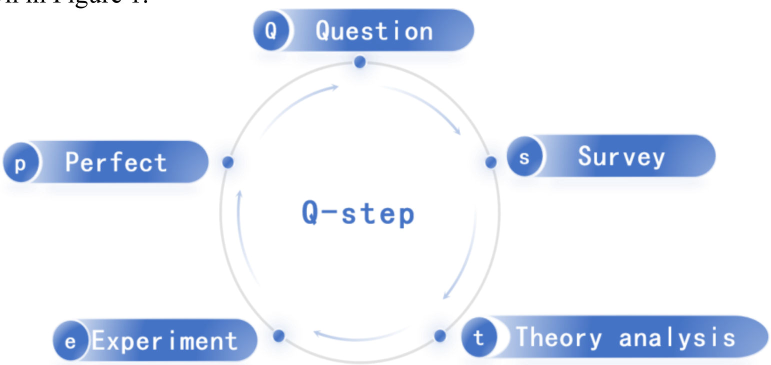

Fig. 1. "Q-step" teaching method.

Q: Question. Set 1-2 related questions regarding the teaching content, using these questions as an introduction. In this phase, the questions should follow the logic of basic thinking. For new theories and new contents, try to select familiar cases that students can relate to and interact with. Then, gradually progress from easy to difficult, from familiar to unfamiliar, expanding the questions in an advanced manner.

S: Survey. Have the students conduct survey on the issue. Whether it is for scientific research or teaching purposes, survey is an essential step, and the same applies to student learning. During the survey process, students can enhance their self-learning ability by reviewing materials. Furthermore, as the survey progresses, students will gradually form their own thinking and understanding of the issue. As the number of surveys continues to increase, its data collection, analysis and screening capabilities are also continuously strengthened. Question raising and survey can be placed before class to allow ample time for in-depth thinking. If the question is easy or there is sufficient class time, it can also be conducted during class time with the assistance of the teacher. During the survey process, it is recommended that students search online on their own, but the initial materials can be provided by the teacher. As the number of surveys increases, the materials provided by the teacher will gradually become more extensive and comprehensive, helping students develop their ability to assess, analyze and screen information, making it the most effective way of pre-study.

T: Theory analysis. In response to the questions raised and based on the results of the survey, guide the students to learn the relevant knowledge of this lesson. Since the students have already thought about the question to a certain extent and even formed their own opinions, the theoretical learning process will be more targeted and effective. This phase should highlight the "teaching-led" approach, that is, the teacher should accurately grasp what content students learn and to what extent. Typical teaching processes that can be adopted include teacher-led lesson and students' independent learning. During the lesson, the teacher pays attention to assisting students in better understanding the relevant content by integrating various information technology means. After the theoretical teaching is completed, the teacher guides the students to analyze the questions raised at the beginning of the class based on the theoretical knowledge to deepen the students' correct understanding of the theory. Furthermore, the self-study mode can be adopted, where the teacher provides relevant learning resources to guide students in self-learning. During the learning process, students should attempt to analyze the questions raised at the beginning of the class, and finally there should be comments and questioning between the teacher and the students. Regardless of whether it is teacher-led lesson or student self-study, the core of this phase is to allow students to understand the relevant teaching content and overcome the key and difficulties in teaching.

E: Experiment. To verify whether the results of theoretical analysis are correct, the experimental verification/practical verification phase comes. There are many verification methods that can be used in this phase, with the most typical being expert knowledge verification and classroom experimental verification. Expert knowledge validation involves experts entering the classroom or remote interviews and recordings, allowing third parties to verify the correctness of the question analysis results, leaving a deep impression on the students and expanding cutting-edge knowledge. Classroom experimental verification allows students to design and verify the answer to specific questions by using experimental equipment or software. This process not only enhance students' practical ability but also, through the repeated mapping between "experiment and theory", allows students to continuously deepen their understanding of the questions and theories, and ultimately achieving good teaching results.

P: Perfect. When students initially use the newly acquired knowledge to analyze questions, there may inevitably be biases or omissions. It is necessary to review the theoretical knowledge and analysis process, continuously improving and refining the theory. Through this repeated process of analysis and verification, students continuously integrate and map theory with practice, deepening their understanding of theoretical knowledge and achieving "study for practical application."

The "Q-step" teaching method can undergo a series of evolutions in accordance with the teaching content. When the question is of certain difficulty, a step-by-step problem analysis is generally used, i.e., a familiar and simple question is first raised. Through the first "Q-step" phase, students achieve understanding and mastery of knowledge and learn this question analysis thinking. Subsequently, the difficulty of the questions is advanced, expanding from familiar life-like fields to professional fields, allowing students to analyze more difficult and specialized questions using the theoretical knowledge they have acquired, and enter the “Q-step” phase for the second time. Continuing in this manner, students can develop scientific thinking through iteration and ultimately solve professional problems. In addition, the “Q-step” can also undergo another level of evolution. Upon entering the experiment phase, students may encounter situations where experimental or expert validation results deviate from or even contradict theoretical analysis results. In such cases, students need to reflect on the process of theoretical analysis in reverse, continuously improve and refine it. Through this iterative process of theoretical analysis and experimental verification, the final conclusions are perfected. Therefore, the “Q-step” teaching method evolves as shown in Figure 2.

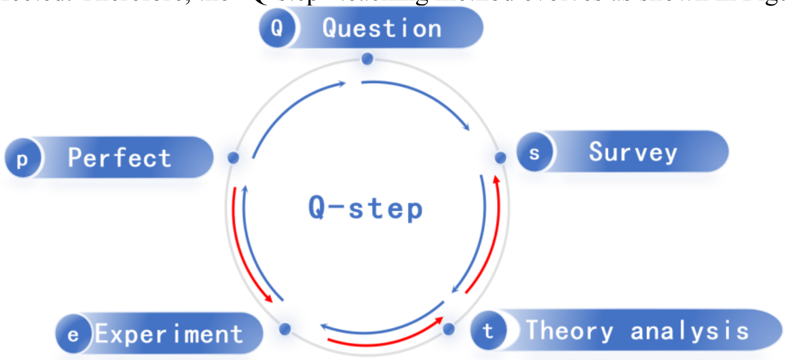

Fig. 2. Evolution of the “Q-step” teaching method

In conclusion, the Q-step teaching method is derived from the research ideas of scientific research projects and has a certain degree of universality. It has been widely promoted and applied in a large number of scientific research projects, and this method is also an attempt at research feedback teaching.

3 Application of the “Q-step” Teaching Method in "Principle of Optoelectronic Imaging"

"Principles of Optoelectronic Imaging" integrates relevant knowledge from multiple different fields, such as semiconductors, digital, electrical, and material science. It is a course featureing interdisciplinary and high integration of knowledge, with high flexibility in theoretical applications. Take the teaching content of "Principles of Linear Array CCD Imaging" in the course "Principles of Optoelectronic Imaging" as an example. Linear array CCD has many applications, such as in scanners that we are very familiar with. It is also used in industrial fields for tasks like parts damage detection through photography. This teaching content serves as the foundation for the subsequent "Principles of Area Array CCD Imaging".

The teaching objectives are to understand the structure and function of the linear array CCD, master the working process of the three functional zones of the linear array

CCD, and be able to analyze imaging issues related to the linear array CCD. The content is abstract and difficult to imagine at a microscopic level. Understanding abstract content and being able to flexibly apply it to analyze related imaging problems are the key difficulties of this class. Therefore, the "Q-step" teaching method is adopted for teaching, and the teaching process is shown in Figure 3.

Q: question. Using the scanner, which students can see and touch, as a starting point, the question is raised: "Why do scanners have varying scanning speeds?" This question is something that students have all experienced while using scanners, and selecting this question as a starting point can better resonate with the students.

s: survey. In response to the question raised, students conduct survey in groups. Given the question of "why scanners have varying scanning speeds," there are numerous related answers available online. Each group searches for and screens the information before sending the results to the teacher. During the survey process, students need to judge and think critically about the myriad of answers found online, forming their own preliminary ideas.

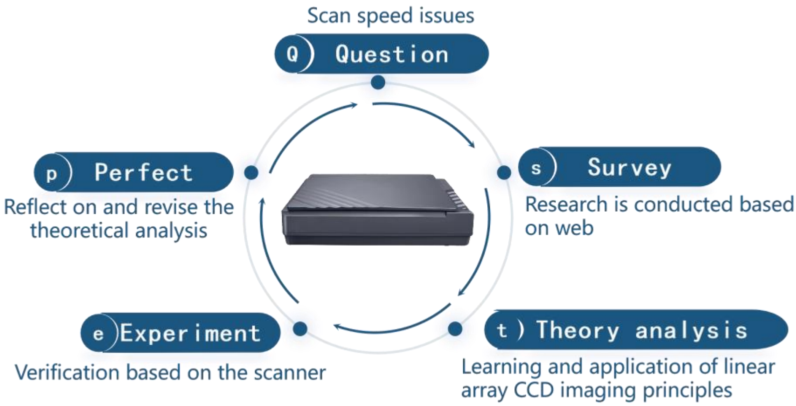

Fig. 3. Application of the "Q-step" teaching method in class

t: theory analysis. The teacher guides students to learn about the structure of the scanner by dissembling it using a three-dimensional model, and to discover that the linear array CCD is the core component of the scanner, with its main functions being Optoelectronic conversion, signal storage, and transmission. Following this, the students gain an understanding of the structure and imaging process of the linear array CCD. As students' understanding of theoretical knowledge deepens, their direction of question analysis becomes clearer and more accurate. After completing the entire imaging process, revisit the issue of fast scanning speed, supplementing and refining it with the survey results to achieve practical application of their learning. Throughout this process, the emphasis is on "teaching-led and learning as the main body", with continuous reinforcement of students' theoretical understanding through teacher-student and peer interactions.

e: experiment. After completing the theoretical analysis, students have formulated their own answers to the question of "why scanners have varying scanning speeds." However, whether these answers are correct requires further verification. As the saying goes, "practice is the sole criterion for testing truth." In the classroom, several different signal linear array CCD scanners and user manuals are introduced, allowing students to verify them in groups and refine their previous analysis conclusions based on the verification results.

p: perfect. The verified answer may differ from the answer obtained through theoretical analysis by students, indicating the possibility of deviation. It necessitates students to reflect, refine, and improve upon their theories once again. This process serves to fill knowledge gaps, aiding students in more systematically analyzing questions while also deepening their understanding of the theory.

Through the above-mentioned teaching process, teachers can evaluate students' learning abilities at various stages. Firstly, during the survey phase, teachers can observe the different abilities of students in data collection, analysis, and screening. In class, some groups solely rely on search engine, resulting in answers without screening. However, other groups start with literature review, finding numerous relevant papers on scanning speed, leading to more professional answers. Secondly, during the theoretical analysis phase, teachers can determine whether students' question analysis directions are correct, identify knowledge gaps, and evaluates the divergence of their thinking. For instance, some groups analyze solely from the perspective of line array CCD imaging principles with limit thinking and resulting in imperfect conclusions. However, other groups, in addition to theoretical analysis, also incorporate their scanning experience, speculating that scanner size could also affect speed, and utilize textbook knowledge along with peripheral information for a more comprehensive analysis. Furthermore, some groups, although finding answers, may have significant biases or even errors in their analytical principles, aiding teachers in pinpointing their knowledge gaps accurately. Finally, through the experiment phase, teachers can evaluate the effectiveness of different verification methods among different students or groups. For example, some groups analyze user manuals before testing the scanner, demonstrating an efficient and targeted verification approach. In contrast, some groups may act more recklessly, directly testing the scanner then viewing user manual, discovering omissions later and repeating experiments multiple times. Through this, teachers can evaluate students' ability to plan experiments. Upon completion of the entire teaching process, both knowledge and skill objectives are achieved, and teachers have precise assessments for evaluating students' abilities at each phase.

Based on the “Q-step” teaching method, it can effectively enhance students' analytical abilities. A comparative analysis reveals that initially, the same student had weak skills in data collection, theoretical analysis, experimental verification, and algorithm improvement. However, as the course progressed and with continuous exercises in the “Q-step” process, students were able to independently and rapidly conduct question analysis in latter stages, developing their own perspectives on problem improvement.

On the other hand, students' grasp of relevant theoretical knowledge based on the “Q-step” teaching method is firmer and their understanding deeper. Throughout the teaching process, the teaching team conducted group experiments to verify the effectiveness of the “Q-step” teaching method. This involved selecting certain content for “Q-step” teaching and assessing students' mastery of various topics without review through random classroom quizzes. The verification revealed that students exhibited deeper understanding and achieved higher scores where the "Q-step" teaching method was applied to their learning. Taking the 2020 level teaching as an example, comparing the final assessment data of the course, it was found that the average score rate of the content taught using Q-step teaching method was 80.58%, while the average score rate of the content taught using traditional teaching methods was 64.8%. The student score rate has increased by 15.78%. At the same time, inspired by this logic, the students wrote and published 4 papers as the first author (including 2 EI papers). Outstanding performance in optoelectronic perception competitions, strong comprehension ability, and quick entry into roles, preliminarily verifying the effectiveness of the conversion of theoretical knowledge into ability generation in the course.

4 Achieved Computing Technology Can be Applied in "Q-step" Method

To evaluate the improvement of students' learning ability, data on teaching practice and student learning behavior can be collected and analyzed through mind maps. Specifically, in class, after completing theoretical learning, students will analyze new problems based on the theory through research, problem analysis, experimental verification, and improvement. The process of problem analysis will be based on mind mapping. Based on the mind map submitted by the students, the instructor can see that the student's ability to search and filter information; The correctness and divergence of the student's problem analysis approach, and whether there are any knowledge gaps; The rationality and scientificity of the student experimental verification plan; And the innovation of reform and improvement. These are essential engineering skills for engineering students, and Q-step teaching method can effectively enhance these abilities. In addition to knowledge graphs, there are many computer technologies that can be applied. During the "survey" phase, students can leverage search engines and large language models[8,9] to query and sift through relevant information on topics. For "theoretical analysis", interactive learning technologies[10-14] between teachers and students effectively observe students' learning progress and discussions. Techniques such as online testing and question-and-answer platforms[15-17] allow students to ask questions and interact in the classroom, making the teaching process more engaging and dynamic, thereby enhancing student participation. In the "experimental validation" stage, virtual reality (VR)[18,19] and augmented reality (AR)[20] technologies provide students with immersive learning experiences and practical scenarios, enabling them to experience and explore knowledge in a virtual environment. Finally, through collecting and analyzing data on teaching practices and student learning behaviors, schools and teachers can conduct evaluations that enhance the scientific rigor and reliability of their assessments.

5 Summary

This paper proposes an innovative teaching method called "Q-step," which takes specific questions as the starting point and integrates the typical problem-solving process of "survey-theoretical analysis-experiment-perfect" into classroom teaching. This method provides more concrete guidance for advancing students' thinking and applying theory. Additionally, the “Q-step” teaching method can be flexibly adapted to different teaching contents, demonstrating strong practicality and offering an innovative approach to effectively improve the teaching effectiveness of engineering courses. Through teaching practice verification, it is found that this method not only effectively enhances students' mastery of theoretical knowledge but also improves their problem-solving abilities. Furthermore, teachers can evaluate and assess students' capabilities at each phase of “step”, demonstrating significant potential for wider adoption and implementation.

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