Teaching Strategies of an Introductory Course by Peer Instruction for Undergraduate Students in Vehicle Engineering

En-hua WANG*, Fu-jun ZHANG and Chang-lu ZHAO
School of Mechanical Engineering, Beijing Institute of Technology, Beijing 100081, China
*Corresponding author

Keywords: Engineering education, Peer instruction, Active learning, Teaching strategy.

Abstract. “Structure and Principle of Internal Combustion Engine” is a fundamental compulsory course for undergraduate students in vehicle engineering. Many instructors have to use traditional lecture method because of a huge assignment and an urgent time schedule, leading to a less understanding and a lower motivation for students. Peer instruction is a new pedagogy which changes the monologue style of traditional lecture. The level of active learning is enhanced via a series of concept tests in class. Four norms including active learning, cooperative learning, instructor-student interaction, and student-student interaction make this new pedagogy effective and prevalent. In this study, the peer instruction is reviewed at first. Then, the theory of peer instruction is presented. Next, the implementation strategies for this introductory course is discussed.

Introduction

According to constructivism theory, lecture by instructor is an incentive not the purpose while learning knowledge by students is the purpose. Traditional teaching is based on the center of instructor. Students are kept on their seats listening lectures for a long time. Lack of instructor-student interaction and less attractive to students make this teaching style is not optimistic. However, for most of engineering education in Chinese universities, traditional lecture is still the dominate way of teaching. The knowledge and conceptual understanding cannot be impressive and it will be forgot very soon in a way of rote learning.

Teaching mode is a relatively stable didactical framework and procedure under the direction of a certain teaching theory. Traditional mode takes teaching as a single-way of information transmission from instructor to students. It is very difficult for students to understand and assimilate their received information, which is not helpful for cultivating innovative thinking and capability of solving practical problem. Studies indicate that cooperative learning is an effective way of knowledge construction and innovative thinking cultivation. In 1946, Edgar Dale proposed a theory of pyramid study, which is shown as Figure 1. The data labelled in the right are the average retention rate of knowledge after two weeks. It is shown that active learning methods are superior than passive learning evidently. The most efficient learning method is not listening to others by your ear but telling it to others by yourself.

![Figure 1. The study pyramid.](Image)

25
In this study, an innovative teaching mode of peer instruction (PI) is presented. First, the current progress of investigations for peer instruction is reviewed. Then, the main procedure and advantages of PI is presented. Finally, the implementation strategies of PI for an introductory course in vehicle engineering is discussed.

**Review of Peer Instruction**

PI is an interactive teaching mode proposed by Professor Eric Mazur in 1991. It is a student-centered method and suitable for large classrooms. A series of specially designed concept tests are inserted to the traditional lectures, which are used to uncover the wrong understandings [1]. Crouch presented the results of PI in an introductory physics course in Harvard University, indicating it could increase the active learning of students [2]. A survey including various universities and colleges also showed that PI can improve teaching effectiveness for almost all classes [3]. Crouch and Mazur summarized ten years of experiences using PI and found that both the concept mastery and quantitative problem solving were improved. They also gave some advices for the implementation process [4]. The studies also indicated that peer discussion could enhance students’ understanding even none of them in a discussion originally knew the correct answer [5]. PI was introduced into China since 2000 or so. Zhang and Mazur presented the procedure of peer instruction, its significance and functions on improving students’ active learning [6].

Currently, PI is used by many instructors from various major backgrounds all over the world. A study showed that PI had an enormous potential to improve teaching and learning in philosophy, critical thinking, and logic [7]. Turpen and Finkelstein analyzed three different norms in a teaching mode of PI including faculty-student collaboration, student-student collaboration, and sense-making vs answer-making [8]. Hu and Zhao used PI in foreign language teaching and it indicated that the language skill and communicative ability were promoted significantly and the confidence of students was also increased [9].

PI has been implemented widely in engineering education. Practice by Ahmed and Roussev in cybersecurity course showed that students could adapt to this new teaching mode soon and a positive experience was obtained [10]. Schmidt applied PI in an introductory engineering dynamics course and described that an audience response system could facilitate the teaching process and increase the learning outcome [11]. The effectiveness of PI on the explicit understanding of undergraduate students in chemical engineering thermodynamics was investigated by a web-based interactive science and engineering learning tool. It was indicated that a statistically significant improvement in concept understanding [12].

In recent years, a lot of instructors in China start to use PI for their lectures. Huang et al. adopted PI in electromagnetism course and found that the learning ability and interest were increased and the conceptual understanding was improved [13]. Wang et al. tried PI in an engineering geology course. Both the active learning of students and teaching capability of instructor were enhanced [14]. Based on the characteristics of elementary engineering mechanics, Wu discussed the advantages and necessity of PI [15]. Liu et al. used PI in a teaching reform of digital electronic technology and thought PI could improve critical thinking during the pre-class, in-class, and post-class processes [16]. Pan and Li studied the effectiveness of PI combined with a mobile APP “Ketangpai” in engineering electromagnetism course. The results indicated that the levels of interaction and active learning were increased and PI was fond by most of students [17].

Some instructors compared PI with other teaching modes. Zhang et al. compared traditional lecture with PI in a physics course and found that the outcome of PI was increased and had a large potential [18]. Nicol and Boyle compared two teaching method: class-wide discussion and PI using classroom communication systems based on experiences of the undergraduates of engineering school in the University of Strathclyde. The results indicated that the effectiveness of PI is better than class-wide discussion and its efficiency was higher [19]. Sun et al. studied class discussion and PI in an engineering material lecture. Both improved the interaction level and PI was more prominent [20].
PI has a good adaptability, which can be combined with other teaching mode without a complete redesign of lecture. Hu presented a combined teaching method with flipped class and PI and a good outcome was achieved [21]. During the implementation process of PI, special attention should be paid to each steps. If they are not tackled properly, the results may not be so evident. Zhang and Lai presented their four years of PI in Guanxi Normal University and found that the effectiveness and interest of students were not improved by PI. The preview process before class could not be guaranteed and a plausible judgement criterion should be developed [22].

**Theory of Peer Instruction**

PI is a teaching method with question-based active learning and peer cooperative learning. Each important knowledge point is accompanied with a concept test. It emphasizes the peer discussion process. The conceptual understanding is constructed by student themselves via these discussions. The construction of conceptual knowledge is central to the development of expertise in professional skills. These concept tests can give an instant feedback about the lecture. The following peer discussion and instructor-student interaction will be helpful to give a deep impression about conceptual understanding. Together with preparation pre-class and cooperative learning in-class, the effectiveness of active learning can be realized.

Traditional lecture organizes a class based on the content in a textbook. Students are required to review and do some exercises after class. Very few interactions happen in class. The primary procedure of PI is shown in Figure 2. The first step is that students study the contents pre-class and answer three questions. The instructor collects these answers and prepare the lecture with some modifications. In class, the entire lecture is divided by several parts. Each one lasts about 15 minutes designed around a critical concept with about 6-8 minutes of lecture and following by a concept test. Students spend about 1 minute to answer it individually. The results are collected by instructor instantly. If the average correction rate is greater than 70%, the instructor gives a brief summary and moves next. If the correction rate is less than 35%, the instructor needs to redesign the lecture process and explains it again. Then, a second concept test is performed. In most cases, the correction rate is between these two values and a peer discussion is organized. Normally, the correction rate will be increased evidently. Finally, the instructor summarizes the concept test and moves to the next part.

![Figure 2. The procedure of peer instruction.](image)

There are three feedback methods: poll by hand, flashcards, and clickers including web-based APPs. Poll by hand can be used in any situations while it has a negative impact on self-respect sense. Flashcards can overcome it but it is not easy to get an immediate correction rate. Clickers are the most advanced method but it needs some cost and modification of the classroom.
The implementation of PI has many advantages. First, the teaching approach is enriched by PI and the interaction level is improved. It is very hard for a student to focus on one thing for a long time. A peer discussion is inserted and can give students a short break. Second, the active learning level can be increased via the concept test step. The teaching effectiveness can be validated immediately and is helpful for instructor to adjust the teaching strategy. Third, the abilities of thinking and association can be developed simultaneously. PI is also helpful for critical thinking and self-expression. Finally, PI can be adapted with traditional lecture without a complete redesign. It is easy to used for various of majors and size of classes.

Implementation Strategies in Vehicle Engineering Course

In this study, the strategies of implementing PI in an introductory course—“Structure and Principle of Internal Combustion Engine” are discussed. This course is a subject foundation requirement for undergraduate students of a four-years vehicle engineering major. The power types of vehicles, structures and principles of typical four-stroke internal combustion engines are presented. Some advanced technologies such as turbocharging and engine emissions and control are also introduced. This course is a combination of comprehensive, theoretical and practical. To learn it well, students are required to think actively, learn delightfully. Relative to practical situations is also critical. During one semester of lecture, some primary strategies and thinking about PI implementation are given as below.

1) Lay emphasis on students’ pre-class preparation. To improve the efficiency of lecture process with PI and save time, a good preview of critical contents pre-class is very important. In this class, the context book is a bit obsolete. The instructor needs to assign the preview content according to the PPT files at the end of last class. If time is enough, giving a short reading of textbook in-class is also allowable. But it must be less than 6-8 minutes. To enhance students’ motivation, the proportion of preview work can be enlarged at the final score decision.

2) Prepare lecture seriously. The concept test must be selected properly and the question must be designed smartly which is helpful to uncover students’ false understanding. Instructor needs to read the textbook carefully and very familiar with what he will present. The mistakes made by students in former homework or examinations are good source material.

3) Appoint the team of peer discussion appropriately and control the rhythm. In class, the importance of peer discuss should be emphasized by the instructor. During the peer discussion, a proper team should be appointed, neither too large nor too small and make sure students can discuss with peers who sitting around to improve the level of student-student interaction. The peer discussion should not be too tedious and must be controlled. If a wrong answer is given by a student, do not criticize but encourage him or her. The innovative thinking of students must be guided and their self-esteem must be protected carefully. In my primary attempt, poll by hand is the main incentive. In the future, more advanced web-based feedback method will be used.

4) Summarize continually after class. After one class is completed, the instructor must rethink it and good experiences should be consolidated and improper ways of lecture should be modified in the next class. Encourage students to discuss with each other after class is also a good method. It is better to provide a website where they can issue their opinions and discuss anytime.

Conclusion

Compared with traditional teaching mode, PI can improve students’ active learning effectively which can be seen from the above review process of literatures. The results of concept tests can give an instant manifest of conceptual understanding. The teaching process can be adjusted according to the instant feedback from the outcome of concept tests. “Structure and Principle of Internal Combustion Engine” include lots of complicated structures of components and many principles of different mechanisms. This characteristic must be considered when implementing peer instruction. A proper teaching process including pre-class, in-class, and post-class needs to be designed. In such a way, the teaching pedagogy reform can be realized and the effectiveness can be improved.
References

[1] E. Mazur, Peer Instruction: A User’s Guide, Prentice Hall, New Jersey, 1993.

[2] C.H. Crouch, Peer instruction: An interactive approach for large lecture classes, Optics & Photonics News 9 (1998) 37-41.

[3] A.P. Fagen, C.H. Crouch, E. Mazur, Peer instruction: Results from a range of classrooms, The Physics Teacher 40 (2002) 206-209.

[4] C.H. Crouch, E. Mazur, Peer instruction: Ten years of experience and results, Am. J. Phys. 69 (2001) 970-977.

[5] M.K. Smith, W.B. Wood, W.K. Adams, C. Wieman, J.K. Knight, N. Guild, T.T. Su, Why peer discussion improves student performance on in-class conceptual questions, Science 323 (2009) 122-124.

[6] P. Zhang, M. Eric, Peer Instruction—A new method for physical course in Harvard University, China University Teaching (2010) 69-71. (in Chinese)

[7] S. Butchart, T. Handfield, G. Restall, Using peer instruction to teach philosophy, logic and critical thinking, Teaching Philosophy 32 (2009) 1-40.

[8] C. Turpen, N.D. Finkelstein, The construction of different classroom norms during peer instruction: Students perceive differences, Physical Review Special Topics—Physical Education Research 6 (2010) 020123.

[9] L. Hu, M. Zhao, Effects of peer tutoring on college English students’ cognitive, communicative and affective development, Journal of Ningbo Institute of Education 10 (2018) 51-55. (in Chinese)

[10] I. Ahmed, V. Roussev, Peer instruction teaching methodology for cybersecurity education, IEEE Security & Privacy 16 (2018) 88-91.

[11] B. Schmidt, Teaching engineering dynamics by use of peer instruction supported by an audience response system, European Journal of Engineering Education 36 (2011) 413-423.

[12] B. Brooks, M. Koretsky, The effect of peer instruction on students’ construction of conceptual understanding in thermodynamics, In: 2010 Annual Conference & Exposition, Louisville, Kentucky.

[13] H. Huang, J. Fu, D. Li, Case analysis on application of peer instruction in college physics teaching, China Educational Technology & Equipment 426 (2017) 118-120. (in Chinese)

[14] T. Wang, G. Rong, Y. He, C. Chu, S. Wang, Teaching reform of engineering geology for water resources and hydropower specialty under peer instruction, Journal of Architectural Education in Institutions of Higher Learning 27 (2018) 116-121. (in Chinese)

[15] A. Wu, Application of peer instruction in the teaching of fundamentals mechanics, Mechanics in Engineering 38 (2016) 673-675. (in Chinese)

[16] Y. Liu, C. Zhu, J. Zhu, Using peer instruction to cultivate students’ critical thinking, Experimental Technology and Management 33 (2016) 155-158. (in Chinese)

[17] J. Pan, T. Li, The teaching practice and thinking of “Ketangpai” combined with peer instruction in electromagnetism, Physics and Engineering 27 (2017) 98-102. (in Chinese)

[18] Z. Zhang, R. Lu, Y. He, Y. Peng, The advantage and development of peer instruction in experiment of college physics, Physics and Engineering 27 (2017) 178-184. (in Chinese)

[19] D.J. Nicol, J.T. Boyle, Peer instruction versus class-wide discussion in large classes: a comparison of two interaction methods in the wired classroom, Studies in Higher Education 28 (2003) 458-473.
[20] Q. Sun, J. Wang, H. Wang, Y. Gao, Application and evaluating of class discussion and peer instruction in teaching of fundamentals of engineering materials, Education Teaching Forum 17 (2017) 175-177. (in Chinese)

[21] L. Hu, Combined Teaching based on Flipped Class and Peer instruction, Academic Degrees & Graduate Education (2017) 54-57. (in Chinese)

[22] M. Zhang, F. Lai, Enlightenment from 4-years practices of peer instruction, Physics and Engineering 26 (2017) 79-82. (in Chinese)