Advances in Economics, Business and Management Research, volume 96
2019 3rd International Conference on Education, Management Science and Economics (ICEMSE 2019)

Innovation in Teaching Mechanics of Materials in Civil Engineering

—Taking Classroom Teaching as an Example

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***Abstract*—Mechanics of materials is considered one of the most difficult introductory courses in undergraduate education in civil engineering. In order to improve students' learning interest and problem-solving ability, we have tried innovation in teaching mechanics of materials in civil engineering. In this paper, first, we present traditional teaching methods. Next, the problems in the current teaching of mechanics of materials are put forward. Finally, we provide insight into the use of various teaching approaches in mechanics of materials and discuss their advantages and disadvantages. We also introduce some engineering cases or examples suitable for mechanics of materials. All these approaches make the mechanics course full of vitality and make students like it. It provides instructors and researchers with the implications for instructional practices to prepare students for engineering practice in the future.**

Keywords—mechanics of materials; innovation; teaching methods; teaching aids; case study

I. INTRODUCTION

Mechanics of materials is an undergraduate foundation course required by many engineering programs including civil engineering, mechanical engineering, and aerospace engineering. Furthermore, many students from different fields such as materials science and architecture also find it useful to study this subject. With roots in physics and mathematics, the subject of mechanics of materials involves analytical methods for determining the strength, stiffness, and stability of the various load-carrying members. The course exposes students to a large variety of problems in mechanics that they may encounter in upper-division courses and engineering design processes. Hence, students must have, as a minimum requirement, a basic understanding and analysis of mechanical behaviors of the solid bodies including bars, shafts, beams, and columns.

In fact, the mechanics of materials is one of the most difficult courses for students to follow and understand, and also for the faculty to teach. Built on the foundation and framework of mathematics and physics, the course requires students to have not only strong abstract thinking and reasoning skills but also solid spatial abilities.[1] With the rapid development of modern technologies, the traditional teaching mode has exposed many drawbacks, which cannot meet the requirements of modern college teaching. The objective of this paper is to explore teaching innovations to improve teaching quality and efficiency.

II. TRADITIONAL TEACHING METHOD

Lecturing has been a traditional method with or without the use of PowerPoint slides to pass on the professional knowledge to the students. In China, traditional teaching in mechanics of materials involves lectures followed by tutorial and laboratory classes. A prominent feature of the traditional teaching method is to consider students as passive learners. The teacher delivers structured packages of theoretical or practical knowledge complete with analysis and conclusions, while students are expected to take notes, memorize and master the imparted information. This teaching method is really instructor-centered. There is no doubt that it is a fast and effective way to master basic concepts, but it is unfavorable to cultivate students' comprehensive ability.

III. PROBLEMS EXISTING IN CURRENT TEACHING

There are several key problems in the current teaching of mechanics of materials:

A. Limited instructional time

Since the 1990s, quality-oriented education has gradually found its place in Chinese education. Educational departments have adopted a series of measures step by step to introduce quality-oriented education. Then, the credit hours of the civil engineering program are reduced for many courses in order to provide a broad educational experience. However, high-quality learning is sometimes conflicted with the limited course hours of curricula.

B. Instructor-centered approach

In traditional lecture-based teaching, students participation in the classroom is minimal. Knowledge is simply transferred to and received by students. This one-way process repeats continuously, and the learning outcome is predetermined. If a student just listens to the teacher, learning efficiency will be low because students have not motivated to learn.[2-3]

C. Lack of ability to solve real engineering problems

In all mechanics courses, solving problems is an important part of the learning process. Though students understand theoretical concepts by lecture-based teaching, it is much more difficult to master how those concepts may be used in practical situations. Generally, most students are focused on concepts rather than on practice. They have little practical experience, which was unattainable through the standard classroom procedures.

D. Teaching and learning for examination

At present, educational departments have adopted a series of measures to introduce quality-oriented education that include encouraging students to take part on their own initiative, be ready for inquiry and try doing things by themselves. For a variety of reasons, teaching and leaning usually revolve around the final exam in China. Most teachers and students have become used to the exam-oriented education system, which ruins students' creativity and ability to solve practical problems. It cannot meet the requirements of quality education.[6]

IV. IMPROVEMENT MEASURES

A wide range of instructional methods exists; however, there is no single technique to guarantee effective teaching.

A. Optimization of Teaching Contents

Mechanics of materials is an academic discipline integrating with great logicality, systematicness and practicality. In the current situation, it has a lot of content and relatively few class hours. In order to ensure teaching outcomes, we deleted or abridged repetitive, old and too complex contents and added up-to-date knowledge on modern technological development based on the characteristics of civil engineering. Some topics are deleted, including fatigue and alternating stress, which are rarely encountered in subsequent courses. At the same time, teachers should devote time to research and keep abreast of the frontiers of knowledge. In the teaching process, we focus on the basic concepts and analytical methods rather than complex derivations. And then, emphasis should be placed on problem-solving as this helps students make the connection between theory and practice.

B. Lecture with Numerous Variations

There is no doubt that lectures are the most common vehicle for transfer of skills/knowledge. In fact, traditional teaching practice based on the textbook–chalkboard–lecture–homework–test paradigm has long been criticized as inappropriate for student learning. Generally, students are often socialized into the standard college-lecture large group format where the instructor lectures, students take notes, and interaction between instructor and student is otherwise confined to question and answer events.

It is essential that the interest of students should be awakened. There are many different ways in which an instructor can make the learning experience more interesting and memorable for students. To this end, more and more teaching aids are being used, which are sure to make classroom teaching more lively and interesting.

1) Multimedia teaching technology

Audio-visual aids serve a very important role in modern education. Multimedia teaching techniques are used widely in most courses. This makes teaching illuminative and impressive. It also saves teaching time and meets the requirement of fewer class hours. Often among the most popular with the students, multimedia presentation, which uses video, audio or both to present information, is an efficient way of supplementary means of teaching.[4-5]

Take the tensile test of low carbon steel as an example. A group of students begins a tensile test of a steel specimen in the materials lab. For a few moments, nothing appears to happen. Suddenly, with a loud bang, the specimen breaks and the test is over. The experiment lasts about a minute, and students are unable to see what had happened to the specimen. In fact, we can show the experiment in the form of video or animation. Knowing where things get interesting, we view the test in slow motion so students may observe the transition from elastic deformation to inelastic deformation and the necking down of the specimen before it fails.

Benefits of audio-visual media are as follows:

- It can bring engineering practice and mechanical phenomena in nature into the classroom.
- Dynamic teaching demonstration and intuitive explanation enable students to acquire knowledge easily.
- As a supplementary means of teaching, It is timesaving, labor-saving and efficient.

2) Real object demonstration teaching

Besides multimedia aids used during the presentation, teachers have access to a variety of objects in the classroom to help students understand mechanical concepts. chalk, textbooks, plastic rulers, and some paper are common examples of this kind of tool. Even a simple plastic ruler can be an indispensable teaching aid for teachers, which can be used to demonstrate the mechanical phenomena such as bending deformation and column stability. Chalk can also be a useful teaching tool to demonstrate brittle material properties, such as tensile or torsional properties.

Benefits of using real objects in teaching are as follows:

- It provides a direct link between theory and practice, which can really improve students' interest and understanding of mechanics.
- It helps to develop the important skill of active, open-ended, self-directed learning.

3) Implementation of case study teaching

Problem-solving skill is essential for engineering students; therefore, students need to be exposed to real-world problems. [7-9] Civil engineering students are taught the theoretical knowledge. However, they often lack the understanding of how to apply this knowledge to solve real engineering problems in the field. Consequently, case study that

encourages the blending of theory into real-life applications should be used.

The case study as a teaching strategy must be elaborated by the experienced teacher, with the active participation of the students. For students who have been exposed only to the traditional teaching methods, this calls for a great change in their approach to learning.

There are numerous advantages to use cases while teaching the mechanics of materials. Study cases help to:

- develop analytical and problem-solving skills;
- enhance cooperative learning skills;
- encourage team-working skills;
- connect theory and practice;
- involve learners in their own learning.

All cases are comprehensive and open-ended works. These cases should be carried out throughout a term, designed in line with course aims and in such a way that their completion will contribute in an important way of gaining a pass. As case studies may not have one right answer, the teacher should consider alternative responses and ask students analytical questions for further discussion of the case. Students study several solutions, choose the best option, and calculate it accurately using their mechanical knowledge learned in class. Deliverables are either a calculation document or a presentation or both, which must be completed at the end of the course.

For example, one of our common teaching cases is an entrance canopy design, as shown in Fig. 1. To design this structure, students should:

A) draw the free-body diagram of the system and write the equations of equilibrium;

B) determine maximum stress and deflection;

*C)*design a cantilever beam--the most important components of this structure.

All of the above requirements are simple and basic. Next, if we're planning a very deep overhang, the cantilever beams obviously cannot support it. What should we do? If two additional components are allowed, where can they be placed in order to increase the structural carrying capacity? The answers are varied. There are several common design methods, such as upper tie bars, lower brackets, columns, etc. (see Fig. 2, 3, 4).

Further, there are many details that must be considered in-depth and even calculated accurately. Take the design of adding lower brackets as an example. First, if a bracket is used to support the cantilever beam, what is the maximum depth that can go with on the overhang? Second, Where is the best supporting point for the bracket on the wall? After all, the farther down on the wall the bracket reaches, the more it acts like a post (or column). This reduces the push and pull on the wall and makes the canopy overhang deeper. Furthermore, Will the bracket lose its stability as a slender compression member?

Fig. 1. An entrance canopy

Fig. 2. A canopy with upper tie bars

Fig. 3. A canopy with lower brackets

Fig. 4. A canopy with columns

To sum up, this case involves a lot of knowledge of mechanics of materials, including material properties, internal force analysis, stress and deformation calculation, design of members in tension or compression, design of beams, the stability of columns, statically indeterminate systems, and even the concept of assembly stress.

Obviously, the aim of the case study is to synthesize, integrate, and apply the knowledge and concepts learned throughout the entire course by means of completing a real civil engineering project. From the analysis of these cases, students really realize that it is important to learn knowledge, and even more important to master the analytical method.

V. CONCLUSION

Mechanics of materials, a sophomore engineering course required by civil engineering major, is the study of the relationship between external loads on a member and the resulting deflections, strains, and stresses. The content in this course, which is foundational for the engineering field, is prevalent throughout junior- and senior-level courses.

Teaching is more of an art than a technology. Just as students can be taught to memorize answers, they can learn to approach problems and develop appropriate solutions. There are many methods for innovation to be introduced into the teaching of civil engineering, such as the case study. It is not suggested that alternate teaching methods (e.g., lectures, laboratories) be replaced by the case study. It is not a question of eliminating traditional education methodologies, but complementing them with the new innovative methodologies, making the most of both of them.[10]

With the comprehensive application of various methods, students can actively learn, understand, and retain even the most difficult contents. These methods play a very good role in teaching, ensure the teaching outcomes and improve the overall quality of students.

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