

Teaching and learning of fundamentals of mechanics in an innovative way to maximise students' understanding

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ABSTRACT: The fundamental subjects such as Statics, Mechanics of Solids and Properties of Materials are the building blocks of engineering knowledge. These subjects can be interesting and enjoyable to learn or they can be dry and boring to students, depending on the teaching methods and strategies that a lecturer uses. This paper describes some common problems that students face in grasping the concepts in these subjects. The author has developed some innovative teaching methods and strategies and these increase student understanding greatly, thus making learning more effective and enjoyable.

INTRODUCTION

The fundamental goal of an educator of engineers is to focus on developing the ability of students to approach creatively the wide range of challenges that they will encounter in their professional lives. The engineers we train should be capable of making the right decisions using sound judgment, have the capacity of critical thinking and be able to develop their engineering intuition. Thus, to prepare students for the engineering profession, a core of fundamental engineering principles, which underpin the applications, must be thoroughly taught and learned. It is the fundamental subjects such as Statics, Mechanics of Solids and Fluids and Properties of Materials that are the building blocks of technical knowledge. If the depth of knowledge of a student in these subjects is adequate, he/she will be able to specialise in any branch of engineering. It is, therefore, true that a great deal of responsibility lies on the shoulders of engineering educators to teach the subjects effectively so that our graduates can excel in their professional lives.

PROBLEMS IN LEARNING FUNDAMENTAL PRINCIPLES AND SOME MEASURES TO ADDRESS THESE PROBLEMS

The failure rates in Statics and Mechanics of Solids in all faculties in Australia and overseas is high. In some faculties, failure rates were found to be as high as 35%. Considerable research has been done on why the failure rate is so high and how to improve learning in these subjects and many papers have been published and presented at engineering education conferences. Goldfinch, Carew et al [1][2] and Dwight and Carew [3] did extensive research and presented a very informative table in which they summarised the causes of failure and the degree of success of various strategies and methods adopted by many academicians. They could not conclude with any concrete measure how to deal with the problems of students' poor performance in these subjects. In the author's experience, a student has real problems in understanding some fundamental concepts and principles if they are abstract in nature. These problems arise from the way in which information is commonly presented in lectures and engineering textbooks. The author describes a few causes of barriers to learning and the measures that he took to improve students' understanding and learning.

Idealised Diagrams

Subjects like Statics and Mechanics of Solids contain numerous abstract concepts, principles and ideas, which students need to use to solve problems related to real-world structures. The theory for the subjects can be found in a large number of text books, but it is difficult for students, who are generally beginners in gathering knowledge in engineering, to connect the idealised diagrams and examples given in the text books to more complex situations found in the real world. To an experienced lecturer and to an experienced professional engineer, connecting the real-world structure or structural member with its idealised model may appear very simple. But it can be a barrier to learning to an inexperienced student. If during a lecture a student cannot make the connection, he/she may see little relevance in the model and may lose the motivation to learn deeply and rote learning does occur.

Let us take an example of an idealised diagram of a simply supported beam as shown in Figure 1. Support A is a hinge, support B is a roller. An inquisitive mind of a student would ask where in practice *am I going to see such peculiar supports* (*a triangle with hatched line*, *a triangle with circles with hatched line*). If the student is not shown the steps before actually arriving at this line with peculiar triangles at the ends, he/she may have difficulty in connecting the idealised models with the real structural member shown in Figure 2. Such a student may simply rote learn the model, without real understanding. Making the steps explicit is very often ignored by lecturers, because it is not done in conventional engineering mechanics books.

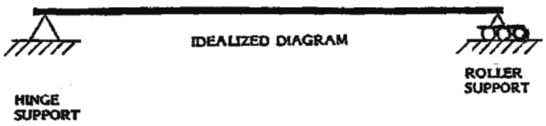

Figure 1: Simply supported beam.

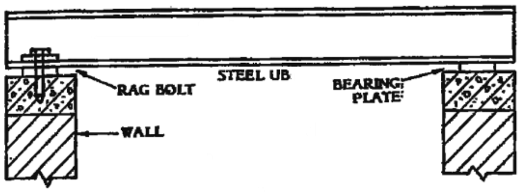

Figure 2: Structural steel beam.

The Use of Assumptions

Many engineering problems are solved using assumptions, which are valid within certain limits. In the author's experience, almost all students had difficulty in understanding what these assumptions mean. They appear to have misconceptions that they can make any assumption rather than using assumptions within defined limits. Let us take a case of one of the valid assumptions that one makes in determining the bending stresses in a beam: A plane section remains plane before and after bending. No matter how much the lecturer may talk about this, students find it difficult to grasp this phenomenon. This is a relatively easy concept to demonstrate using three dimensional model beam made of sponge with vertical and horizontal lines drawn on it (Figure 3). A lecturer can explain by showing this to students and students can see that vertical lines remain straight and they do not warp, which proves that the assumption is valid.

Figure 3: A plane section remains plane before and after bending.

Application of Three Golden Rules of Statics and Free-body Diagrams

Solutions of almost all problems in engineering mechanics (Statics) require application of three equations of equilibrium and drawing of free-body diagrams. If, as educators of Statics, we could instil an understanding of these two topics vigorously to a student, he/she can solve any problem in Statics with ease. Students often find it difficult to grasp these concepts as we do not see with our open eyes all the forces that have been acting on a rigid body and perpetual equilibrium is maintained. Here the lecturer can show some examples of structures that failed catastrophically in the real world due to excessive loadings and when equilibrium has been disturbed.

Responsibility on the Part of the Faculty

Engineering Mechanics is a building block of engineering knowledge and it is taught in the early years (mostly first year) of any undergraduate degree. Its importance makes it critical that faculties/schools are careful in dealing with all aspects of managing these subjects.

Very often a newly appointed academic staff member, with no or very little practical knowledge in structural design, is assigned to teach these subjects and, often, it is found that he/she is not an effective teacher for students' learning. To become an effective teacher in Statics and Mechanics of Solids, one has to have knowledge and skill in design and construction of structures and or machines. These subjects should be taught and managed by a senior academic who has practical experience in design and construction of structures.

Effective Teaching of Fundamental Principles

Lecturers teaching fundamental principles need to consider their goals very carefully in relation to student learning. A lecturer in these fundamental subjects should take into consideration the fact that the concepts, principles and laws were developed over many centuries by scientists and engineers like Galilio, Verignons, Euler, Columbs, Newton et al, and it is hard for a student to grasp all those theories within one semester. The author sees his role as:

- To be aware of, and help students to overcome, the common barriers to learning in fundamental subjects, such as engineering mechanics and mechanics of materials;
- To motivate the students to learn the subject and to create enthusiasm and curiosity by bringing examples from real world structures and structural members;
- To facilitate students' learning by adopting improved methods of teaching and learning: inventing, creating and devising teaching resource materials, which illustrate and reinforce concepts;
- To foster students' critical thinking regarding engineering problems by providing choices based on the critical assessment of alternatives;
- To create an environment in the tutorial class, which is conducive to learning, where students are encouraged to participate actively in the class;
- To urge students to form a positive attitude to their studies and future profession and make aware of their social responsibility in designing a structure.

As an example of how to achieve the objectives and goals, the author carefully plans his teaching strategies and methods to incorporate a range of measures, beginning with idealised diagrams in transparencies and handouts to physical models that illustrate conceptually difficult principles.

Transparencies

The author has experience in teaching fundamental subjects with the help of chalk/markers and black/white board. It has been a successful approach for small classes for many years but it has limitations for a large class. He has found that teaching with transparencies with the help of two over-head projectors (OHP) is very effective. In the fundamental subjects there are many machine parts and structural elements which need to be drawn and it is time consuming to draw on the board.

The structural elements and machine parts can be drawn beforehand, and in the class, the slide can be placed on one OHP. The solution of the problem can be shown step by step and with ease on another OHP. With OHPs, it is possible to make eye contact with students during the lecture and this further helps the lecturer to keep the attention of the whole class. When compared to Power Point presentations, drawing and solving problems related to parts of structures and machines on transparencies are more effective for students' learning.

Figure 4: Eccentrically loaded member.

Handouts

For conceptually difficult topics in these subjects, handouts, which illustrate underlying principles with diagrams and graphics, greatly enhance the learning ability of students. Handouts should not be long winded and writing should not be descriptive. In fact, it is more effective if you use as little writing as possible and make sure that the topic is not fully discussed in the handout. Handouts should have blank spaces, where student can write on the diagrams, sketches and photographs during the lecture.

The usefulness of small physical models in explaining the conceptually difficult principles in Statics and Mechanic of Solids cannot be underestimated. The author believes that these are probably the most effective teaching aids one can use to explain abstract concepts, principles and ideas. A lecturer can easily design, devise and fabricate physical models such as truss models with balsa wood and drinking straws; models of beams made of sponge; plastic rods to explain buckling of columns. A few diagrams of such models are given in Figures 4, 5, 6 and 7.

Figure 5: Shear in steel bolt and timber.

Figure 6: Horizontal and vertical shear in timber.

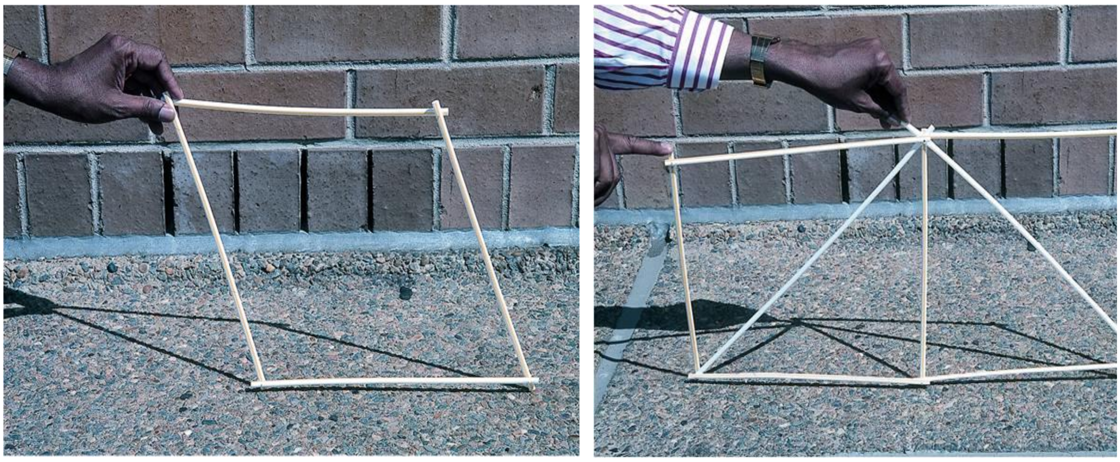

Figure 7: Construction of trusses.

Practice Problems

To link the foundational learning in the classroom with application in the real world, the author developed a number of problems which are directly related to practical engineering problems. A UNESCO study on the design of curricula has this to say:

... One series of studies conducted at the college level reported that 50 percent of the material known when a student finished a certain college course is forgotten within one year, and 80 percent is forgotten in two years. These students also have suggested certain conditions which can greatly reduce the amount that is forgotten. One such condition is the opportunity to use the new knowledge in daily life. This suggests that objectives concentrating on specific knowledge are more attainable, and the results are more permanent, when there are opportunities for the students to use this knowledge in their daily activities [4].

The author has developed some practice problems from structures in and around students' immediate environment. Some of these structures and structural members from the surroundings of UTS are shown below in Figures 8, 9, 10, 11, 12 and 13.

Figure 8: Vertical Cantilever (Street Light Tower).

Figure 9: UTS Tower (R.C. Framed Structure).

Figure 10: Pedestrian bridge joining two UTS buildings: member in tension and bending.

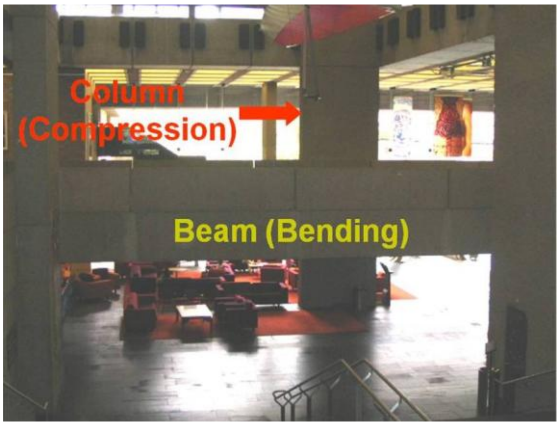

Figure 11: Frame structure (outside class room in UTS).

Figure 12: Bus stop with Cantilever Roof.

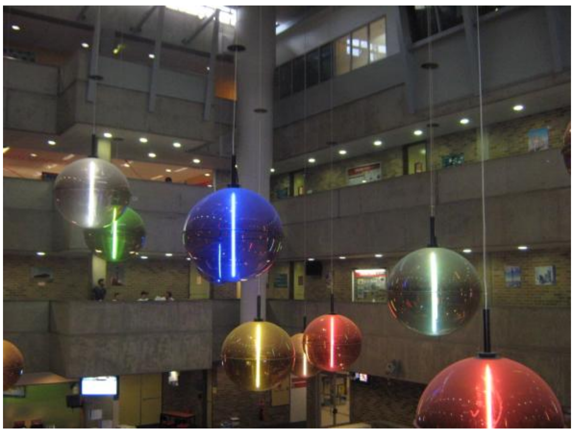

Figure 13: Tension structures (outside class room in UTS).

CONCLUSION

It is important for a lecturer, who is in charge of teaching fundamental subjects such as Statics and Mechanics of Solids to recognise the fact that students experience problems in learning these subjects. Once this is recognised, the lecturer can adopt a variety of teaching strategies, which make these subjects interesting and comprehensible so that learning can be effective and enjoyable. Experience has shown that use of the methods and strategies described in this paper have proved successful in creating interest and enthusiasm, and the author has received consistently positive feedback from students.

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