Teaching and Learning of Statics and Mechanics of Solids: Some Problems and Solutions

Rezaul Karim
University of Technology, Sydney, Sydney, Australia
rezaul@eng.uts.edu.au

Abstract: *This paper describes some common problems that students face in grasping the concepts in fundamental engineering subjects such as Statics and Mechanics of Solids. It also presents some simple methods and strategies that the author has adopted which increase student understanding greatly, thus making learning more effective and enjoyable.*

Introduction

In all branches of engineering, there are core subjects, which focus on fundamental principles, concepts and ideas. As they provide a foundation for later engineering subjects they are taught in the initial years of students' academic life. Conceptual and practical understanding of each topic in the fundamental subjects such as Engineering Mechanics (Statics) and Mechanics of Solids are of utmost importance to almost all engineering disciplines (civil, mechanical, aeronautical, marine, mining engineering and etc.). Application subjects such as Structural Design and Machine Design require a sound knowledge and skill of a student in Statics and Mechanics of Solids to design and construct any structure or structural member and any machine or machine part. It can thus rightly be said that these fundamental subjects are the building blocks of engineering knowledge. A student with poor foundations in these subjects will not only face appreciable difficulty in the subsequent years of his/her studies, but also later in his/her professional life. As such the standard of assessment in these subjects should be high and the academic, who are in-charge of teaching these subjects, ought not to contemplate lowering the standard.

The failure rates in these two subjects, Engineering Mechanics and Mechanics of Materials, in all faculties in Australia and overseas is considerably high. In some faculties failure rates were found to be as high as 35%. Considerable research has been done on why failure rate is so high and how to improve learning in these subjects and many papers were published and presented in engineering education conferences. Goldfinch, Carew and et al (2008) and Dwight and Carew (2006) did aextensive research and presented a very informative table where they summarized the causes of failures 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. This paper outlines some of the approaches that have been found to be effective in addressing students' understandings when learning engineering mechanic and mechanics of materials.

Problems in Learning Fundamental Principles and some measures to address these problems

In the author's experience, a student has real problems in understanding some fundamental concepts and principles which 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 that generally create barrier to learning and the measures that he took to improve students' understanding and learning.

The Idealized 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 idealized diagrams and examples given in the text books to more complex situations found in real-world. To an experienced lecturer and to an experienced professional engineer connecting the real-world structure or structural member with its idealized 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 idealized diagram of a simply supported beam (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 a 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 idealized models with the real structural member (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

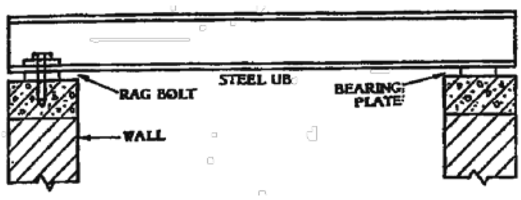

Figure 2: Structural steel beam

The Use of Assumptions

Many engineering problems are solved using assumptions which are valid within certain limits. In author's experience he noticed that almost all students had difficulty in understanding what these assumptions mean. They appear to have misconceptions that they can make any assumption rather than use assumptions within defined limits. Let us take a case of one of the valid assumptions that we make 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). 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 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 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 Faculty/ Schools are careful in dealing with all aspects of managing these subjects. Very often newly appointed academic staff with no or very little practical knowledge in structural design are 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 academician who has practical experience in design and construction of structures.

In many Faculties in Australia lecture classes are very big and typically are three hours in duration. This long duration, even with break, is not conducive to learning due to the fact that students' concentration decreases with time. Recently (Autumn 2010) in the Faculty of Engineering of UTS Engineering Mechanics (Statics), lecture duration time has been amended from one three hours class to two-two hours classes each week. There has been a marked improvement in students' learning and their performance. Number of failure has been reduced markedly from average 35% per semester previously to 21% in Autumn 2010 when the amendment has been introduced.

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 of the fact that the concepts, principles and laws were developed over many centuries by scientists and engineers like Galilio, Verignons, Euler, Columbs, Newton and et al and it is hard for a student to grasp all those theories within one semester. Author sees his role:

- 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 structure 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 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 got 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 it is placed on one OHP. The solution of the problem can be done step by step and with ease on another OHP. With OHP it is possible to make eye contact with students during lecture and this further helps the lecturer to keep the attention of the whole class. When compared to Power point presentation drawing and solving of problems related to parts of structure and machine on transparencies are more effective for students' learning.

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.

Models

The usefulness of small physical models in explaining the conceptually difficult principles in Statics and Mechanic of Solids can not be under estimated. 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 straw; models of beams made of sponge; plastic rod to explain buckling of columns. A few diagrams of such models are given below (Figure 4, 5, 6 & 7).

Figure 4: Eccentrically loaded member


Figure 5: Shear in steel bolt and timber

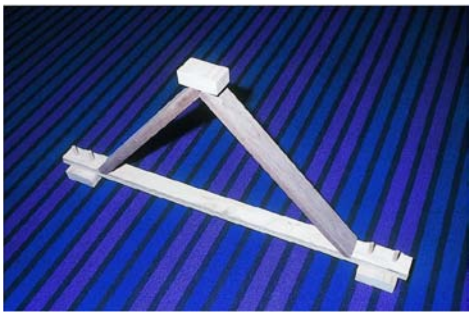


Figure 6: Horizontal and vertical shear in timber

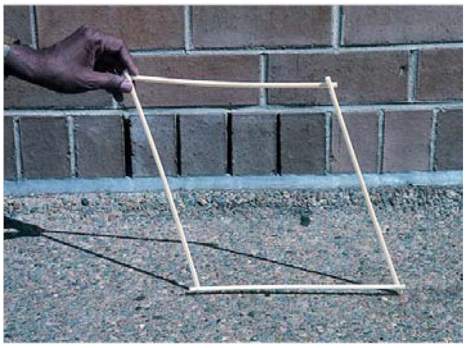
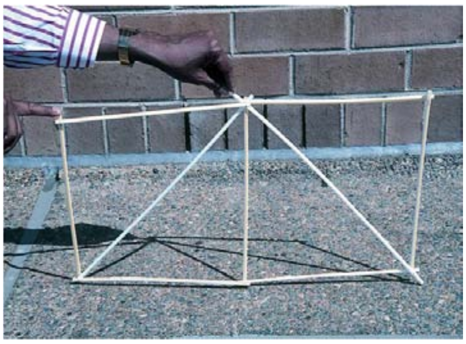

Figure 7: Construction of trusses

Practice Problems

To link the foundational learning in the classroom with the application in the real world the Author developed a number of problems (questions) which are directly related to practical engineering problems. A UNESCO study (Grayson 1977) 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"

The author developed some practice problems from structures in and around students' immediate environment (in and around UTS City campus). Some of these structures and structural members from the surrounding environment are given below (Figures 8, 9, 10 & 11)

Figure 8: Vertical Cantilever

Figure 9: Tension Structures (Outside class room)

Figure 10: Pedestrian Bridge: Member in tension and bending

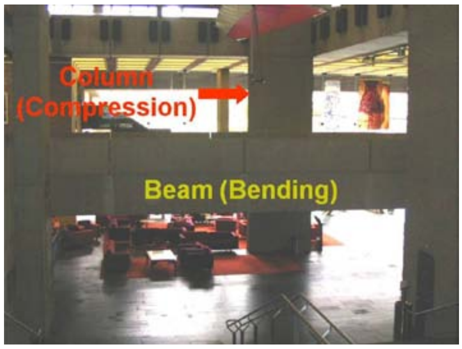

Figure 11: Frame structure (Outside class room)

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 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.

References

Goldfinch, T., Carew, A. L., & McCarthy, T.J.(2008). Improving Learning in Engineering Mechanics: The Significance of Understanding; *Proceeding of AaeE Conference.* Yeppoon.

Goldfinch, T., Carew, A. L., Gardner, A., Henderson, A., McCarthy, T. J. & Thomas, G.(2008). Cross-institutional comparison of mechanics examinational: A Guide for the Curious; *Proceeding of AaeE Conference.* Yeppoon.

Dwight, R., & Carew, A. (2006). Investigating the causes of poor student performance in basic mechanics. *Australian Association of Engineering Education 17th Annual Conference.* Auckland, New Zealand.

Grayson, P. L. (1977). *The Design of Engineering Curricula*. UNESCO, Paris.

Karim, M.R. (2002). Teaching fundamentals of engineering, *6th Baltic Region Seminar on Engineering Education & 2nd German Seminar on Engineering Education*. Wismar/Warnmunde, Germany.

Karim, M. R. (1993). Use of Simple Physical Models to Facilitate Students' Learning, *Proc. conf. on Aiming for Quality in Engineering Education.* AAEE, Auckland, New Zealand.

Rezaul K. (1993). Interesting, Effective and Enjoyable Approaches to Teaching Fundamentals of Engineering. *Teaching Quality and Quality of Learning in Professional Courses* (pp. 147-153). Australasian Government Publishing Service, Canberra.