Abstract— Engineering Mechanics and Strength of Material are foundation courses to civil and mechanical engineering disciplines. The courses, by nature, are highly conceptual and abstract. The state of the art techniques like active learning or team based learning do not help reduce the abstractness of the courses and do not really succeed in accruing adequate learning. The courses are taught too early in the programs that make it difficult to use project based learning approaches. In fact, lack of conceptual clarity in these foundation courses comes in the way of developing industry standard capstone projects. Authors have therefore conceived a self learning model based learning approach for these courses. Authors have developed various models that demonstrate different concepts such as difference between the action of bending moment and twisting moment and effects thereof, difference between the action of axial force and shear force and their effect, the concept of moment of inertia and its effect on deflection of a beam. The student survey shows these models not only enhance conceptual understanding of complicated terms and theories in highly conceptual courses but also motivate the students to think on their own. The hands on experience on these models helps student to understand the connection between theory and practical problems. These results in developing critical and innovative thinking skills required to solve challenging real world problems.

Introduction

The learning process can be divided into three steps comprehension, recollection and application. Comprehension is the absorption of new ideas, whereas, recollection is the process of remembering. The application – an essential element of any learning, especially in engineering education - is an important step. However, most engineering programs devote the bulk of their contact hours to cater to the first two steps at the cost of the application. That results in preparing the students mostly for examination than for industrial practice. Engineering is an unforgiving and demanding environment and for students to succeed as engineers, they must go far beyond theories and exam-taking(Gordon, 2007). In addition to a good understanding of engineering science fundamentals, the important desired attributes of an engineer include application using creative thinking (Desired Attributes of an Engineer, The Boeing Company, 2006). One of the important Graduates Attributes defined by NBA (NBA, 2013) is the ability to apply the knowledge of engineering fundamentals to the solution of complex engineering problems. In this paper, the focus is on using self learning models as an innovative teaching and learning strategy to cultivate application oriented creative thinking.
Literature Review

It is now generally accepted that students learn in a variety of ways, many of which may not match their professors’ preferred ways of thinking or teaching (Felder et al., 2000). Numerous studies have demonstrated that active, collaborative, problem-based learning are superior to traditional lecture-based methods (Dym et al., 2005; Hake, 1998; Prince, 2004; Rosselli and Brophy, 2006; Smith et al., 2005). Review of number of studies comparing lecturing with other methods have found that: unsupervised reading is better than lecturing; lectures are quite ineffective for stimulating higher-order thinking and cannot be relied on to inspire students; and the attention span of the students in lectures can be maintained for about 10 to 15 minutes, after which learning drops off rapidly. (Bligh, 1971; Biggs, 1999). The hands-on approach to engineering education is pedagogically sound, sustainable and cost effective (Morell et al., 1998).

In the traditional approach to higher education, the professor dispenses wisdom in the classroom and the students passively absorb it. Research indicates that this mode of instruction can be effective for presenting large bodies of factual information that can be memorized and recalled in the short term. If the objective is to facilitate long-term retention of information or to help the students develop or improve their problem-solving or thinking skills or to stimulate their interest in a subject and motivate them to take a deeper approach to studying it, instruction that involves students actively in the process has consistently been found more effective than straight forward lecturing. (McKeachie, 1999, Bonwell and Eison, 1991, Sutherland and Bonwell, 1996). ABET (Accreditation Board for Engineering and Technology) Engineering Criteria 2000 expects engineering programs to develop an ability to identify, formulate, and solve engineering problems and an ability to engage in life-long learning.

Physical models have better potential, both to educate and motivate the students and can significantly improve their learning. To understand the views and perceptions of engineering undergraduate students on engineering education, a survey of forty-seven undergraduate engineering students (17 females and 30 males) was carried out. The results showed that students strongly emphasized the importance of hands on experience and real work examples in enhancing the quality of engineering education. (García and Liu, 2007)

Industry is one of the primary customers of the university. Those customers are constantly demanding the academia to make curricula more relevant to professional practice. Engineering education faces significant challenges as it seeks to meet these demands from the engineering profession in the twenty first century. Engineering faculty should mould itself to meet the changing environment and demands of the industry, which in turn will require effective professional development for both new and experienced instructors alike. Lecturing alone is not sufficient; students benefit from interactive hands-on experiences; and experiential, team-based learning involving student, faculty and industrial participation enriches the educational process and provides tangible benefits to all. (Lamancusa et.al., 2008)
Significance Of Experience

The traditional methods of teaching engineering involves passive lectures and practicals that require little emotional involvement or imagination on the students’ part. In the desire to prepare students for every contingency that they may encounter in their careers, we run the risk of overwhelming them with facts on a superficial level, at the expense of deep understanding and transference. Since it is not possible in four years to teach students everything they will need to know, the ability to acquire new knowledge is the most important outcome for a successful engineering career.

\[
\begin{align*}
I \text{ hear and I forget.} \\
I \text{ see and I believe.} \\
I \text{ do and I understand.}
\end{align*}
\]

– Confucius.

\[
The \text{ only source of knowledge is experience.}
\]

- Albert Einstein

The “doing of engineering” on meaningful self learning models can motivate students to learn the difficult fundamentals and will develop an ability to engage in life-long learning. These hands-on demonstrations use visual learning; they ensure that the student is active and, when done right, clearly show enthusiasm and the joy of learning. Hence it motivates students to think critically, analytically and solve problems.

Background

The first author joined teaching - after successful graduation and industry experience – to realize challenges in teaching concepts related to the subjects like Applied Mechanics and Strength of Materials. That resulted in development of self learning models described in the foregoing sections. These models helped to explain these theories and concepts thoroughly to the students in stipulated period 14 weeks. They are being improvised over last five years. The models and methods have resulted in excellent feedback from peer teachers, students and experts from industry. It was pointed out by many that these models help develop creative and innovative thinking ability in the student required to solve challenging problems in industry.

Description Of Models

A. MODEL 1

This model explains the difference between the action of bending moment and twisting moment. It also differentiates between the effects of these moments.

a) When the applied couple is in the plane of the member it is subjected to bending. To study the effect of bending on the member observe the changes in the shape of squares and straight line
marked on the surface the member. The length of the member on the upper side will increase where as the length of the member on the lower side will decrease. This indicates that compressive stresses are developed on one side and tensile stresses are developed on the other side. The length of straight line remains constant. That means the length of middle layer do not change. So it is called as neutral layer.

![Fig. 1a:- MODEL 1, Effect Of Bending Moment](image1) ![Fig. 1b:- MODEL 1, Effect Of Twisting Moment](image2)

b) When the applied couple is in the plane normal to the member it is subjected to twisting or torsion. Due to this each cross-section is subjected to shearing. So shear stresses are developed in the member. Maximum stresses are developed at the surface of the member. This can be experienced by observing the changes in the shape of squares and straight line marked on the surface the member.

B. **MODEL 2**

This model explains the difference between the action of axial force and shear force. It also differentiates between the effects of these forces.

a) When the applied load is normal to the top surface there will be decrease in the length of the member. That indicates the development of compressive stresses in the member. Refer Fig 2a.

![Fig. 2a:- MODEL 2, Effect Of Axial Force](image3) ![Fig. 2b:- MODEL 2, Effect Of Shear Force](image4)
b) When the applied load is parallel to the top surface of the member, its shape will change from rectangle to parallelogram. However there will not be any change in the length of the member. That means the member is in pure shear. Refer Fig 2b.

C. MODEL 3

This model explains the concept of moment of inertia and its effect on deflection of a beam.

a) The beam having rectangular cross-section is positioned such that its width is more than its depth. When the load is applied on it, it is subjected to considerable deflection. Refer Fig 3a.

b) The same beam is then rotated through 90 degrees. Hence it is placed such that its depth is more than its width. When the load is applied on it, it is subjected to negligible deflection. Refer Fig 3b. This is because, in first case the moment of inertia of the cross-section of the beam is very small as compared to that of the second case.

D. MODEL 4

Students often have difficulty with “what is shear in the beam?” and “How is it developed?”. This model explains the concept of shear force and shearing action of load on the beam. Model
consist of beam in three parts, connected to each other by magnets. Ends of the beam are fixed. When the transverse load is applied on the beam, shearing action can be experienced.

E. MODEL 5
This model explains the effect of axial force on long and short columns. When the axial load is applied on the long column it bends or buckles or cripples. When the same load is applied on the short column it remains straight i.e. it do not buckle. Hence short column can support greater load as compared to long column having same cross-section. Refer Figs 5a and 5b.

F. MODEL 6
Another difficulty which is faced by the students is “Even though the applied load is vertical, how come horizontal shear is developed in the beam?” This model explains the concept of horizontal shearing action of the vertical load on the beam.

a) The beam consist of five strips placed simply on each other. When the load is applied on this beam these five strips bend independent of each other. Because these strips are not connected to each other. It results in considerable deflection, which can be noticed in the Fig 6a. In second case the five strips are firmly pasted to each other. When the load (same as that of first case) is applied on it it undergoes negligible deflection, which can be noticed in Fig 6b. This is because in this case the five strips act as one unit. The shearing between the strips is resisted by the adhesive. In other words the moment of inertia of cross-section of the beam in second case is 25 times that of the first case.

Students’ Response
To evaluate the performance of these self learning models in improving students’ understanding following exercise was performed. The course of Strength of Materials was taught to the Second Year Civil Engineering students using these models for three consecutive years. The students were divided into two groups A and B of 30 students each. We taught ‘Shear Force and Bending Moment’ using the models 1, 3, 4 and 6 to group A and without using the models to group B. We also taught ‘Stresses and Strains’, ‘Columns’ and ‘Torsion’ using the models 1, 2 and 5 to group B and without using the models to group A. The students were then asked to evaluate the
performance of these self learning models through a questionnaire. The students were asked to rate criteria A, B, C and D on 1 to 5 scale. The overall response of the students was consistently favorable in three consecutive academic years (AY 2010-11, AY 2011-12, AY 2012-13). The evaluation of performance of AY 2012-13 is tabulated in Table -1. Yearwise mean ratings of evaluation of performance of Self Learning Models

### Table 1: Percentage and mean ratings of evaluation of performance of Self Learning Models for A. Y. 2012-13

<table>
<thead>
<tr>
<th>Criteria</th>
<th>1 Strongly Disagree</th>
<th>2 Disagree</th>
<th>3 Neutral</th>
<th>4 Agree</th>
<th>5 Strongly Agree</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Made the lecture interesting</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>31.67</td>
<td>68.33</td>
<td>4.68</td>
</tr>
<tr>
<td>B Made the lecture interactive</td>
<td>0</td>
<td>0</td>
<td>11.67</td>
<td>26.67</td>
<td>61.67</td>
<td>4.5</td>
</tr>
<tr>
<td>C Helped to understand the concepts in Strength of Materials thoroughly</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>23.33</td>
<td>76.67</td>
<td>4.77</td>
</tr>
<tr>
<td>D Helped to understand the link or connection between theory and practice.</td>
<td>0</td>
<td>0</td>
<td>15</td>
<td>36.67</td>
<td>48.33</td>
<td>4.33</td>
</tr>
</tbody>
</table>

Fig. 1: Year-wise mean ratings of evaluation of performance of Self Learning Models
Conclusion

The student survey indicates that self-learning model-based approach made the lecture interesting and interactive. The hands-on experience on these models helps students understand the connection between theory and practical problems. Hence this approach, not only enhances conceptual understanding of complicated terms and theories in highly conceptual courses but also motivates the students to think on their own. This thinking process leads to development of critical and innovative thinking skills required to solve challenging real-world problems.

REFERENCES


