Active Learning Methods for Teaching Dynamics - Development and Implementation

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Abstract - An active learning approach was developed and implemented to address inherent difficulties in teaching subjects in engineering dynamics. A variety of active learning exercises have been introduced to replace a portion of traditional lecture presentations. Demonstrations sessions involving student participation in simulations using MECHANICA_Motion, physical models and Videos have been introduced. Evaluation of this activity was performed via traditional feedback mechanisms as well as student journals. They indicate that such activity could bring about significant benefit in teaching subjects in engineering dynamics.

Introduction

In many subjects in physical sciences and engineering, students often have difficulties visualising some of the theoretical concepts. This problem is of greater concern, when teaching subjects with substantial mathematical content and rich industrial applications. To this end, it is known that textbook or assignment problems can only provide limited help.

An active learning method is developed and implemented, to address this problem in teaching subjects in Engineering Dynamics. An element of active learning is introduced to replace a portion of the conventional lecture presentation. Primarily, this component is introduced via student participation in building demonstration models to enhance visualisation of some important theoretical concepts and/or practical applications. The demo models are created using a variety of techniques. Efforts were concentrated on building physical models as well as multi-media presentations. It is believed that these so called “show and tell” demonstration sessions can only lead to a better visualisation and understanding of theoretical concepts throughout the project. Although, this project is initially concerned with the year 2 dynamics subject in Mechanical Engineering, the approach developed can easily be adapted for teaching other subjects in Dynamics, dynamical systems and control systems.

Studies by many educational researchers confirm that active learning strategies will result in more retention of subject matter and a deeper comprehension of the concepts covered in class. A comprehensive view of this approach has been given in the book by Meyers and Jones [1]. The authors of this book not only try to define and give an understanding of this approach, but suggest many useful strategies and also discuss the required resources in general.

In this paper, the term “active learning” is used to describe a classroom environment where the learner plays an active role in the information processing during a lecture. Thus, a completely passive class would be one where the instructor delivered lectures and the students merely took notes throughout the class time. For the subject under consideration, this element is introduced partially at present. However, the experience gained from this exercise indicates that increasing this form of learning in the future, for subjects in Dynamics, is beneficial.

In this paper, the problem is first stated in detail and a brief description of the subject planning is introduced. Subject Planning consists of design of the subject as well as the “show and tell” demo sessions. Also, in order emphasise the nature of the subject, a brief description of the demonstration topics and the bases for their development is provided. This report also briefly highlights the assessment details of this activity as well as the resource implications. Possible benefits to be gained from this form of learning or alternatively the goals of this project are also summarised. The effectiveness of this teaching approach for this subject is evaluated using student journals and organised feedback sheets. The results from these instruments are discussed. The results show that the initial goals set for this project have been achieved.

Subject Description

The subject under consideration in this project was year 2 Dynamics taught within the Department of Mechanical Engineering. The above subject is rich in mathematics and forms the basis of understanding of many industrial applications. The subject also stresses the importance of mathematics as an effective problem solving tool. In teaching this subject a proper marriage between the two is important. In teaching these subjects, while rigorous development of
theoretical concepts are considered important, the relevance of the theory to important practical examples must not be neglected. Large class size (90 students) makes this task even more difficult. This subject forms the fundamentals of two other subjects in this stream (Year 3 Dynamics and Year 4 Control Systems Design) and hence it is important that the students get a good understanding of the concepts. Past experience in teaching subjects in this stream indicate that certain basic concepts are not easily passed on to students via the conventional lecture based presentation. Hence, a change to include an element of “active learning” was introduced.

Why Active Learning Methods?

Active learning as described by educational researchers is based on the basic assumptions that learning is an active process and that different people learn in different ways. Meyers and Jones [1] recognise that two corollaries stem from these assumptions: Students learn best when learning process is achieved by doing and that any one teaching approach often fail to get through to significant number of students. Kolb’s learning style inventory (Kolb [2]) also reassures that “doing” plays a major role in the learning cycle.

Thus, lectures can be more effective when they are punctuated with brief active learning exercises. The role of conventional lectures as well as the information processing during lectures pose several questions (Beasely [3], Johnstone and Su [4]). Active learning methods for teaching the subject under consideration are primarily driven by the following:

- Motivate students to learn to appreciate mathematics for problem solving:
  Brief active learning exercises are proposed for providing motivation for the students to enjoy mathematics and establish a strong correlation with the physical processes they investigate. Many researchers have commented the seriousness of this issue (see, e.g., Stice [5]). In order for the students to apply the concepts they learn to problems that they have not encountered before, it is essential that a strong foundation in developing important concepts be provided to students. “What matters is… not just what students know but what they can do with what they know”

- Students with diverse learning, cognitive, and motivational styles:
  In the recent past, diversity in student population has significantly increased. There is an appreciable increase in the student numbers owing to the pressure from the community and hence from the government. This increase leads to classes with a wide range entrance scores. Also, in engineering faculties throughout the world, numbers of minorities, in particular, women have been on the increase. In the future, the engineering faculties will be expected to increase the women in take. In addition, a significant increase in the foreign student take is also desired by many institutions to increase the revenue to be gained via full fees. In order to accommodate this diversity as well as inherent learning styles (Felder and Silverman [6]) of students, some change from conventional teaching methods is warranted.

- Reduce the conventional activity “listen, take notes, give it back” and replace with some alternatives:
  It has been shown in many studies that during a fifty minute lecture, students retain more (about 70 %) in the first ten minutes and only very little (about 20 percent %) in the last 10 minutes (see, e.g., Meyers and Jones [1]). Hence, it makes sense to turn part of the lecture (say last ten to fifteen minutes ) in to a totally active learning exercise. This change can only be of benefit to the students and can only result in very little drawbacks.

- Give students an opportunity to gain knowledge effectively:
  Addition of active learning component will undoubtedly increase the level of understanding and retention while providing them with knowledge about more topics which would not have been possible to introduce via conventional teaching activity.

Education Elements of Project

The prime educational element in this project is the subject design which is described in detail in a subsequent section. It essential that the subject is designed so as to obtain maximum benefit from the active learning exercise. In order to make this activity a success, various developments and innovations in the instructional technology were employed. Finally, significant care was taken to evaluate the success of this activity, in order that the usefulness of this activity may be ascertained. The future modifications of this form of activity heavily rely on the evaluation.

Approach for Subject Design / Assessment

It was first necessary to identify the essential principles that must be conveyed to students within the present subject, in order that the subject may be designed properly. It is expected that all students must get a good understanding and retention of these principles before they take other subjects in the
dynamics stream and also when they complete their degrees. Then, the following important question was posed: Can these principles and their application be demonstrated as part of the lecture / tutorial by (a) Simple physical Models (b) Numerical Experiments and Animation using MECHANICA motion / Matlab / Simulink / Maple / Other High level Language or (c) Practical Examples via videos. In order to maximise knowledge transfer as well as retention, introduction of “show and tell” sessions to be performed by groups of students was proposed. It may be noted that these sessions were considered to be much more valuable than the conventional laboratory sessions, since the number of topics/principles that can be covered via the former activities is much greater. However, topics for this activity was also chosen to complement principles covered in conventional laboratory sessions.

Much care went into the choice/design of topics. A common desirable element present in all of the topics was the dynamic visual information. By adding the dimension of time which is a “must” in learning dynamics, the delivery of information was to be greatly enhanced. To varying degrees, these topics were expected to assist the students in enhancing the depth of understanding as well as the retention rate.

It was considered that the topics must also offer a variety in modes of presentation and concepts to suit the interest of a particular group. This was thought to be essential for the success of completion of a demo. Topics were discussed during week #2 and were assigned based on students’ choice (using an order of preference). In cases where more than one group indicated liking on one project, lecturer made an arbitrary decision. A change of mode of presentation was also allowed if the students could justify that another mode was more suitable for demonstration of a particular topic. It was thought to be important since choice of the most suitable demo was desirable.

Sufficient information on the topics as well as the usefulness of these sessions were provided to the students so that they knew exactly what roles they were playing. Twelve groups comprising of eight students were chosen. To maximise communication within groups, same groupings were used for regular lab sessions in this subject and in another subject.

Two presentations by each group were scheduled during the semester. First presentation was distributed during the semester. Final presentation was arranged during 3 lecture / tutorial slots. The final presentation was arranged at the end of the semester for the following reasons: (a) to give students sufficient time to work on their projects (b) to enable reiteration of some of the concepts before the exams. In one sense, having a final presentation during a lecture when the concept is taught is desirable while co-ordination efforts to achieve this is felt to be enormous. However, this arrangement may be easily achievable in the following years.

Four tutors were assigned for this activity. They played a role of a manager/consultant. Each tutor looked after 3 groups. It was believed that they played a major role in this activity as well. They were expected to help the students discover the concepts while the students were expected to ascertain the details of the delivery themselves. Also, their guidance was thought to be essential since the students would require assistance in topics which were scheduled to be covered in the latter part of the semester.

In general, the assessment of this activity was based on the following: “Quality” of demo, Demonstrated Link to concepts associated with Dynamics, Clarity of Presentation. Assessment of this activity was in some sense a difficult task due to the various aspects which had to be assessed. An additional difficulty arose, since the projects were carried out in groups. There are several ways a group activity can be assessed. Autorating is one process which has been used successfully in the past (see, e.g., Brown [7]) and could have been easily adapted to the present situation. However, since the demo activity is worth only 15 % of the overall subject marks, it was decided not to make an elaborate scheme for this purpose. Instead a portion of the marks was given based on a simplified Autorating scheme. The details of the agreed scheme can be found in the study by Asokanthan [8].

### Student Feedback

Student Feedback was considered to be an essential part of the project to bring out the important aspects of this project. Three different modes were used for this purpose. First approach made use of a lecturer designed feedback sheet. As described earlier, four groups performed MECHANICA simulations, four groups built physical models, three groups prepared videos while only one group was involved with MAPLE simulation. Hence, to make any meaningful judgements, data for the MAPLE group cannot be considered seriously due to its small sample size.

The second approach used journals that were written by students on chosen days when the demos took place while the third approach used the traditional TEVAL form at the end of the semester. This form enabled meaningful comparison with results obtained for this subject during previous years in the absence of any active learning element.

### Feedback via Instructor designed sheet

The details of the feedback conducted are documented in the paper by Asokanthan [8]). In order to demonstrate the
effectiveness of the approach used, an overall summary of the feedback is provided.

Overall Feedback

![Overall Feedback Results](image)

Figure 1: Overall Feedback Results

The questions posed to the students regarding this activity are as follows:

Q1: Demonstrations helped me understand the link between the theory and practice better

Q2: Demonstrations provided a way to acquire more knowledge in an efficient manner.

Q3: Demonstrations helped me to learn to work as a group

Q4: Demonstrations helped me to appreciate mathematics as a problem solving tool

Q5: Demonstrations made the subject more enjoyable

Q6: Demonstrations play an essential role in learning (compared to lectures, Tuts and Practicals)

Q7: Design of the demonstrations cultivated creative thinking

Q8: Topics are suitable for this subject and are directly related to the scope of the subject.

Q9: Marks assigned for the demonstrations are appropriate considering the work load

Q10: Tutors and the lecturer provided adequate help for the demo activity

Q11: Design of MECHANICA Simulations/Physical Models/Video/MAPLE procedures helped me grasp the underlying concepts in Dynamics

Q12: I consider the time spent on learning MECHANICA/designing and building models/establishing contacts with local industry/learning MAPLE to be valuable

Q13: In next year’s activity, given a choice, I take a demo of the same form

This link between theory and practice was the key question that rated the effectiveness of the approach since this requirement was one of the prime objectives for introducing the new approach. It is quite clear that majority (more than 80%) of students agreed. Distribution among different groups also suggests that all groups felt nearly the same manner. About 55% of the total number of students have also agreed that this approach certainly resulted in efficient knowledge transfer. However, the distribution among the various groups suggests that the MECHANICA and the MAPLE groups agreed on this more than the others. The dissatisfaction from the VIDEO groups may be attributed to unproductive time spent searching for the editing and related equipment. If the Dynamics stream or the department gives access to basic editing and video equipment to the students, this dissatisfaction could be minimised.

The response for the Q4 is quite encouraging since trying to make students appreciate mathematics as a problem solving tool was one of the primary aims of the demo activity. Due to the nature of the projects involved with the non-video demos, these groups seemed to have responded more positively when compared to the VIDEO groups. It may be noted that the VIDEO demos had less mathematical links to the subject. However, they concentrated on other aspects like industry links, practical issues etc.. It also becomes evident that the MAPLE group, due to significant mathematical links, have provided the most positive response.

An almost unanimous positive response has been obtained for the question that concentrated on whether or not this activity made the subject more enjoyable (Q5). All groups had very little reservation on this issue. This response also gives a significant motivation to the lecturer to develop this form of activities in the future for other subjects in the dynamics stream.

The response to Q7 indicates that the design of demo exercises has played a significant role in cultivating creative thinking. Response to Q8 emphasises that it is important to carefully choose topics. The topics chosen this year have succeeded in this respect. In general, all groups with the exception of the MAPLE group felt that the marks were not appropriate for the work load. It may be recalled that the demo activity was assigned 15% of the overall mark. This response suggests that more marks should be assigned for this activity in the future. The response from the MAPLE group cannot be interpreted in this case due to small sample size associated with this group.

Although, an overall positive response was obtained for Q11 MECHANICA and the PHYSICAL MODEL groups have responded more positively in this category while VIDEO group had some reservation about this. On the other hand, significant disagreement to this was expressed by the MAPLE
group. Although the sample size in this group is small, one could attribute this to the lack of link to animation or real life examples in this demo model.

Although, the project has been successful, as demonstrated by the feedback data, some useful feedback information came through the general comments and through students journals. Majority of the students felt that group sizes were large making the co-operative learning more difficult. In order to address this issue, for year 2 students, if the group sizes are made smaller, the number of demos would become large and would be difficult to supervise and organise presentations etc.. A solution is warranted to cope with this issue. Some expressed the view that they learnt the most from their own demo when they performed and less from the others. To address this issue, emphasis must be placed on presentations. Students must be encouraged to make their presentations simpler and should be instructed to take time to explain. This could lead to allocation of more for this activity. Another desirable feature that could be used is the proper synchronisation of demo presentations and the lecture material. This could mean that the demos can play an active role in assisting the students grasp the lecture material. This arrangement could be pursued in the future to further improve the present active learning approach.

In addition to the above mentioned desirable outcomes from this project, a significant improvement has been attained in the rating given to the lecturer by students on the effectivenes as a university teacher. This question on the standard TEVAL form received a rating of 6.1 while in the previous year (1995) a rating of 5.5 was obtained.

Conclusions

An active learning method has been implemented to replace a portion of conventional lectures for subjects in engineering dynamics. Owing to rich mathematical analysis, relevance to industrial applications and large class sizes involved in these subjects, conventional teaching methods have been found to be inadequate in the past. Demonstration modules to be designed by students using simple physical models and multi-media presentations introduce an active learning environment in the year 2 Dynamics subject. These modules when integrated into the subject have produced several desirable outcomes. Feedback from students obtained via a feedback sheet and student journals have been discussed. Suggestion for further improvement of this activity have also been provided. With some modification, this approach can become one of the most efficient ways of teaching subjects in Engineering Dynamics in the future.

References