Interactive Learning Applied in Undergraduate Mechanical and Mechatronics Courses at the University of Waterloo

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Abstract

It has been shown that when students are actively involved in the learning process they learn the concepts presented better than with “traditional” learning techniques where the students do not participate or participate very little. Ideal implementations of this approach require significant one to one interaction with students, which can be relatively easily done in small classes; however, this can be very challenging in undergraduate engineering courses that can have anywhere from forty to one hundred students. Interactive teaching techniques have been implemented in four undergraduate courses at the Department of Mechanical and Mechatronics Engineering of the University of Waterloo. The new methods have been implemented within the existing course structure and using similar resources to those that have been traditionally available for the courses. Three different approach have been implemented in the tutorial sections of the courses; 1) provision of real world problems for the tutorial, using half the tutorial time for the students to solve the problem with the aid of other students, the teaching assistants (TA’s) and the instructor, with the second half used to present the solution; 2) dividing tutorials into a review, a quiz that is worked on individually by each student, then by a group and finally individually again, and a discussion of the solution to the quiz; and 3) compulsory attendance tutorials for which part of the problem to be discussed was assigned as mandatory pre-tutorial work, during the tutorial the time was divided between discussion time and a presentation of the process to solve the problem, throughout the tutorial TAs actively engaged the students. Both formal and informal student surveys were conducted with most respondents indicating that the interactive tutorials were better than other tutorials they had

attended. The results of these interactive teaching methods are positive and have shown increased student participation in the learning process.

1 Introduction

Getting students involved in the learning process has been shown to improve the retention and understanding of the material [1,2]. Prince [1] identifies the four approaches to get students involved: active learning, collaborative learning, cooperative learning and problem-based learning. This paper reports on the implementation of the first three approaches in undergraduate mechanical engineering courses. Active learning involves getting the students involved in the learning process [1]. This involvement can be achieved by any means and can be as simple as asking questions or providing structured group problem solving exercise.

Collaborative and cooperative learning are similar yet differ in the structure of the work and the evaluation of the students. Collaborative learning is achieved when “students work together in small groups toward a common goal” [1]. Cooperative learning also involves groups with a common goal, but in a more structured environment and with students being assessed individually [1].

The position of Teaching Chair was created as part of the continuous improvement efforts at the Mechanical and Mechatronics Engineering Department of the University of Waterloo. Through this Chair the faculty of the department has been exposed to the advantages of interactive learning methods and techniques. These methods have been implemented,

to different degrees, by some instructors on undergraduate level courses with positive results.

2 Interactive Learning Approaches

Implementing these techniques within the existing course framework proved a challenge and required the adaptation of the methods to the classroom realities. Ideal implementations of this approach require significant one to one interaction with students and student group work, which can be relatively easily done in small classes; however, this can be very challenging in undergraduate engineering courses that can have anywhere from forty to one hundred students. The solutions to this challenge tried in the department involved implementing active learning in the tutorial section of the courses, where the students gathered for one hour a week. Active learning practices were also implemented by the instructors during normal lectures by trying to get the students to participate in the class by asking questions and actively encouraging students to ask questions.

The traditional approach used for tutorials in the department is for a Teaching Assistant (TA) to solve problems from homework assignments or a specific tutorial problem. In this type of tutorial, the bulk of the tutorial is spent presenting the solution to the problem on a blackboard. If the students have a question then it is expected that they will ask. This fits in with a traditional mode of teaching where the students are essentially passive participants. Three different implementations of the interactive teaching methods were implemented to change the tutorials from a passive learning experience to one where the students are actively involved; 1) provision of real world problems for the tutorial, using half the tutorial time for the students to solve the problem with the aid of other students, the teaching assistants (TA's) and the instructor, with the second half used to present the solution; 2) dividing tutorials into a review, a quiz that is worked on individually by each student, then by a group and finally individually again, and a discussion of the solution to the quiz; and 3) compulsory attendance tutorials in which part of the problem to be discussed was assigned as mandatory pre-tutorial work, during the tutorial the time was divided between discussion time and a presentation of the process to solve the problem, throughout the tutorial TAs actively engaged the students.

2.1 Interactive Problem Solving Tutorial

This approach was implemented in the tutorials section of Introduction to Control Systems-ME 360, a 3rd year Mechanical Engineering course. The approach taken was to provide an additional problem for the tutorials that was based on a real world application and was more difficult than what the students were used to solving. The objective was to challenge the students and make them think while in a safe environment when there were no marks involved.

The problem was broken down into parts and the tutorial was divided into 10 minute segments. The students would spend 10 minutes working on the first part of the problem with the aid of the teaching assistants (TAs) and the instructor. This was followed by a presentation of the solution by the TAs. Then the students would attempt the next part of the problem followed by the solution. The tutorial time was balanced between encouraging the students to solve each part of the problem on their own followed by a presentation of the solution to each part. By solving the problem in increments, if a student was stuck, they would be able to continue with the rest of the problem. The instructor attended the tutorials to help answer questions and provide guidance to the students in solving the problems. This also provided the instructor with immediate feedback on what the students were having problems with, which could then be addressed in the next lecture.

Attendance was positively affected by this style of tutorial, with approximately 70% of the class regularly attending the tutorials as opposed to the standard 20-30%. Another benefit to this approach was that the format of the problems was the same one used for the final exam of the course.

Feedback provided by the students on the end of term course critique indicated the tutorials were one of the better and more effective tutorials they had attended during their time at Waterloo. Specific comments indicated the interactive tutorials: i) gave the students a chance to think first before being presented with the solution, ii) made concepts easy to understand and made the TAs more approachable, iii) were extremely helpful, there was no pressure, there was lots of help, and were well run. Over the past several years, as measured by the course critiques, the usefulness of the tutorials was rated at an average of 67/100, a grade of 'C'. With the implementation of an interactive tutorial, the usefulness of the tutorial was rated at 89/100, an 'A'.

As discussed in Section 2.3 of this paper, this method of interactive tutorials requires good time management

from the TAs and coordination of the material between the lectures and tutorials.

2.2 Review and Interactive Quiz Tutorials

These tutorials were implemented in two second year mechanics of deformable solids (MOD) courses ME 219 and MTE 219. The courses are very similar, with one being for Mechanical Engineering students (ME 219) and the other for Mechatronics Engineering students (MTE 219). The course plan consisted of lectures, tutorials, a group project, midterm and final exams. There were 9 tutorial quizzes with the average of the best 7 out of 9 accounting for 7% of the course mark. Group project accounted for 15%, midterm 20% and final 58%. Students with an average of 60% or better in tutorial quizzes were given the option of an 85% final.

The tutorials had three parts. First, there was a five minute review of the topics being covered in the tutorial provided by the TA. Then, a quiz was given to the class on the material. The quiz itself had three parts. First, the quiz was attempted individually by each student. The students were then grouped in teams of three to work on the quiz. The grouping of students was done before the tutorial and therefore the students were in different groups each time. Finally, each student attempted the quiz individually and handed it in. The quizzes were collected, marked and returned to the students in the next tutorial section. The solution to the quiz was discussed right after it is collected. This approach combined both active learning and cooperative learning techniques.

It was found that student engagement was very high during the tutorial, especially during the quiz, and when the solution to the quiz was discussed. To better gauge the response of the students to the tutorials surveys were carried, with very positive feedback. . A questionnaire consisting of eight multiple choice questions and two open ended questions on “what you liked most” and “what needed improvement” were posted on the course website. Students were encouraged to take 10 minutes to submit their answers to the questionnaire and were told that the submissions would remain anonymous. The response rate to the questionnaire was 65%.

The students ranked the MTE 219 tutorials as one of the best they had attended in their time at the university. The students were asked if the tutorials helped in their understanding of the concepts when compared to the traditional methods and the majority of the students said that they did, as can be seen in Figure 1.

Figure 1: Student response to “Compared to the traditional method, W 10 (winter 2010) MTE 219 tutorials have helped with better understanding of the MODSs concepts”

The students were also asked about the effectiveness of the tutorial in promoting learning when compared to traditional tutorials. The students surveyed agreed that the new tutorial approach was more effective (Figure 2).

Figure 2: Student response to “Compared to other tutorials in 1st year and 2A, the effectiveness of the MTE219 tutorials in promoting your learning was:”

The students were also directly asked about their overall evaluation of the tutorial. There was a

significant agreement among students that the new tutorial approach was positive (Figure 3).

Figure 3: Student response to “My overall appraisal of the W10 MTE219 tutorials is positive.”

The students surveyed found that the tutorials were a more “fun” learning environment than the traditional tutorials. The group discussions and interactions were received very well by the students, many of who identified these features as what they liked the most about the tutorials. One of the most positive results of the tutorials, as reported by the students, was that the tutorials forced them to constantly keep up with the course material. Similar comments were made by the students who attended the compulsory attendance tutorials described in the next section.

Implementing these types of tutorials results in additional challenges that must be addressed by the instructor and some of these were mentioned by students as things that had to be improved. Proper use of the time was mentioned as something to be improved, with many students feeling that there was not enough time and that the tutorials were rushed. This issue is difficult to solve since a lot of activities have to be done in the 50 minutes allocated to the tutorials. The coordination between the lectures and the tutorials was a challenge and it was singled out as one of the areas for improvement.

The difficulty of the quiz questions, especially when compared to the questions on the midterm and final examinations, was a point that required improvement according to the students. This is a difficult issue to address since the questions on examinations can not be too similar to the questions previously given in the course. Solving the quizzes in groups received overall positive comments from the students; however, some thought that weak students were benefiting unfairly from being in groups with strong students. This is a

common criticism levelled at group work. It has been suggested that both weak and strong students benefit from group work [1].

Both the surveys and the perceptions gained from interaction with the students indicate that this approach to the tutorials provided a better learning environment for the students.

2.3 Compulsory Attendance Tutorial

Compulsory attendance tutorials have been implemented in four successive Mechanical of Deformable Solids II (ME 220) classes starting in the fall 2008 term. This is a second year Mechanical Engineering course that is the continuation of ME 219. The data presented here is for the first three implementations. In this implementation the tutorials were made compulsory and they were given a value of 5% of the final mark, with the rest of the marks being distributed between a 25% midterm and a 75% final. There were nine tutorials in a term and all of them had to be attended to obtain the 5% mark. Prior to the tutorials, part of the problem to be discussed was assigned as mandatory pre-tutorial work. Each pre-tutorial assignment consisted of stating the steps that were required to solve the problem in plain English. Then, the students were asked to perform the first steps of the solution, e.g. the free body diagram. This work was checked at the beginning of each tutorial and it was required to obtain the tutorial mark. The tutorials started with a brief discussion of the pre-tutorial problem and a presentation of its solution. The students were encouraged to discuss these amongst themselves and with the TAs. The remaining time was divided between discussion time and a presentation of the process to solve the problem. During the discussion time students were encouraged to work in groups, bringing in elements of collaborative learning to the process. There were two TAs in each tutorial and during the discussion time they were available to answer questions and proactively engaged the students to discuss the material. The final part of the tutorial consisted of one of the TAs presenting the method used to solve the problem. The complete solution was not presented to discourage students from following solution “recipes”, but was posted after the tutorial. The TA presenting the material tried to keep the class engaged by asking questions throughout the presentation. While one TA was presenting the method the other was among the students answering any questions that might arise. At the end of the tutorial the checked pre-tutorial work was handed in to determine attendance.

The first indication of an improvement over the traditional tutorials was in the attendance. The first time this approach was used 60% of the students attended all nine tutorials and 23% attended eight of the nine, resulting in 83% of the students attending at least eight tutorials. The second time the tutorials were ran in this fashion attendance was 98% and for the third 94%. Although no precise numbers on attendance of the traditional tutorials exist, it is believed to be approximately 20-30% and even lower on occasion. It must be noted that students had an option for a 100% final if they completed five ungraded assignments, so students did not have to attend the tutorials to still be able to obtain 100% on the course.

A brief student survey was conducted during the class evaluation for each of the three terms. For the three terms, 188 students out of a possible 275 filled the class evaluations, with 33 students choosing not respond to the survey. The students were asked to complete the following statement “Compared to the other course’s tutorials this term I found the ME 220 tutorial:”. The combined results of all three surveys are presented in Figure 4. It can be seen that most of the students that responded (82%) found the tutorials slightly better or a lot better than other tutorials. This was considered as a clear indication that the students considered the interactive approach better than the traditional approach. One factor that must be considered is the effect of the quality of the TAs used on the perception of the relative quality of the tutorials. The TAs for the ME 220 course have been, fortunately, excellent.

Figure 4: Student response to “compared other course’s tutorials this term, I found the ME 220 tutorial:”

As part of the same survey students were asked to state the best feature of the tutorial and to state one

thing that they would improved. Typically, students provided more than one item for each category. As it will be seen some of the same issues were raised by the ME 220 students as were raised by the ME 219 and MTE 219 students (note that none of the students that participated in the ME 219 and MTE 219 courses discussed here were in any of the ME 220 sessions discussed here).

The feature that received the most mentions as the best feature for the tutorials was the pre-tutorial work, receiving 43 mentions. The most common comments related to the fact that the students were forced to think about the problem prior to the tutorial. This allowed them to review concepts and encouraged them to keep up to date with the material. The second highest ranking feature was the TA interactions and discussion sessions, which received 33 mentions. The discussion segments of the tutorials encouraged so much communication, that it lead to issues with the volume of discussions in certain class rooms. The difficulty level of the questions, the fact that the tutorials helped students stay current and the 5% mark, were also stated as the “best” feature of the tutorials.

As for the one thing that students would change, there were a larger variety of suggestions. Eliminating the discussion time received the most mentions with 22, but 21 came from one class (fall 2008), which indicates that there was an issue regarding this that was specific to that class. The second item was the desire for more questions during the tutorials, which was mentioned 19 times. The limited amount of time and its effect on the presentations was an issue. Also, mentioned was the coordination between the class and tutorial materials, which was a problem on some occasions where some of the material for the tutorial was covered too close to the tutorial sessions. A similar number of students were not happy with the 5% mark as were happy with it.

Several of the things that were identified by the students as needing improvement had to do with the organization of the tutorials. The importance of proper organization was also recognized by the TAs and the instructor. Time management was the most challenging aspect of implementing the tutorial from the TAs point of view. During the 50 minutes allowed two TAs had to check assignments, answer questions, actively encourage participation, present material and collect the pre-tutorial work. This was a difficult task and it was thanks to the TAs assigned to the courses that this went relatively well. The instructor responsible for a tutorial such as this one must be prepared in advance. The problems for the tutorials,

the pre-tutorial work and the solutions should be ready in advance, so that they can be provided to the students when required and to TAs with enough time for them to properly prepare for the tutorial.

The most difficult challenge encountered by the instructor was ensuring proper coordination between the class material and the tutorials. This issue is not as critical when students are just copying down a solution from the board on a traditional tutorial; however, it becomes critical when this type of tutorial is implemented. Since a significant amount of work and time is being demanded of the students and the tutorials have a grade value, the students expect, and rightly so, that they will have all the material in time so that they can meet the requirements.

The TAs that participated in these tutorials reported having a good experience and all of them requested to be assigned to the course again. The TAs ranked the tutorials as being at least as good as the traditional tutorials. The amount of interaction with the students was cited as a positive aspect of the experience. The compulsory attendance received mixed reviews, with one TA considering it good since it resulted in increased attendance and a clear division between dedicated students and those that were there just to obtain the 5% mark. The TA used that distinction as a means of gaining feedback from the class, if the dedicated students understood the subject it was considered to have been well presented. Another TA had the opposite view of the compulsory attendance, considering that the presence of students that did not wish to be there made presenting the material more difficult.

In terms of instructor impressions, the students asked more questions during lectures and office hours than in previous classes when traditional tutorials were given. The fact that the pre-tutorial work was required prompted the students to look at the concepts and ask questions if something was not understood. The questions ranged from simple clarifications to explanations of all the concepts involved.

3. Conclusions and Future Work

Three interactive learning approaches were used on four different undergraduate Mechanical and Mechatronics engineering courses. It was found through formal and informal surveys, as well as observation and interaction with the students, that the interactive tutorials were considered better than the traditional ones. All the approaches involved active learning techniques and group work, in either a

collaborative or cooperative learning implementation. Active learning was promoted by encouraging significant levels of student discussions with fellow students and the TAs in charge. The active encouragement of discussion bore fruit in that significant increases in student involvement were observed. The group sessions were highly regarded by the student, whether they were informal or more formal with the specific goal of writing a quiz.

The implementation of these techniques requires more effort by the instructors and TAs of the course. Time management during the tutorial is a critical issue due to the challenges faced by trying to fit all the activities into a 50 minute time slot. Longer time slots would provide relief to this issue. Proper coordination between the classroom and tutorials is of critical importance and instructors must make every effort to ensure that they are properly coordinated.

The importance of good TAs can not be overstated. The responsibilities given a TA in an interactive tutorial are greater than in a traditional tutorial. TAs must be good time managers and must be able to adapt to the time use in each tutorial. Good interpersonal skills are a must.

The implementation of these interactive techniques has improved the student learning experience. As with any new endeavour, improvements are constantly being made as more experience is gained. A future goal will be to implement some of these techniques in the classroom time itself as well as in the tutorials. Although student surveys and instructor observations have provided good feedback on the effectiveness of this approach, it would be desirable to obtain more quantitative information to evaluate their effectiveness. However, this is not a straightforward exercise when it comes to evaluating student learning and retention [1]. All the instructors that implemented this approach found them to be superior to the traditional approach and they will continue to use them and recommend their implementation to other instructors.

References

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