Implementing Active Learning Principles in an Engineering Technology Fluid Mechanics Course

Mr. Michael W Martin, Northern Michigan University

Michael Martin received both his bachelor's and master's degrees in mechanical engineering from Michigan Technological University. He then worked for fifteen years in industry; four years at General Motors, nine years at Engineered Machined Products, a Tier I supplier to the heavy diesel industry, and two years at Industrial Maintenance Service, a onsulting/contracting firm. Martin's varied professional background has given him exposure to many facets of communication and working relationships of engineers with technicians, skilled trades, and unskilled trades workers. Martin then made the switch to academia and has been teaching mechanical engineering technology classes at Northern Michigan University for the past four years. He strives to, and gets great satisfaction from, bringing his work experiences into the classroom.

Implementing Active Learning Principles in an Engineering Technology Fluid Mechanics Course

Abstract

This paper describes the implementation and outcomes of applying an active learning methodology to a senior level engineering technology fluid mechanics course. This application is an element of a larger effort at Northern Michigan University to implement active learning through an NSF – TUES project (National Science Foundation – Transforming Undergraduate Education in Science, Technology, Engineering, and Math). In this project a dedicated, student centered, high technology, active learning classroom was developed and used to teach various classes in the STEM disciplines, including the fluid mechanics class. Various approaches to implement active learning in this class, including the use of the technology items available in the dedicated classroom, will be explored.

The effectiveness of these active learning approaches was evaluated using instructor observation, student feedback, and student test scores. After the some initial hesitancy, the students ended up appreciating the teaching approach and thought that they learned the material well. This was supported by student test scores in which students taking the active learning-based class significantly outperformed their counterparts taking a more traditional lecture-based class.

Introduction

A student centered teaching methodology was employed in a senior level fluid mechanics course required in the Mechanical Engineering Technology curriculum at Northern Michigan University. Through significantly reduced lecture time, in-class problem solving activities, out-of-class student preparation, and an out-of-class student project, the students became responsible for their own learning. The instructor was a guide and a consultant to lead the students through the material and aid in clarifying difficult material, but the instructor did very little "teaching". Despite initial student reservations about the class format and increased out-of-class workload, by the end of the semester all of the students thought the class format was beneficial to their learning. The students also performed better on the exams than the students that took the class the previous year under a conventional lecture-based format.

Background

The approach in this course was part of a larger initiative at Northern Michigan University to implement active learning in the STEM disciplines. This initiative is driven by the receipt of an NSF grant titled "Increasing adoption of active learning in STEM disciplines by integrating a faculty development program and a technology-facilitated learning environment". Six faculty in the STEM disciplines from across campus and one staff member from the IT department were involved in this effort. The author is the representative from the Engineering Technology Department. A high technology room to facilitate the active learning concept was constructed,

and the class was taught in this room (see Figure 1 below). This room has 8 round tables that can seat 8 people. These tables are scattered about the room with the instructor station at the center of the room. There are 2 overhead projector screens so all students are able to see one of the screens without rotating their chair. Each table is allocated a Smart Board and a document camera, as is the instructor station. The room also has access to ResponseWare[©], an on-line survey tool to provide instant feedback to the instructor, similar to a "clicker" type system.

Considerable research has been done regarding the effectiveness of the active learning teaching methodology. Results of these studies show the student outcomes vary widely depending on the approach of active learning used. However, the bulk of these studies indicate that the general active learning concept has merit in increasing student test scores and material retention.[1] Implemenation of active learning can vary from the instructor taking a couple minute break a few times in their lecture for the students work on an example problem in class, to a complete "flip" of the classroom model in which no new material is presented in class, but the students are working collaborativily using knowledge they had gained outside of the classroom. Therefore any discussion of the merits of active learning need to be accompanied by the exact methodology that is applied.

Figure 1: Photograph of the high technology active learning classroom at Northern Michigan University.

Multiple types of learning models were used in the fluid mechanics class that this paper discusses. The students did self-directed study of material prior to class. This was done by generating information to present to their peers on the new topic being covered. They passively received information in a 10 minute mini-lecture put on by one of their fellow students. The students worked cooperativley in class on homework problems that the class struggled with. They also worked collabortively in class on example problems presented by the instructor, and they worked on their own again, outside of class, to do the homework problems. Details of the implementation of these approaches is discussed in the next section.

Class Format

This method was implemented in the MET420 Fluid Mechanics class, which is a 3 credit class with no lab component associated with it. The class was scheduled to meet twice a week for 1 hour and 15 minutes each meeting time. A very consistent format was used throughout the semester. The first 1/3 of the class time was spent reviewing the previously assigned homework problems. The middle 1/3 was spent with a student reviewing new material including presenting an example problem. The instructor also spent a small amount of time discussing the new material as well. The last portion of the class was spent with the instructor presenting problems

for the students to work on either individually or in groups. The class had 10 students enrolled and they were divided into 2 groups of 3 and 1 group of 4. The groups were preselected by the instructor who placed an "A", "B", and "C" student into each group. Each group sat at a specific round table that was present in the room.

Approximately the first 1/3 of the class was a review of homework problems and was facilitated by using the classroom survey tool ResponseWare[©]. This is a web-based "clicker" type system in which the students provide immediate feedback to instructor questions. An MS PowerPoint presentation was created for each homework assignment in which each problem was stated and multiple potential answers for each problem were provided. The students would provide their answers to each question. This enabled the instructor to immediately determine if the problem was well understood by the majority of the class. If a number of students did not get the correct answer, they were tasked to work in their groups and resubmit their answers. During this time, the instructor would walk around the class, give hints, answer questions, and in general observe student understanding. If the perceived student understanding was low, the instructor would often work out the problem on the white board. If the perceived student understanding was high, and the bulk of the students got the correct answer upon their resubmission, the instructor would move on to the next question. Occasionally there would be a student who would still struggle after the group work, in which case the student was referenced to review the worked out problem solutions posted on the instructors office window, or to consult the instructor during office hours. This method seemed to keep the class moving, generate an understanding of the problems for the bulk of the students, and not bore the ones that had a mastery of the material. The students were responsible for "grading" their homework by simply marking each problem correct or incorrect with a red pen. They were encouraged to write out the correct solutions to problems that they did not get correct. The homework was collected and a grade was assigned to it by the instructor and returned to the student the next class period. It should be noted that the quantity of assigned homework was reduced to about 2/3 of what the instructor previously assigned in a lecture based class.

The middle portion of the class was spent reviewing the new material for the day. In the previous class period the student would have been assigned the chapter and sections that would be covered in the next class. Each student was responsible for preparing to present that material to the class then next day. The only guidelines given to the student was that the presentation should be around 10 minutes and include a unique example problem (one they made up, not copied out of text). The bulk of the students gravitated toward generating a handwritten outline of the textbook material. Each student had their name on a piece of paper in a cup and a name would be drawn out of the cup by the student that has presented the previous day. The student whose name was drawn would then present the material to the class. The typical student presentation format was a verbal discussion of the material supplemented by writing important equations on the board and utilizing the document camera to project relevant information out of the text onto the overhead projector screen. The presenter would present their example problem either by writing it on the white board, or on a piece of paper, utilizing the document camera. The instructor prepared a MS Power Point presentation over this material as well and upon completion of the student presentation, the instructor would review their prepared material. The bulk of the student presentations (>75%) were very comprehensive and the instructor would only spend 3-5 minutes reinforcing important points, or perhaps relating the information to an industrial experience they had. A couple of the student presentations were a little weaker and the

instructor would review the material in a more detailed fashion, perhaps up to 10 minutes in total length. This 3-10 minute review of new material, done twice a week, was the extent of actual "teaching" that the instructor did for this 3 credit class. This format was very effective in getting the students to prepare for the new material on their own, which was a cornerstone for the class.

The last part of the class involved students working on example problems over the new material which had just been covered. The students were encouraged to work with the other group members at their table to confirm their answers or to ask questions. During these activities the instructor would collect, grade, and return the preparation materials the students had for the new material that was covered. In this way, the students had these materials to aid them in doing the homework for this material. Upon completion of that task, the instructor would float about the room, giving hints, answering questions, etc. Once it seemed the bulk of the students had completed the problem the solution would be reviewed via a prepared MS Power Point presentation, which expedited the review process. Occasionally it was observed that the students still struggled with a portion of the problem, in which case a clarifying sketch or sub-section of the problem would be worked out on the white board by the instructor. At the completion of the class, the instructor would assign homework problems and the preparation of new material, both which would be reviewed the next class period.

Results

A comparison of student outcomes of the class under this format was compared to that of the same class taught the previous year by the same instructor. The class was only taught 1 year by this instructor in a traditional format, so there is only 1 year of historical data to compare to. Outcomes were analyzed quantitatively by use of overall exam scores as well as student performance on selected exam problems/questions that were similar, or the same, as problems/questions given the previous year. Class outcomes were also evaluated qualitatively using the standard course evaluation forms the students fill out at the completion of each semester. The online assessment tool SALG (Student Assessment of their Learning Gains) was given to the students at the beginning and end of the active learning formatted class and is another way in which the success of the class was gauged.

Three in-class exams were given throughout the semester in both courses (conventional and active learning). A total of 3 students data were removed from the analysis due to either; withdrew from class, failed class (very sporadic attendance and homework completion), or elected not to be included in the study. A total of 10 students from the 2011 class, and 8 students from the 2012 class were included in this analysis. A summary of the results can be seen in Table 1.

Note that the Cohen d, effect size, has been determined to statistically define differences between each group. The effect size is defined as the difference between the means of the two populations divided by the pooled standard deviations. Cohen defined effect sizes of 0.2, 0.5, and 0.8 as small, medium, and large respectively.[2] Albanese, supported by Prince, takes exception to these rankings as finding effect sizes greater than 0.8 are rare for any academic intervention and indicate remarkably impressive gains.[1,3] Therefore notice should be taken for effect sizes approaching, or exceeding, 0.8.

	2011(conventional)	2012(active learning)	effect size (Cohen d)
Overall Student GPA	3.01	3.13	.25
Overall Exam Scores	81.2	86.8	.68
Common Problem Exam Scores	81.5	91.1	1.67

Table 1: Mean values of students overall GPA, overall exam scores, and scores on common problems between both years is shown for both a lecture-based class (2011) and an active learning based class (2012). The effect size, indicating the statistical difference between the two groups, is also shown.

It can be seen that the 2012 class had a slightly higher quality student body with an average GPA higher than the 2011 class by .12 points. This results in an effect size of .25, thus determining the difference to be small. The overall exam scores have a larger difference as the average exam score increased from a B- (81.3) in 2011 to a solid B (86.8) in 2012. The effect size for this difference is .68, which indicates a significant difference. It is possible that some of this difference can be attributed to the student makeup. Additionally, the class content was slightly different between the two classes as well. The 2011 class reviewed concepts of buoyancy and stability which were replaced in 2012 by compressible flow. It is possible that students found the content of the 2012 class easier to grasp. These issues present some difficulties in comparing overall test scores from year to year.

To eliminate some of the variables found in comparing overall exam scores, a comparison between like problems given on the exams was done. Exams were returned to the students only during the class period in which they were reviewed; they were recollected and kept by the instructor to minimize the impact of "scoop" on future exam scores. About 45% of the exam points in the 2012 class were from problems that were exactly, or nearly exactly, the same as problems given in the 2011 class. When looking at the subset of these problems it is very apparent that the 2012 class had a better grasp of the material, with an average grade of an A- (91.1) versus a B- (81.5) for the 2011 class. The resulting effect size from this difference is 1.67, indicating a truly impressive gain in knowledge[1,3]. It appears that the students simply learned the material better in the active learning format of the 2012 class.

University administered class evaluations were given at the end of semester to each class. The data includes all students who chose to fill out the evaluation. 9 out of 10 students from the 2011 class filled out the evaluation. 10 out of 10 students from the 2012 class, including the two that were omitted from the quantitative analysis above, filled out the evaluation. There were two questions on this evaluation related to student learning. The results of this class evaluation are shown in Table 2. The results of these two questions indicate that students from the conventional class had a slightly higher evaluation of the learning that took place than the active learning class.

Question	2011 (conventional)	2012 (active learning)
My understanding of the subject has increased or improved.	7 – Strongly Agree (78%) 2 – Agree (22%)	7 – Strongly Agree (70%) 2 – Agree (20%) 1 – Disagree (10%)
My ability to interpret and evaluate information has improved.	6 – Strongly Agree (75%) 2 – Agree (25%) (1 omitted)	4 – Strongly Agree (40%) 5 – Agree (50%) 1 – Neither Agree or Disagree(10%)

Table 2: Selected results of end of semester class evaluations for both 2011 (lecture based) and 2012 (active learning) classes.

Students were also surveyed using the online SALG (Student Assessment of Learning Gains) instrument both at the beginning, and upon completion, of the class. This survey instrument is specifically designed to decouple student's opinions of the teacher and class from the actual knowledge gained in the class and how specifically that knowledge was gained[4]. This survey was not given to the conventionally taught class, so no comparisons between the classes can be made. However, the survey provides some insight into the student perceptions of their own learning and the methods by which this was attained in the active learning based class.

The survey given at the beginning of the class was reasonably short and focused on the current skills and attitudes of the students. A summary of some significant questions from this survey can be seen in Table 3 below.

Question	not at all	just a little	somewhat	a lot
Presently, I understand fluid forces generated by fluid pressure.	11%	11%	67%	11%
Presently, I understand elements included in the energy of flowing fluid.	56%	22%	22%	0%
Presently, I understand causes of energy loss in fluid flow.	33%	33%	33%	0%
Presently, I am confident that I can understand the subject.	33%	33%	22%	11%

Table 3: Summary of SALG survey results from survey taken at the beginning of the semester of the active learning based class.

Based on the above ratings, there are two primary outcomes of this survey:

1. Students have very little prior knowledge of fluid mechanics.
2. Students have low confidence that they will be able to master fluid mechanics.

The SALG survey given at the end of the semester was more comprehensive and covered topics such as student learning and methods by which they learned, student attitudes about the topic, and general understanding of class content. The three highest and three lowest ratings on this survey are summarized in Table 4. From these results it is apparent that the students thought they learned a great deal in the class, though their enthusiasm and interest in the subject was not especially great. The students were also clear that they did not gain a lot from watching the student presentations.

Question	no gains /no help	a little gain/ a little help	moderate gain /moderate help	good gain /much help	great gain /great help
What gains did you make in your understanding of forces and pressures due to static fluids?	0%	0%	0%	30%	70%
What gains did you make in your understanding of analysis of fluid flow systems?	0%	0%	0%	20%	80%
What gains did you make in your understanding of analyzing energy losses in a fluid flow system?	0%	0%	0%	30%	70%
How much did watching student presentations help your learning?	10%	40%	20%	20%	0%
What gains did you make in your interest in discussing the subject area with friends or family?	0%	30%	40%	30%	0%
What gains did you make in your interest in taking additional classes in this subject?	10%	30%	30%	30%	0%

Table 4: Results of the three highest rated and lowest rated questions from the SALG survey taken at the end of the semester of the active learning based class.

The bulk of the survey focused on methods of student learning, and is summarized in Table 5. As can be seen in the table, numerous methods contributed to student learning. The most beneficial methods of student learning were; the textbook, preparing to present material to the class, and working with peers during class time. One method which did not contribute significantly to student learning was watching student presentations of the new material (see Table 4). These results are also supported by numerous student comments on both the SALG survey and the university class evaluations expressing their dislike of viewing the student presentations, but the value of preparing for them.

- "I did not like that students had to do presentations. It is hard to learn a new section from someone who has no idea what they are doing."
- "Listening to presentations was what I liked least about the course."
- "I liked that we were forced to prepare for class each day. I feel that it helped me learn faster than if I only listened to a lecture."
- "Making the students teach the class really made me responsible for my own learning and helped me to better understand the material. I would suggest continuing to do that."

Question	no help	a little help	moderate help	much help	great help
How much did the instructional approach used in the class help your learning?	0%	0%	40%	30%	30%
How much did preparing material to present to the class help your learning?	0%	0%	20%	40%	40%
How much did doing the textbook homework problems help your learning?	0%	0%	10%	60%	20%
How much did the textbook help your learning	0%	0%	10%	50%	40%
How much did the visual resources used in the class (Powerpoints, demonstrations) help your learning?	0%	0%	30%	50%	20%
How much did interacting with the instructor during class help your learning?	0%	0%	30%	30%	40%
How much did working with your peers during class help your learning?	0%	0%	20%	40%	40%

Table 5: Summary of the results related to methods of learning from the SALG survey taken at the end of the semester of the active learning based class.

It also must be noted that the possibility of presenting material to the class provided a very high incentive for the students to prepare and learn the new topic. Of the total of 128 presentation preparations (16 presentations x 8 students), 122 (95%) received a grade of 8/10 or higher.

Students also commented on the value of working with their fellow students and use of the textbook, supporting their numeric ratings.
- "Working with other students forces you to discuss why you did what you did and forces you to really think about your approach and to be able to explain it"
- "Working through problems with peers is for me the best way of learning."
- "Most of the info I used in the class I gathered from the textbook myself, but the instructor was available for clarification"
- "I have learned to study in ways I have not before, and the information sticks"

Since student confidence was so low in the beginning of semester survey (Table 3), it was of interest how that attitude changed by the end of the semester. A question relating to this was given on the end of semester survey and is shown in Table 6. Based on this it appears as if the low level of student confidence at the beginning of the semester has been remedied.

Question	no gain	a little gain	moderate gain	good gain	great gain
As a result of your work in this class, what gains did you make in your confidence that you can do this subject area?	0%	0%	20%	60%	20%

Table 6: Result of a question on the end of semester SALG survey relating to student confidence.

This appears to be further supported by numerous student comments such as;
- "Something I can carry with me to other classes is that I can look something up and figure it out if I want"
- "Because we had to teach ourselves, I now feel more confident that I could teach myself other subject materials if I wanted to".

It has been said that the single most important thing you learn in an engineering education is that you "learn how to learn". Perhaps this class taught this skill to a number of students.

Analysis / Recommendations

Based on student test scores it is apparent that students learned the fluid mechanics material much better under the active learning format than a conventional, lecture-based format. It is also apparent that numerous instructional methods, such as preparing prior to class, working with classmates, interacting with the instructor, and doing homework, aided the student learning. It must be noted that the sample size in this study is very small (10 students in the traditional class and 8 in the active learning class). However the difference in performance between the 2 groups is statistically significant.

The students in general did not get a lot of benefit from viewing the student presentations. However, these presentations provided a high motivation level for the students to learn the new material. One reason for the high motivation is the likelihood of having to present in front of their peers (1 out of 10 chance each day). In a larger class, with a reduced likelihood of being drawn to present, the motivation may not be as great. It is also possible to provide other motivations for preparation of material. One way could be short quizzes at beginning of class, possibly on-line to minimize the grading impact on the instructor. Or simply collecting prep materials but not have the students present. Another way may be to randomly ask verbal questions of the students at the beginning of class and grade the responses. It is not clear whether these incentives would provide as high motivation for the students as the presentations did.

Other feedback received from the students indicated that they were not happy with the circumstance of a number of students being selected to present the material two or more times, and others never having to do it. To remedy this situation, yet still keep the "randomness", the instructor intends to "stack" the cup about halfway through the semester with names of those students that had not yet presented.

Regarding the technology items available in the student centered classroom, the document camera and student response system were utilized on a daily basis. Both of these items were important in keeping the class moving and getting the most efficiency out of the class time we

had. The other items, such as Smart Boards and microphones were never used. The round tables in the room contributed to the casualness of the class, which is a benefit in getting the students to be comfortable in the environment. But based on the tables large size (8 person table) compared to the group sizes (3-4 students), they provided little benefit to working with fellow students over a conventional classroom.

Final recommendations are:
- Implement active learning principles in fluid mechanics courses.
- Format the class to have 3 distinct sections; review of homework, brief review of new material that the students have previously prepared for, and students working on example problems over the new material in groups.
- Ensure that the homework review time is spent on the topics the students struggled on. In this class the instructor used an on-line "clicker" type system to gauge student understanding, but simply asking for a raise of hands may be as effective and require less preparation.
- Provide an incentive for the students to prepare for the new material on their own. The instructor found that presentation of the material by randomly selected students provided a high incentive in a class with low enrollment.
- If random presentations are the incentive of choice, somehow ensure that all students get picked to present.
- Ensure that the textbook is clear and understandable for the level of your students. In this class the instructor used "Applied Fluid Mechanics" by Robert Mott, which was found to be an excellent text. A number of students also commented that they liked the textbook.

Conclusion

A student centered teaching methodology was employed in a senior level fluid mechanics course at Northern Michigan University. Through significantly reduced lecture time, in-class problem solving activities, and student preparation for their own lecture on new material, the students became responsible for their own learning. This resulted in statistically considerably higher exam scores than students that took the same class the previous year from the same instructor under a more conventional, lecture-based format. The course also received high marks from the students on their end-of-semester evaluations. There are some areas that could use improvement such as minimizing the time that students are presenting, and ensure that all students get picked to present. The class format worked well for the small class of 10 students that it was implemented in, some suggestions were provided to adapt this format to larger classes. In summary, the implementation of the active learning format in the fluid mechanics class yielded very positive results for the students.

References

[1] Prince, M., "Does Active Learning Work? A Review of the Research". J. Engr. Education, 2004. 93(3): p.223-231.

[2] Cohen, J., *Statistical Power Analysis for Beheivoral Sciences*, Revised Edition, Englewood Cliffs, NewJersey: Erlbaum; 1997.

[3] Albanese, M., "Problem Based Learning: Why Ciricula Are Likely to Show Little Effect on Knowledge and Clinical Skills", Medical Education, Vol. 34, No. 9, 2000, p.729.

[4] Seymour, Elaine, et al., 2000, "Creating a Better Mousetrap: On-line Student Assessment of their Learning Gains," *Proceedings of the American Chemical Society Symposium "Using Real-World Questions to Promote Active Learning"*.