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ScienceDirect

Procedia - Social and Behavioral Sciences 191 (2015) 990 – 995

Procedia Social and Behavioral Sciences

WCES 2014

Engaging Engineering Students in Active Learning and Critical Thinking through Class Debates

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Abstract

Within the program of engineering, typically there are courses that are heavily dependent on mathematics and derivations of fundamental concepts. A lot of active learning can be done in these classes by using the engineering fundamentals to solve engineering problems, i.e. number crunching. This keeps the students busy and interested in the subject. On the other hand there are some courses that involve a lot of reading and less intense in mathematics. Teaching such courses to engineering students can be a challenge. The objective of this paper is to share an innovative method that not only engages active learning in such classes, but also critical thinking in classes that is text heavy. The pedagogy approach adopted is utilizing the idea of a debate competition between students. The students were given the lecture material by the instructor for several weeks. Student teams are formed and are given the task to prepare Questions and Answers on the topics that have been covered in class. These questions cannot be trivial but has to involve higher levels of the Blooms Taxonomy such as application and analysis. Teams take turn to ask questions to each other and the final score is tabulated. At the end of the process, the instructor will focus on individual team members by giving them similar questions. The objective of this is to identify the weak students within teams and to focus on them before the semester ends. The outcome of this pedagogy exercise was interesting. In comparison to the other semesters, students' performance increased, besides increasing their interest in the subject. Student survey showed that the enjoyed the methods used in the class and it has really helped them to better understand the material by peer team-working. The innovative pedagogy approached using in this particular engineering course has showed that active learning is an important element in enhancing students' performance. Besides this, with guidance and examples, students will be able to think in a critical manner on subjects that are text heavy. This is an important element because it develops critical thinking skills in analyzing information. It is recommended that such or similar approaches is adopted for courses that are less mathematics intense in the engineering programs.

Selection and peer-review under responsibility of the Organizing Committee of WCES 2014

Keywords: Active Learning, Blooms Taxonomy, Debate, Text heavy

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doi:10.1016/j.sbspro.2015.04.379

1. Main text

Engineering students enrolled in universities have strong mathematics and physics background primarily because engineering curriculum strongly depends on these two fundamental sciences. Many engineering core courses offered are very intense in mathematics and fundamental physic sciences. These subjects are less text heavy in comparison to the amount of reading done by students in the Art and Social Science majors. However, there are some courses in engineering which are texts heavy. For an example, the Material Science course. Even though this course is fundamental science in nature, but the amount of reading required is much greater in comparison to other engineering courses. Material science course covers from the atomic level to the macro level, covering the strength and strengthening mechanisms, defects, composites, etc. It is a challenge to conduct this course effectively yet fulfilling all the learning outcomes set for this course. Typically this course involves students listening to the instructor, reading the textbook and solving textbook problems. This creates a passive engagement of the students which in return leads to minimal retention of knowledge as shown in Figure 1. In a separate study by Dale, it was found that the levels of effectiveness in learning are directly related to the participation of students.

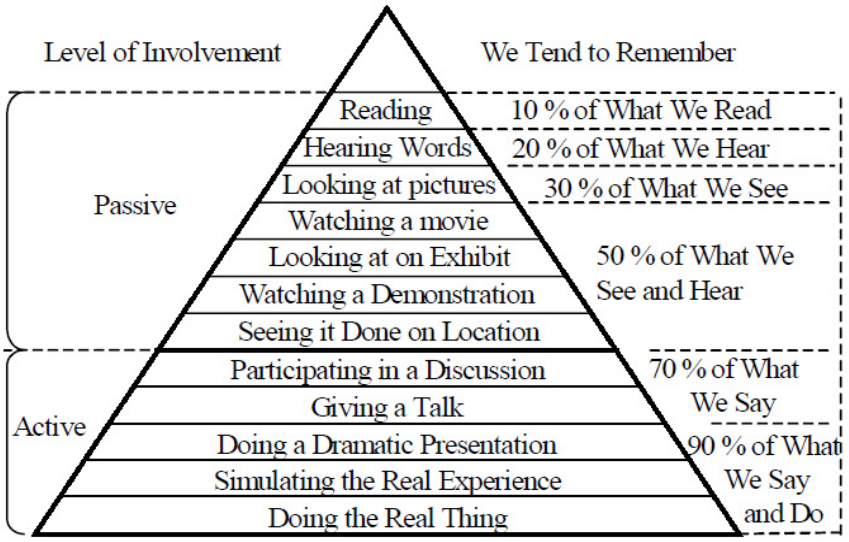

Fig. 1: The cone of learning Krivickas (2005)

This brings us to the topic of active learning. Basically active learning is a method that involves the participant directly during the learning process. Any activity that engages students besides listening to lecture is a form of active learning. In this scenario, active learning would be an interesting pedagogy approach. The question is how to get students actively learning in a course that is not that math intensive? In engineering in particular, teaching style of an instructor and the learning method of a student are very important (Felder and Silverman, 1988; Felder and Spurli, 2005). Hence carefully understanding these styles is a crucial factor for implementing effective teaching – learning strategies. Hence, here in the Department of Mechanical and Industrial Engineering of Qatar University, the course Material Science was chosen to adopt a new active learning approach. The approach chosen involves various combinations of active learning leadings towards a final active learning activity which is the team debate. The following section details the approach taken.

2. Material Science Active Learning Approach

Material Science course is a very text heavy course for engineering students. In this course, the relationship between structures and properties of material is taught. The course looks at atomic structures, bonding, crystalline

and molecular structure and imperfections. These are then related to the mechanical properties such as creep, fatigue, fracture and corrosion of metals, alloys, polymers and composites. The course learning outcomes are as follows:

- Describing the general characteristics of the various engineering materials
- Selecting materials for industrial applications based on engineering and cost constraints
- Explaining the concepts of corrosion and failure analysis
- Design and conduct experiments to determine relationships between different material properties

With regards to the ABET generic program outcome, these learning outcomes are mapped to ABET outcomes a, b, c, e, h, k.

From random sampling amongst students, many students agree that this course is text heavy. Text heavy is in the sense that there are a lot of factual points to be remembered with little real life applications to apply them on. Many find reading the books and typical passive lecture modes are not effective. Reading on oneself such factual points can be a bore at times. Hence to make reading enjoyable and fun, several active learning activities were devised. These activities involve the following:

- Listening to lectures
    - Instructor will present the material in class and have a normal discussion on the topic covered. This will be done for the first 8 weeks of the semester, followed by a midterm exam
    - Video presentations and real life case studies were discussed and linked to the course material

- Field study
    - Students were taken for field study to Qatar Steel where there were exposed to various production mechanisms and were given an assignment to relate what they have seen to what was taught in class.

- Experimental Labs
    - Many students were not aware of the concepts of corrosion and failure. Hence, a lab activity was developed where students had to conduct their own expriments to explain the modes of failure due to certain loads and to show through experiment the concept of corrosion
    - The students had to demonstrate the usage of the knowledge from lecture to the lab activity.

- Formation of teams
    - After the midterm exam, the class is broken up into several teams with members ranging from 3 – 5 students per team.
    - Each team is required to prepare 45 Question and Answers based on the material that had been covered in class
    - These questions cannot be trivial questions. It has to involve higher levels of Blooms Taxonomy

- Debate
    - The debate starts by one team questioning another team. Scores are given for teams who are able to answer, and deducted for teams unable to answer.
    - The team posing the question has the opportunity to rebut the answer given by the opposing team, hence creating a debate environment.

- All members in the team have to answer the questions posed to them by another team.
- The debate focuses on time management, team work and critical thinking.

- Instructor Questions
  - The instructor will have his own questions developed.
  - Whichever team answers the instructors question has the opportunity to start the game.
  - The instructor will be observing the entire debate process. Part of the observation is to identify weak students.
  - After the debate, these weak students are given individual questions by the instructor to observe the level of understanding. If these students are not able to answer them, the instructor will work with them on an individual basis and prepare them for the final examination.

The course is assessed by using the following assessment schemes:

- Debate 10%
- Assignments and Quizzes 10 %
- Lab work and Oral Presentation 15 %
- Exams 65 %

From the listed assessment methods, about 35 % are evaluated based on a certain active learning activity. The exams are most as summative assessments.

3. Results and Discussion

The following sections will be discussed by using the activities carried out in the class:

- Listening to lectures
  - In general, students found the lectures interesting due to the active discussions that were taking place in class. It kept the students alert and responsive to questions or answers given by other classmates.

- Field study
  - Students truly enjoyed this trip and certain words or processes described in the textbook make sense when they physically observed them taking place in the industry.

- Experimental Labs
  - Having to design and conduct their own experiments to relate the concepts of corrosion and failure made the student more confident in themselves besides having to understand the material much better.

- Debate
  - The debate was the most enjoyable activity stated my most of the students. Their exposure in class, in the field and while conducting the experiments really made them develop questions relating to Material Science at a higher level of Blooms Taxonomy.
  - The students also enjoyed the team dynamics such as time management, team work and critical thinking while developing these questions.

In general, most students suggested that the debate approach should be adopted in the coming semesters.

Figure 2 shows the final grades for the Material Science course. Semester 2 is where the debate was fully in institutionalized. The number of students for Semester 1 was 29 and Semester 2 was 31. The quality of intake for both batches are the same based on the same entry requirements to the university and the ethnicity of the students are the same, predominantly Arabs. The only major difference is that the debate was implemented fully in semester 2. Hence, with confident the both the batches could be compared. It was found that in Semester 2, where the students were exposed to the debate the percentage of students obtaining a grade of B and higher increased from 35 % to 58%. This is an increase of 65% across the semester. This amazing result has shown that the method of introducing the debate is effective and will be continued. A survey was conducted at the end of the course and majority showed that the learning outcomes for the course were achieved.

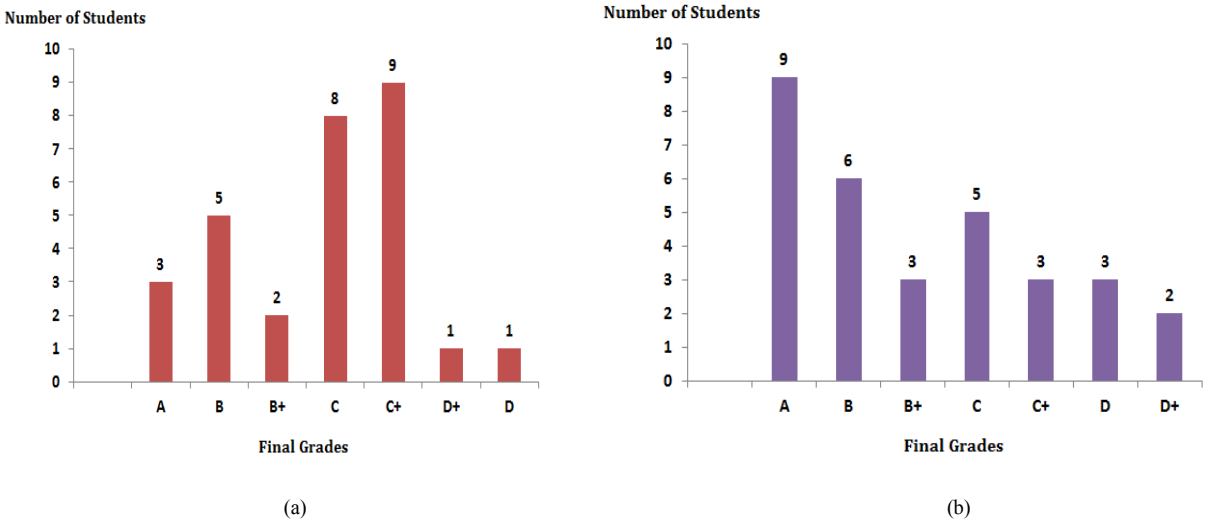

Fig 2. Final grades of students taking the Material Science: (a) Semester 1 (b) Semester 2

4. Conclusion

In conclusion, the active learning methods used in the Material Science Course have shown to be an effective method that significantly improves student achievements of good grades and impact on the enhancement of student attainment of course learning outcome. This method will be continued in the coming semesters to obtain a longitudinal study data for further analysis and enhancement of this teaching pedagogy.

Acknowledgements

The authors acknowledge the Department of Mechanical and Industrial Engineering of Qatar University for its support towards this initiative.

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