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A group project based approach to induce learning in engineering thermodynamics

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A group project based approach to induce learning in engineering thermodynamics

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Abstract

A group project was introduced to undergraduate students in engineering thermodynamics. The goal was to provide students an opportunity to work in groups to apply fundamental principles of thermodynamics that were taught in class. The principle motivation behind introduction of the group project were to examine if learning effectiveness is improved when students work in groups and also to determine whether application of fundamental principles to real-life problems enhance student learning experience. The undergraduate class included students from a range of engineering disciplines, including mechanical engineering, civil engineering and electrical engineering at mostly the junior and senior levels. The lectures in class primarily discuss fundamental principles related to the first and second laws of thermodynamics with some examples of applications related to power cycles and refrigeration. For the project, the students were encouraged to explore relevant topics from day-to-day life where principles of thermodynamics could be employed. Each group comprised 5-7 students with varying performance based on quizzes, homework and in-class exams. The projects were evaluated based on a written report and group presentation that clearly mentioned the contribution of each member. Additionally, students were encouraged to make anonymous comments on their overall experience in working towards the project. The outcomes of the assignments as well as anonymous comments are analyzed to provide qualitative and quantitative insight into the effectiveness of the student group projects. Overall, this article will present the outcome of the student group projects and its effectiveness in engaging them and improving their understanding of principles of thermodynamics, relative to their overall engagement and performance based on other assignments.

Introduction

Thermodynamics, a subject that deals with energy, is an important and necessary part of mechanical engineering curriculum globally.[1-3] Engineers apply principles of thermodynamics to solve myriad problems in applications that include air conditioning, refrigeration, power conversion in power plants and automobiles, energy storage and heating and ventilation systems.[4] While fundamentals of thermodynamics is not mathematically challenging and involve very simple mathematical tools, most students find it difficult to grasp the basic concepts such as energy balance and definition of entropy associated with the second law of thermodynamics.[5-7] Various methods have been explored to enhance learning of thermodynamic concepts at the undergraduate level.[5,8,9] Since learning is a process of garnering and assimilating concepts, engagement of the students is critically important.[10] In particular, extensive study by Felder et al[11-14] on has elucidated the positive impact of cooperative activities on student learning. This paper presents a student group-project based approach to encourage active student-centered cooperative learning of thermodynamics. The central hypothesis of the present study was that introducing group projects to assess student performance in thermodynamics will motivate them to work in groups outside of class and induce peer-to-peer learning that would not only help assimilate the concepts discussed in class but also foster innovativeness in applying these ideas to real-life applications, which is an essential component of learning in any engineering discipline. Questionnaires passed out in class, which were filled anonymously, were used as tool in evaluating the effect of group-project on student learning. The analysis of the average grade of the students prior to the announcement of the group project and after its completion also provided valuable insight. The overall motivation was to equip the next generation of engineers with knowledge and experience in using thermodynamics as a powerful modeling tool for engineering design and analysis.

Methods

In order to evaluate the effectiveness of student-centered learning, the current study introduced group-project as a mandatory assignment that counted towards 10% of the overall grade in the thermodynamics class. The assignment required students of the thermodynamics class, comprising primarily of sophomore and some junior students, to define an engineering problem that can be solved by applying the principles of thermodynamics. Students were to form groups of size 5-7 and discuss ideas for the project. The size of each group was justified by the large size of the class, which comprised 125 students. The students were allowed to independently choose topics for the projects. Each project required the application of fundamental concepts of thermodynamics to analyze real-life processes and devices and to seek methods to improve the efficiency. The project provided students an opportunity to collaborate with fellow class mates, discuss new ideas for applying principles of thermodynamics, and come up with an innovative solution to the stated problem.

The specified outcome of each group project included a written report and a short presentation by each group of students. The reports were to include sections: project introduction, problem definition, objectives, proposed approach, analysis/calculation using principles of thermodynamics, discussion of the solution to the problem and conclusion. The reports were also required to explicitly mention the contribution of the individual group members towards the project.

The projects were graded based on the innovativeness of the idea, stated problem and the solution, the in-class presentation of the project, the written report with analysis/quantitative results and finally relevance to principles of thermodynamics. An online forum was created where students were able to post topics of interest and to facilitate discussion on the topic to form groups. Each student in a group was required to define a specific role within the group such that each participant contributed equally.

Topics of Student Group Projects

The students came up with innovative topics for the group projects. For instance, some of the topics were "*Advancements in Solar Collector Heat Exchangers*", "*An Analysis of Ramjet Propulsion*", "*The Effect of Various Operating Fluids on the COP of a Refrigeration Cycle*", "*How does Forced Induction Affect the Otto Cycle?*" "*The Modification of a Diesel Cycle for*

Use in a Hybrid Automobile Drivetrain", "*Nuclear Fusion as a Heat Source*", "*Find Ways to Improve the Efficiency of the Turbo Jet Engine*", "*Reheat Rankine Cycle, Specifically the Cost Efficiency of Adding Turbines*", "*Differences with using Propane in the Otto Cycle Vs. Gas in the Otto Cycle*", and "*Examine Using a Turbine Instead of a Throttling Valve in a Refrigerator*", and "*Pulsejet Engines.*"

Assessment of Student Learning

The assessment of student learning outcome was achieved through two mechanisms. The first mechanism involved two questionnaires that were passed out in class, one before the project was announced and the other after completion of the project. The second mechanism involved comparative analysis of the average performance of the students prior to and after the assignment of the group project. The first questionnaire included the following questions:

1) **Which of the following has been the best source for learning concepts of thermodynamics**?
   a) Text book
   b) Class notes
   c) Peer-to-peer mentoring
   d) Group discussion
   e) TA Recitation

2) **Which form of assessment has been the most useful in helping with self evaluation of performance in the course**?
   a) In-class quizzes
   b) Home works
   c) Midterm exams

3) **Which form of assessment has been the most useful in helping with learning concepts of thermodynamics**?
   a) In-class quizzes
   b) Home works
   c) Midterm exams

The second questionnaire was slightly modified version of the first and included student group project as a response option. Specifically, it included the following questions:

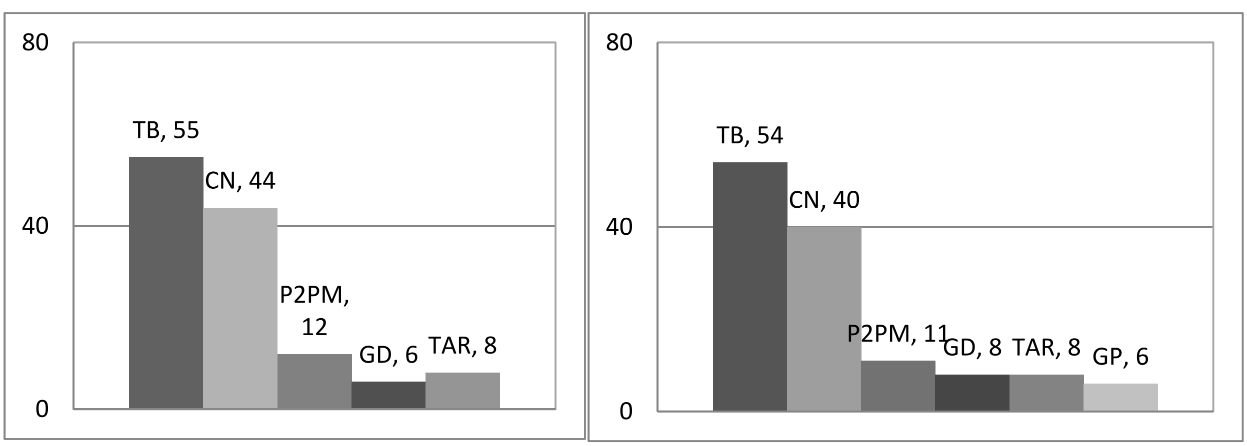
1) **Which of the following has been the best source for learning concepts of thermodynamics**?
   a) Text book
   b) Class notes
   c) Peer-to-peer mentoring
   d) Group discussion
   e) Working towards group project
   f) TA Recitation

2) **Which form of assessment has been the most useful in helping with self evaluation of performance in the course**?
   a) Group project
   b) In-class quizzes
   c) Home works
   d) Midterm exams

3) **Which form of assessment has been the most useful in helping with learning concepts of thermodynamics**?
   a) Group project
   b) In-class quizzes
   c) Home works
   d) Midterm exams

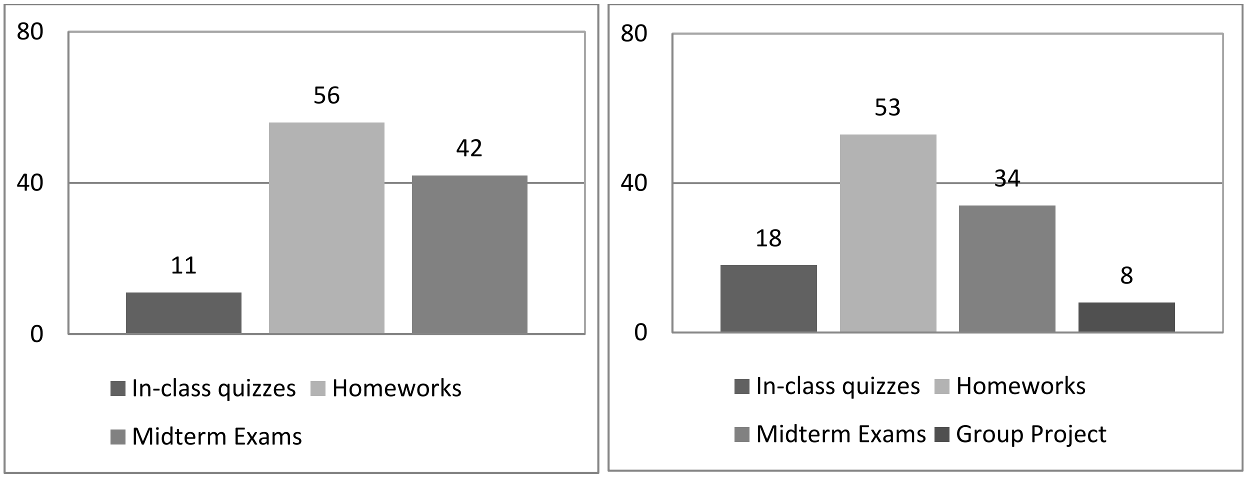
Students were allowed to choose multiple options as responses to the questions. In addition to responding to these multiple-choice questions in the survey, students had the opportunity to provide comments to describe what they found most and least useful to learning.

Figure 1 presents the responses to question 1. The distribution of response to the questions before and after the assignment of the student project shows that students rated the text book and class notes consistently as the most important sources for learning concepts of thermodynamics. However, it is important to note that the students were not provided feedback about their performance on the project prior to the second set of questionnaires. Based on previous experience of the instructor in teaching the same class, students typically favorably rate any form of assignment where the class average score is high. This trend is reflected in the response to the second question in the questionnaires. Amongst the three forms of assessments prior to the first questionnaire, the least number of students indicated quizzes as useful in self-evaluation, while most students indicated home works as the most useful mechanism for self-evaluation. It is important to note the direct correlation between the response and the average grades in these assignments. While the average home work grade prior to the first questionnaire was 85.6, the average grade for quizzes was 58.9.



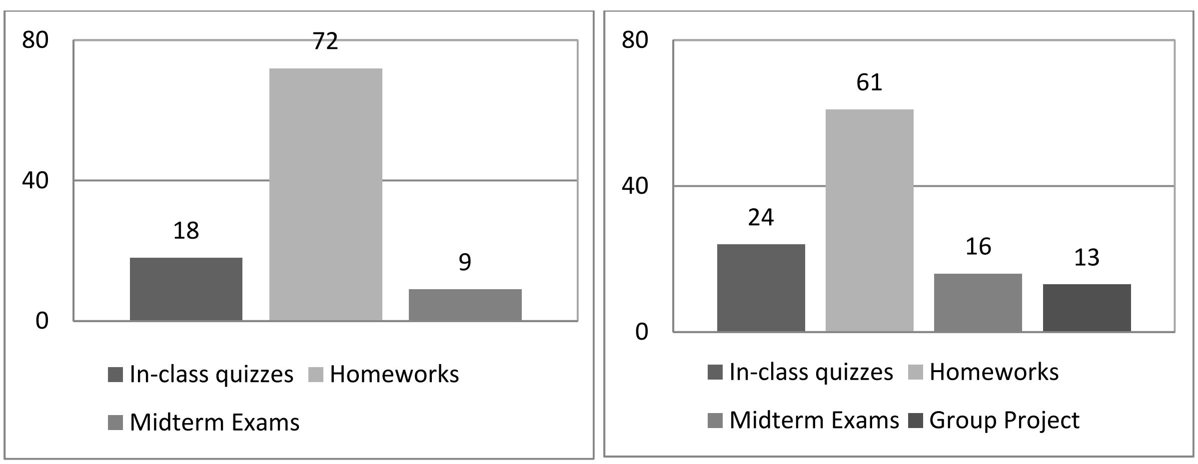
(a) **(b)**

Figure 1. Distributions showing number of responses in favor of each option in question 1 of the survey questionnaire (a) before the students were assigned the group project, and (b) after the assignment of the group project, are presented. The full forms used in the legends on top of the vertical columns are: TB – Text Book, CN – Class Notes, P2PM – Peer-to-peer Mentoring, GD – Group Discussion, TAR – TA Recitation.



(a) **(b)**

Figure 2. Distributions showing number of responses in favor of each option in question 2 of the survey questionnaire (a) before the students were assigned the group project, and (b) after the assignment of the group project, are presented.



(a) **(b)**

Figure 3. Distributions showing number of responses in favor of each option in question 3 of the survey questionnaire (a) before the students were assigned the group project, and (b) after the assignment of the group project, are presented.

The general trend in the responses to the third question in the first questionnaire, shown in Fig. 3(a) is identical to that of the second question, shown in Fig. 2(a). However, while students rated exam as a good source for self-assessment of learning, they did not find exams to particularly help in learning concepts of thermodynamics. This pattern in response is consistent with the fact that while students frequently discussed quizzes outside of class and worked on homework problems together, thus enhancing their understanding of fundamental concepts, exams were a one-time form of assessment. The responses to the second and third questions in the questionnaire that was handed out after completion of the project show interesting trends, as presented in Figs. 2(b) and 3(b). Figure 2(b) shows that the students rated the group project low in helping with self-assessment, which is consistent with the fact that the students did not know their performance in the project at the time the questionnaires were passed out. On the other hand, the students rated the group project somewhat high as a mechanism to help understand the concepts of thermodynamics.

In addition to the questionnaires handed out in class, which did not account for the students' awareness of their performance on the project, the overall grades on assignments prior to the announcement of the group project and after its completion were also analyzed. The average grade on the group projects, determined based on independent inputs from three teaching assistants and the instructor was 90.7, which was significantly better than that in home works, quizzes midterm exams, and the final exam. The average grades for these four forms of assignment were 84.7, 58.9, 72.3 and 77.3. In particular, the students performed extremely well in both presenting their project and writing the reports, both of which were accounted for while grading the project. While the overall grade of students prior to the project was 76.6, that after the completion of the project and final exam was 79.0, which implied improvement in overall performance after the project was assigned.

The performance of students in quizzes (the form of assessment with lowest average grade) before and after introducing the project was compared. While the average grade prior to assignment of quizzes was 57.6, that after the assignment of project was 61.7. The fact that the scores improved despite the fact that many more students missed quizzes over the final weeks of the semester compared to the first few weeks, further underscores the conclusion that involvement in the project helped students understand the concepts better. Furthermore, the average score in the two midterms, which were given before the group projects were assigned, was 72.25, while that in the final was 77.3 and showed significant improvement.

While this preliminary study indicates some improvement in student learning by assigning group projects, there is scope for further improvement. In particular, making specific changes to the way the students form project teams and assessment of individual performances within groups can enhance student experience and engagement in the group project. For instance, the author let students choose teams, which could have led to some skewness in the teams. While some groups comprised students that were already highly engaged in class, other groups had students that were not as interested. Forming more well-rounded groups with a range of students in each would promote positive interdependence, collaborative skills and peer-to-peer mentoring as shown by studies of Felder et al.[11] For future offerings of this course with the group-project component, the author plans on letting students fill brief survey based on which students would be selected to form teams.

In this particular study, students were required to explicitly state their contribution to the group project. However, the students were graded based on group performance without rewarding individual performances within a group. This was partly due to the fact that the class was big with groups of up to 7 students. Therefore, it would be challenging to track and grade students based on individual performances. However, previous work by Felder et al[11,12] indicate that individual accountability can improve student engagement in a cooperative project-based learning environment. The author plans to include components of the assessment geared towards encouraging all students to perform equally, for future assignments.

Finally, the questions asked in the second survey questionnaire required students to choose a form of assignment or source of learning that was most effective in helping them learn and also perform self-evaluation. While the students chose answers to these questions with accurate knowledge of their performance on home works, quizzes and exams, they did not have information about their performance in the group project, which might have affected their responses. The author intends to pass out similar questionnaires at a future offering of the same course. However, the author will pass them out three times, once before assignment of the group project, once after its completion and finally once after the students are informed about their performance.

Summary and Conclusions

The effectiveness of group project in enhancing student learning of the concepts of thermodynamics was evaluated based on a set of two questionnaires passed out in class prior to announcement of the group project and after its completion. Additionally, the performance of the students in class was analyzed and used as a metric. Analysis of the responses to questions as well as the grades indicates positive influence of the group-project on student learning and engagement. These outcomes have been discussed in details along with scope of improvement in future offerings of the group project. In particular, forming groups that have a range of students in terms of prior performance in class, as well as incentivizing and encouraging students to excel in their individual performance within groups, are expected to provide improved outcomes.

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