A Study in Collaborative Learning in Flipped Class Environments

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Abstract

Student collaboration should encourage students to teach one another. Thus, course material is cemented in the teacher's mind, and the student being taught also benefits. It is hoped the taught becomes the teacher at another time on other topics.

Before this study, the authors used class time in their flipped classrooms for quizzes, which served as formative assessments, and solving practice problems in informal groups. Many studies have shown the benefit of collaboration between students[1] so the authors hoped to increase the amount of collaboration among students by assigning students to groups and quizzing them in these groups at the end of each week.

To test the group quizzing hypothesis, in Spring 2016, the authors conducted a study in two different courses, each having two sections, all taught in flipped mode. One section for each course was the control group. Collaboration was encouraged in the control group, but not formalized. In the study sections, after the middle of the semester, groups were chosen by the instructors. The groups worked as teams on practice problems, and took a group quiz at the end of the week. Groups were changed each week.

Assessment was by comparing changes in exam performance between the control and study groups and through a survey.

Comments in the survey indicated a change in student attitude when assigned to a group. Students revealed a desire to be supportive in their groups, and said they prepared accordingly – an encouraging result. However, less encouraging, students confessed to preparing less for group

quizzes, knowing others in their groups would provide what they lacked. Exam scores did not indicate a significant difference between the control groups and the test groups.

Introduction

The flipped or inverted classroom has been widely researched and continues to be an area of much interest. However, several recent studies provide evidence that, when compared with other active learning pedagogies, the flipped classroom itself does not improve students' performance on traditional classroom assessments or design activities.[2–10] However, as one of the authors writes in a recent ASEE paper[11] there may be other reasons beyond students' immediate content learning to utilize the flipped classroom. One of these other reasons to flip a class is to implement structured student collaboration.

Student collaboration is widely viewed[1] as good pedagogy. One particular type of student collaboration is collaborative testing. Slusser and Erickson[12] found that in a sociology class students' exam scores were not improved by using collaborative quizzes. However, they did find that collaborative quizzes encouraged students to come to class prepared and students who took collaborative quizzes viewed the quizzes more favorably. Enz and Frosch come to a similar conclusion stating "Peer collaboration improves quiz scores, is favorably perceived by students and enhances their course satisfaction, but does not improve subsequent performance on midterm and final examinations taken noncollaboratively."[13] However, Roa, Collins, and DiCarlo find "completing the quizzes in groups enhances the understanding of the material."[14] Moreover, Leight et al. hypothesis that collaborative testing might improve students' obtainment of lower-order learning outcomes (Bloom's levels 1 and 2), but not higher-order learning outcomes (Bloom's levels 3–6).[15]

Background

Informal collaboration has always been encouraged in the two inverted courses of the present study: Thermodynamics and Mechanical Engineering Analysis. Most students form a small group with whom they study consistently. A few students work individually, despite opportunities for collaboration.

The authors were interested in assessing, if possible, the benefits of structured collaboration on student performance and attitude using collaborative quizzes. Although student attitude and performance may be closely linked, performance is easily quantified.

Flipped Classes

Thermodynamics: Two sections of the first semester course in thermodynamics were included in the present study. Classical thermodynamics is predicated on the conservation of mass, conservation of energy (the "first law" of thermodynamics), and the second law of thermodynamics, in which entropy is defined.

Mechanical Engineering Analysis: Mechanical Engineering Analysis at Trine University is a freshman level course used to introduce students to formal problem solving in several different mechanical engineering contexts. Therefore, problems in statics, dynamics, thermodynamics, fluid mechanics, strength of materials, and engineering materials are all solved by the students. As one might expect, these problems constitute only the most basic concepts in each of these classes.

Both courses were inverted or "flipped." Lecture videos were viewed on students' own time. During class time, quizzes were administered and a small number of example problems presented by the instructor. However, students spent most of the class time working on practice

problems that were not handed in. There was insufficient time to complete all the practice problems during class. Therefore, to prepare properly for the weekly quizzes, students had to work practice problems outside class.

The instructor was available for questions the entire time the students worked on practice problems.

In one class period per week, a quiz over one of the practice problems was proctored. The practice problem used for the quiz might be slightly modified, such as changing a number or switching unit systems (e.g. SI to English units). This is the quiz students took in groups when that phase of the study was current.

During other class periods in the week, students were given a quiz intended only to prove they had viewed the lecture video and had taken notes. These were open-note quizzes. Understanding of the material in the lecture was not required to pass the quiz. No partial credit was awarded for these quizzes.

The Study

Thermodynamics: Section 01 was used as the control group. Collaboration was encouraged but neither required nor formally structured. When collaboration occurred, section 01 students chose those with whom they would collaborate, and on what topics they would collaborate. All quizzes and exams were the work of individual students.

Section 01 began the semester with 25 students. Two students dropped during the semester, leaving 23 to finish the course spring 2016. Of those who finished the course, 21 provided their approval to include their scores for this analysis.

Section 02 was the experimental group. Collaboration was simply encouraged until after Exam II. After Exam II, groups or teams were assigned by the instructor. Generally, groups of three (3) were chosen, but since the class population was not always divisible by three, some groups of two were also assigned. Groups were assigned each week right after the weekly quiz over a practice problem. The groups worked together until the next quiz, and each quiz was worked as a group. Each member of the group was given the same quiz score. No effort was made to ensure that the members of the group shared the load.

Individual students took exams in both sections the same way. Group exams were not given.

Section 02 began the semester with 24 students. Two students dropped during the semester, leaving 22 to finish the course spring 2016. Of those who finished the course 19 provided their approval to include their scores for this analysis.

The instructor recorded the following observations about the experimental group during the semester. These were only observations, no attempt was made to quantify, measure, or assess these behaviors.

- Prior to the second exam, section 02 (later the experimental group) was quieter than section 01 (the control group) and collaborated less.
- Students appeared to be better prepared for class when assigned to instructor-appointed groups.
- The students appeared to be collaborating actively.
- More questions are being asked in class.

Exam scores for both the control group ("Partners") and the experimental group ("Without Partners") are summarized in Figure 1. Both Exams I and II were taken before the collaboration experiment began.

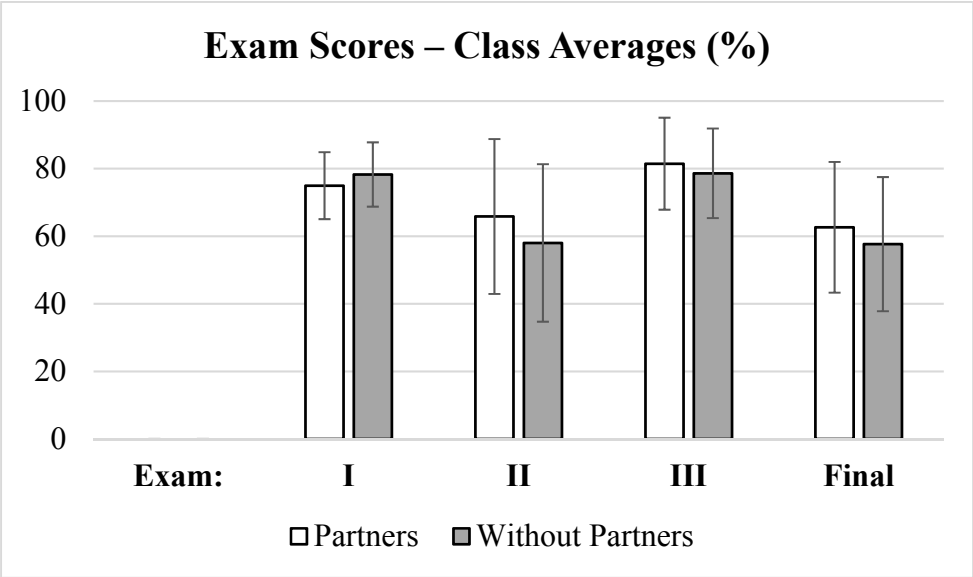

Figure 1. Average Exam Scores for both Sections of Thermodynamics. The error bars represent one standard deviation.

As can be seen, the collaboration section had already surpassed the control group after Exam II and before the structure for formal collaboration was established after Exam II.

A two-sided *t*-test was performed on the students' test scores for each of the four exams given. The calculated value of *t* in each case was less than the tabulated *t*-value for a significance level of 0.1. So the null hypothesis may be accepted, the conclusion drawn that there is no significant difference in the sections' mean values for any of the test scores.

Mechanical Engineering Analysis: In Mechanical Engineering Analysis section 02 was the control group while section 01 was the experimental group. Just as in thermodynamics, collaboration was encouraged but neither required nor formally structured in the control group.

Moreover, in the control group all quizzes and exams were the work of individual students. Additionally, in the experimental group, collaboration was just encouraged until after Exam II. After Exam II, groups were assigned by the instructor in much the same way as described above.

The control group had 18 students while the experimental group had 19 students who completed all course work. The control group consisted of 15 men and 3 women who ranged in age between 18 and 19-years-old. The experimental group consistent of 17 men and 2 women who again ranged in age between 18 and 19-years-old.

The results of the three exams for Mechanical Engineering Analysis are shown in Figure 2.

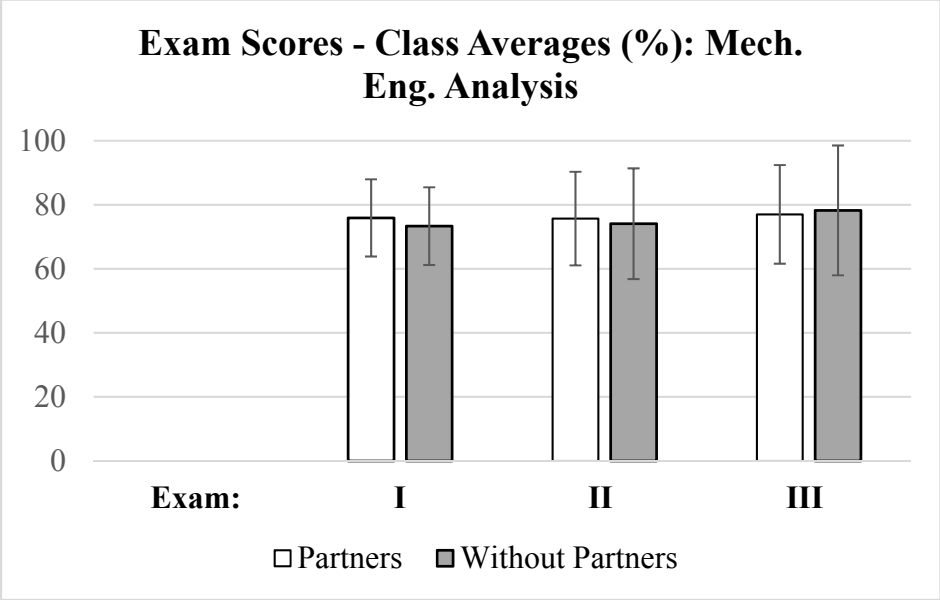

Figure 2**.** Average Exam scores for both sections of Mechanical Engineering Analysis. The error bars represent one standard deviation.

A two-sided *t*-test was performed using scores for Exams I and II and no significant differences were found between the two sections before collaboration was encouraged in the experimental group. Moreover, a two-sided *t*-test was performed using the Exam III results and again there was no statistically significant difference between the two groups. From this the

authors conclude weekly group quizzes did not improve student performance on individual assessments since each exam is the work of individual students.

Survey Questions

Thermodynamics: A survey was administered to the students in both thermodynamics sections near the end of the semester. It was not possible to separate the responses of the two sections, except for the comments, in which statements made permitted the determination of the commenter's section.

The numbers in the legend refer to question numbers. The ordinates on these plots are numbers of students responding according to the response options shown on the abscissa.

Below, the survey questions are listed in pairs, and the number of student responses to the appropriate categories are plotted for each pair of survey questions.

1. How often do you work on practice problems with other students outside of class?
2. How often do you work on practice problems by yourself outside of class?

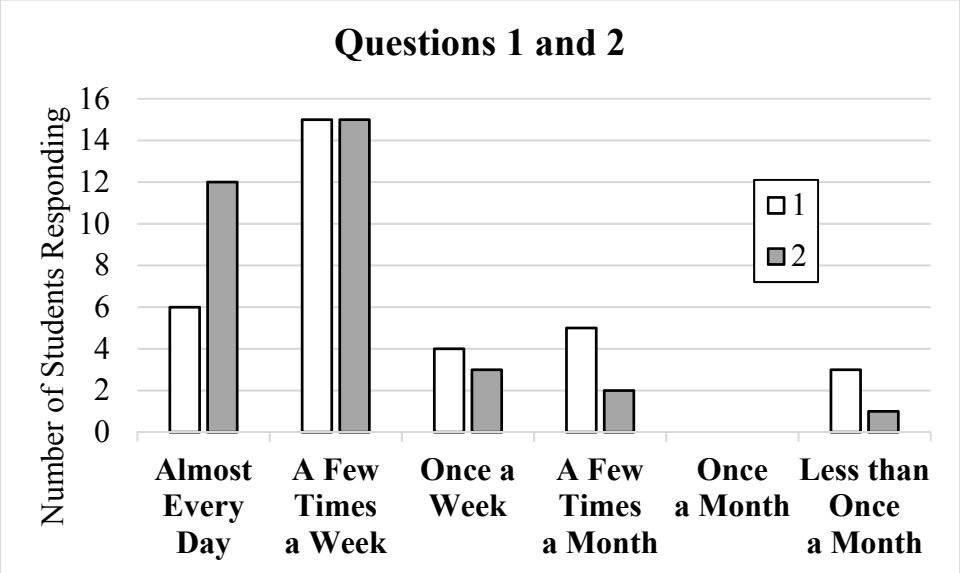

Figure 3. Student Responses to Questions 1 and 2.

Based on the data of Figure 3 students worked alone most frequently, and with others less frequently. Apparently, students often collaborated outside class. Perhaps scheduling conflicts resulting in group work being less frequent than working alone.

3. Do you work on practice problems outside of class more often than you did at the start of the semester?
4. Do you work on practice problems outside of class with other students more often than you did at the start of the semester?

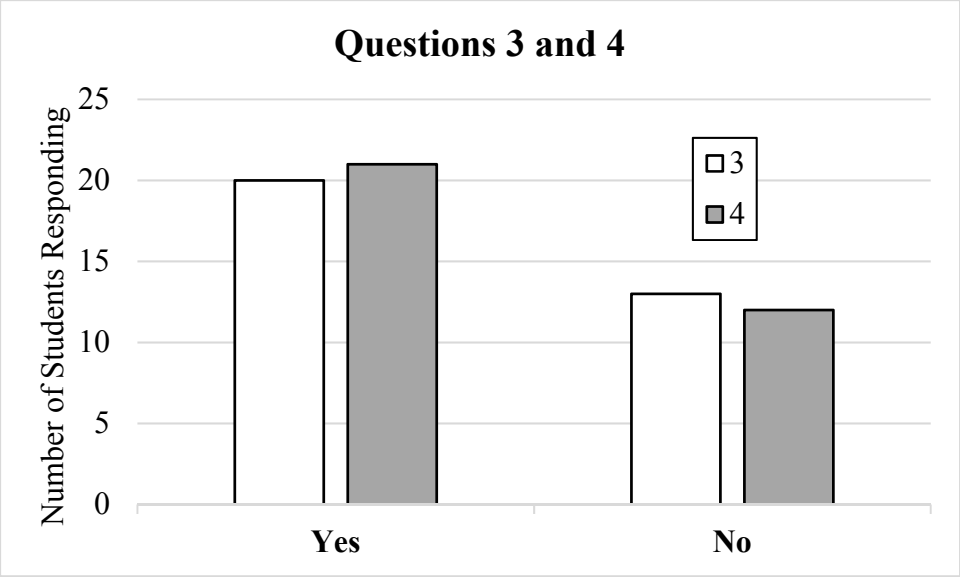

Figure 4. Student Responses to Questions 3 and 4.

There is nearly no difference, according to Figure 4, in those who worked alone and those who worked with others. A majority of students apparently learned working thermodynamics problems outside class was necessary for success.

Mechanical Engineering Analysis: The same survey given in thermodynamics was also given to the Mechanical Engineering Analysis students. Unlike thermodynamics, the learning

management system was configured in such a way in Mechanical Engineering Analysis that the results from the control group and the experimental group can be compared.

Figure 5 seems to show students in the experimental group worked on practice problems with others outside of class much more often. In particular, six students in the control group (33%) responded they worked with other students on practice problems outside of class less than once a month compared to zero students in the experimental group. However, Figure 6 shows students in both groups increased their collaboration on practice problems outside of class at almost the same rate (9/17 for the control and 10/17 for the experimental). This seems to indicate that the students in the control group were simply less likely to collaborate on practice problems outside class and the formal collaboration setup by the instructor for the experimental group was not the cause of the results shown in Figure 5.

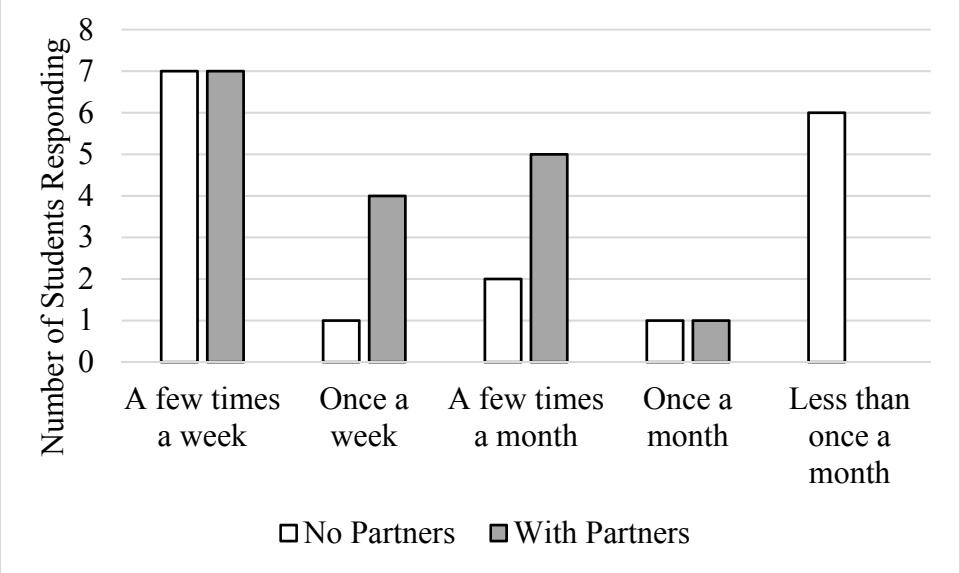

Figure 5. How often do you work on practice problems with other students outside of class?

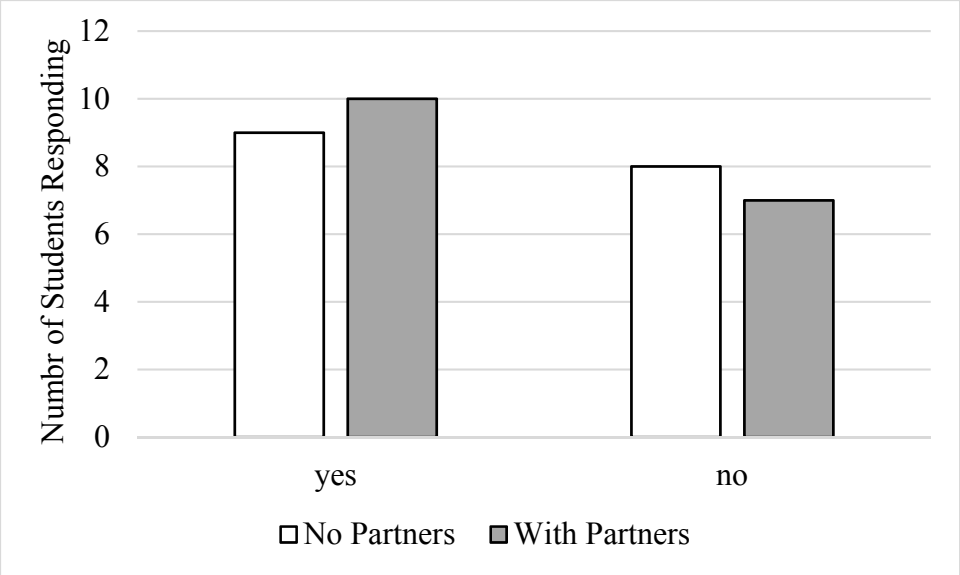

Figure 6**.** Do you work on practice problems outside of class with other students more often than you did at the start of the semester?

Additionally, the students' responses from the experimental group show 16 of the 17 students either strongly agreed or agreed that they enjoyed taking the quizzes in groups. However, only 9 of 16 students strongly agreed or agreed with the statement that they did better on the individual exams because of the group quizzes. Nevertheless, the fact that 9 of 16 students in the experimental group believe they did better on the exams despite the quantitative evidence to the contrary is interesting. Perhaps the fact that the students enjoyed the group quizzes makes them believe it positively impacted their content learning.

Survey Comments

Thermodynamics: The anonymous survey included a request and space for comments. Twelve students in the control group and fifteen students in the experimental group provided comments.

Below, parts of some of the comments are reproduced. Except where mistakes greatly impeded understanding, these quotes are provided verbatim. As the purpose is to provide

evidence of student feelings about the collaboration project and not to point out errors in these comments, *[sic]* is not used.

Ten of the twelve students in the control group expressed a wish they had been included in the collaboration group. The other two felt taking group quizzes was not in their best interest. One believed taking a quiz as a group would not be a group effort:

- I did not take the quizzes in small groups, and do not wish I had been given the opportunity. Not only were the quizzes a way for me to assess my understanding of the concept being tested, I believe the intended focus of the study, collaboration, would have been lost in the scramble to write down a correct answer. In other words, I think it would have been a single person doing all the work.

The other control-group student felt he or she would have had an unhealthy reliance on others in the group at quiz time:

- I did not take the quizzes in small groups, and I don't think that I would want to. I feel like quizzing with a group would give me a reason maybe to not completely finish or understand the practice problems and would possibly lead me to trying to rely on other people instead of working harder to ensure that I could do the problems myself.

Students in the collaboration group were likely to have positive attitudes toward group work, but three felt group quizzes were not beneficial:

- However i do not believe it [collaboration] has helped me do better on the class or the quizzes. i think it might have hurt me on my quiz grades.
- Taking the quizzes in groups was not very helpful for me because I knew how to do the problems on my own.

- While there was less anxiety [at quiz time], I felt like I would have performed more efficiently by myself.

Two other collaboration group students had mixed feelings about group quizzes:

- I have mixed feelings about the group quizzes. In theory, it is a great idea. But I didn't like when I had group members that didn't know much about the topics covered. I also felt bad when I didn't know something and felt like I was dragging my group's grade down.
- I would say that there were pros and cons to the group quiz format. i believe it improved how i did on the quizzes because when i didn't know exactly how to solve a problem a member of my group did. so, this impacted my study habits because if i knew one of my group members was well studied in the material it was easier to spend less time working the practice problems that week. ... basically, when i had to solely rely on myself for solving the quizzes i was more inclined to work more of the practice problems.

One of the apparent positive results of the present collaboration study was student perception they worked at being more prepared for class time work with their instructor-assigned groups. Some of the student comments supporting this included the following:

- I felt I needed to study/do the practice problems more to understand them so I didn't let my group down.
- I think the group quizzes motivated others to work on the practice problems as I noticed people who normally didn't try, actively working together.

A small number of students who experienced work in groups had the opinion they were not more motivated to be prepared to work practice problems as a consequence of being in a group:

- Although having small groups for the practice problem quizzes was interesting in giving the opportunity to work with different people, I felt no change in motivation to work on the practice problems. [This student indicated he/she was naturally highly motivated.]
- … if i knew one of my group members was well studied in the material it was easier to spend less time working the practice problems that week.

Some students commented on the teamwork aspect and indicated they appreciated working with students they normally would not have sought out.

- It brought much more than teamwork to the class. It promotes me to understand the concepts in order to help others as well as myself.
- During the quiz you talk to your groups on how to proceed on a problem and check each other's work.
- … it was beneficial to be able to confirm thoughts on calculations and answers with others.
- Working with other people helps to see a different perspective on how to solve certain problems.
- On quiz day, if I was not sure of a certain aspect my partner more than likely knew it and vice versa. The main reason small groups were nice was being able to have two members (at the same spot in the practice problems) to talk through each problem and explain any confusing issues that arise.
- It is also nice to be able to talk through problems.
- Working in a group allows for collaborative thinking and extra checks.
- Having partners allowed for us to bounce ideas off of each other and get to a solution faster than an individual would be able to.

- I beleive that taking the quizes with a group was a great idea. It also allowed collaboration in between students, whom might otherwise not have any contact.
- … it gave me a group of people to think through problems with instead of trying to tackle a problem I wasn't sure about by myself.

Because this project was to study the impact of collaboration, structured collaboration was not initiated at the beginning of the semester. A few students commented on that topic.

- I wish we had groups from the start.
- I believe this would be great to implement at the beginning of the year so people begin forming study groups early.
- I think that it would have been better to start off with the groups in the beginning of the year.

Mechanical Engineering Analysis: Again, the student survey left space for comments. Fifteen students in the control group and seventeen students in the experimental group provided comments. Five students in the control group wished they had the opportunity to take the practice problem quizzes in groups. For example, one student in the control group stated:

- I really wish I would have been given the opportunity to work in small groups for the quizzes because I feel like I do better knowing that I am a part of something

However, five students in the control group also stated they were glad they did not have to take the practice problem quizzes in groups because students were more motivated to diligently prepare for the quizzes. For example, students in the control group stated:

- I'm glad I didn't take the quizzes in small groups because it made me study harder and be more motivated to have a clear understanding of the subject/topic

- I feel that the partner quizzes inevitably lead to people free-boating off of people who actually pay attention and results in a higher mean grade that is not representative of the actual performance level of the class.

As discussed previously, this feeling was also expressed by two student in thermodynamics.

A second reason cited for not wanting to do quizzes in groups was because the quiz score would be less useful as an assessment of their own learning. Students stated things like

- So I would actually prefer to not take quizzes in groups so I can learn from my own mistakes and improve
- I do not really wish I had the opportunity to take the quizzes in small groups, yes it would have most likely been better for my grade, but I feel taking them by myself is a better gauge of my abilities and shows me what I need to study for the tests

While the control group seemed to be conflicted about the opportunity to work in groups on the quizzes the experimental group mostly stated that group quizzes were beneficial. Overall, 12 students provided positive comments, one student provided negative comments and two students had mixed comments about the group quizzes. The mixed and negative comments did address a lack of motivation either with themselves or their partners as the reason for their comments. For example, these students stated:

- I do not think it [quizzes] helped to motivate me to work on the practice problems because if I was busy then I wouldn't study as much. I knew I could rely on classmates to know how to do the quiz.
- sometimes I felt like I was carrying my partner along for the ride. I didn't have time to properly teach him/her the concept if he/she didn't fully understand it, so I just had to tell him/her how to do it. Therefore, while I benefited from the partner quizzes, I don't know

that all of my partners actually did. Sure they might have gotten a better grade than they would have on their own, but they didn't necessarily learn the concept, which is the goal is it not?

- I felt like I studied harder, because I had a partner for the quiz. The feeling of letting down my teammate is unbearable to me. Unfortunately, I've found that, on occasion, my teammate did not have the same thought process as I did.

The last comment above, and those immediately below, show many students found working with a partner motivated them to prepare as well as they could for the quizzes.

- In my case, i felt more of a responsibility to do well on the quizzes, because it was not only my grade being affected, but someone else's grade as well
- I believe that the quizzes helped motivate me to work the practice problems because when taking a small group quiz you have to be able to help your partner(s).
- When we got to take the quizzes as a group, first off it pushed me to try harder outside of class because I didn't a.) want to be the kid no one wanted to have as a partner on the quiz b.) want to negatively effect someone else's grade.

Again, this echoes the comments of students in thermodynamics.

Just like the students in thermodynamics, many of the students commented on the teamwork skills they developed.

- I believe taking quizzes in groups has helped me better develop my group work skills, and has taught me how to better work with other students.
- … it was also a good way to get to know some of the other students that I didn't know as well

- Being able to see how someone else looks at the problem in a different way can be helpful …
- The small group quizzes were enjoyable and helped generate discussion of how to solve certain problems and also tested both partners problem solving ability and knowledge of the material.

Additionally, several students commented on the fact that group quizzes helped reduce the stress associated with the evaluation.

- … overall it took away a lot of the negative stress brought by quizzes and allowed me to focus on understanding the material.
- … it also took away a lot of daily stress when it came to quizzes because if I didn't know the concept perfectly I had a partner that also could help me through.

Conclusions

Direct and significant impact on exam scores was not observed. Despite this, students exhibited more enthusiasm for working practice problems. The majority of students liked working in groups. Some found they appreciated working with group members they normally would not have. This conclusion is in agreement with the work of Slusser and Erickson and Enz and Frosch. Moreover, since most of the questions on the exams in thermodynamics and Mechanical Engineering Analysis are at Bloom's level 3 and perhaps 4 this study also agrees with Leight et al. statement that higher-order learning objectives are not helped with collaborative quizzes.

Group work remains important because most graduates can expect to work in teams and generally interface with others in their occupations. Frequently, in the working world, workers

cannot choose all their team members. Hence, it is believed experience working with students other than one's circle of friends is a useful exercise.

Perhaps further studies focused on quantifying the effect of collaborative quizzes on students' performance in teams is warranted. This might be especially interesting in courses such as Mechanical Engineering Analysis which assess students using a design project as well as traditional exams. Perhaps the collaborative quizzes lead to better team dynamics and projects.

References

1. Prince, M. "Does Active Learning Work? A Review of the Research," Journal of Engineering Education, 93(3), 223-231. 2004.
2. Canino, James V. "Comparing Student Performance in Thermodynamics Using the Flipped Classroom and Think-Pair-Share Pedagogies". *Proceedings of the 122rd ASEE Annual Conference & Exposition*. Seattle, WA, 14-17 June 2015. ASEE, 2015. Internet. 28 January 2016.
3. Saterbak, Ann, Tracy Voltz, and Matthew Wettergreen, "Implementing and Assessing a Flipped Classroom Model for First-Year Engineering Design," Advances in Engineering Education, Vol. 5, no. 3, 2016.
4. Prust, Cory J., Richard W. Kelnhofer, "The flipped Classroom: it's (Still) All About Engagement," *Proceedings of the 122rd ASEE Annual Conference & Exposition*. Seattle, WA, 14-17 June 2015. ASEE, 2015. Internet. 28 January 2016.
5. Jenson, Jamie L., Tayler A. Kummer, Patricia D. Godoy, "Improvements from an Flipped Classroom May Simply Be the Fruits of Active Learning," Life Sciences Education, Vol. 11, no 1, March 2015. Internet. 28 January, 2016
6. Lape, Nancy K., Rachel Levy, Darryl Yong, Nancy Hankel, and Rebecca Eddy "Probing the Inverted Classroom: Results of A controlled Study of Teaching and Learning Outcomes in Undergraduate Engineering and Mathematics". *Proceedings of the 123rd ASEE Annual Conference & Exposition*. New Orleans, LA, 26-28 June 2016. ASEE, 2016. Internet. 28 January 2016.
7. McClelland, Carrie J., "Flipped a Large-enrollment Fluid Mechanics Course – Is it Effective?", *Proceedings of the 120th ASEE Annual Conference & Exposition*. Atlanta, Georgia, 23-26 June 2013. ASEE, 2013. Internet. 2 January 2015.
8. Mason, Gregory, Teodora R. Shuman, and Kathleen E. Cook, "Inverting (Flipping) Classrooms – Advantages and Challenges". *Proceedings of the 120th ASEE Annual Conference & Exposition*. Atlanta, Georgia, 23-26 June 2013. ASEE, 2013. Internet. 19 January 2015.
9. Cavalli, Matthew K., Neubert, Jeremiah J., McNally, Dustin, and Debbie Jacklitch-Kuiken, "Comparison of Student Performance and Perceptions Across Multiple Course Delivery Modes". *Proceedings of the 121st ASEE Annual Conference & Exposition*. Indianapolis, IN, 15-18 June 2014. ASEE, 2014. Internet. 2 January 2015.
10. Thomas, J. and T. Philpot, "An Inverted Teaching Model for a Mechanics and Materials Course," *Proceedings of the 119st ASEE Annual Conference & Exposition*. San Antonio, TX, 10-13 June 2012.
11. Batson, B. W., '"Other" Reasons to Invert a Class,' *Proceedings of the 123rd ASEE Annual Conference & Exposition*. New Orleans, LA, 26-28 June 2016. ASEE, 2016. Internet. 13 March 2017.
12. Slusser, S. and R. Erickson, "Group Quizzes: An Extension of the Collaborative Learning Process," Review of Educational Research, Vol 34, 249-262, 2006.
13 Enz, Stephanie and Donald R Frosch, "Effect of Collaborative vs Noncollaborative Quizzes on Examination Scores in a Pharmaceutical Calculations Course," American Journal of Pharmaceutical Education, Vol 79, no 5, 2015.

14. Roa, Sumangala, Heidi L. Collins, and Stephen E. DiCarlo, “Collaborative Testing Enhances Student Learning,” Adv. Physiol. Educ, Vol 26, 37-41, 2002.
15. Leight, Hayley, Cheston Saunders, Robin Calkins, and Michele Withers, “Collaborative Testing Improves Performance but Not Content Retention in a Large-Enrollment Introductory Biology Class,” CBE-Life Sciences Education, Vol. 11, 392-401, Winter 2012.