Flipping the Classroom - Do Student Learning Gains and Perceptions Vary Based on Gender?

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Abstract

This work expands previous work (Doyle and Nilsson, 2016) on the impact that pedagogical changes, including a hybrid flipped classroom, have on student engagement and retention of material in engineering statics. During two academic years (2015-2016 and 2017–2018), data were collected from eight total engineering statics sessions. The data set includes prerequisite grades, final statics grades, scores from pre- and post-statics concept inventory and a post-course survey administered via google forms. The additional data collected during 2017-2018 provides a more robust data set to draw conclusions on the effectiveness of the pedagogical changes. The data show underrepresented minorities (females) are more engaged in the material with the hybrid flipped classroom, and more importantly, make greater gains in knowledge compared to their male counterparts. Across all data, female students concept inventory scores show greater gains from pre- to post- course. Female students (n = 36) increase concept inventory score by 138% compared to an increase of 77% by male classmates (n = 90). The value of active pedagogies was reinforced as 58% of all students stated that this course 'increased' or 'greatly increased' their interest in engineering with a greater percentage of females indicated the course 'greatly increased' their interest in engineering. Results from this study are of particular interest as engineering programs strive to retain all students, especially underrepresented minorities, and to increase diversity and inclusion in engineering. An unexpected result of this work was the reinforcement of the need for targeted faculty development in the implementation of active-learning methodologies to insure the method has the intended effect on student learning and engagement.

Introduction:

Teaching methods are known to affect student performance in a course. The meta-analysis of 225 studies on active-learning by Freeman, *et al* [1] found students in STEM courses taught with extensive lecturing are 1.5 times more likely to fail, earn a D, or withdraw from the course than students taught with active-learning methods in the same STEM course subject. A second meta-analysis of engineering and technology education journal articles confirmed that small-group and collaborative learning pedagogies increased student performance by close to a half a standard deviation [2].

Teaching practices have also been shown to impact student self-perceptions of their intent to persist, perceived responsibility for learning, outcome expectations, confidence in their ability to be an engineer and motivation to be an engineer [3]. Colbeck, *et al,* [3] found teaching practices that included instructor interaction and feedback, collaborative learning, and a high level of clarity and organization consistently and positively related to gains in the five self-perceptions listed above. Classroom climate and pre-college characteristics (e.g. SAT scores, parent education, ethnicity and gender) did not lead to the same gains in self-perception. When looked at specifically by gender, collaborative learning along with clarity and organization had the greatest influence on female students' self-perceptions. Instructor interaction and feedback provided greater gains for male students [3].

Additional studies have reported the importance of collaborative and small-group instruction on the performance and motivation of female students [4], [5]. Female students also indicate stronger frustrations with what they view as poor teaching and are more likely to leave engineering than male counterparts with equivalent GPAs [6]. In a large survey of undergraduates' characterizations of the pedagogical methods used in STEM classes [7], male students classified typical lecture style approaches as cognitively based methods. Female students of similar abilities and interest in the subject matter gave this teaching method a high passive-learning factor and labeled the approach as teacher-directed with limited engagement or collaboration. Further, the female students believed the courses promoted the memorization of discrete facts instead of conceptual understanding of course material.

In an effort to promote student engagement and overall material retention at our own institution, the authors reworked the sophomore-level statics course to create a highly active and collaborative environment. During the 2015-2016 academic year, four sections of statics were taught using the new course materials: two by the authors and two by tenured faculty who agreed to use the new course materials but who have minimal experience in teaching with active-learning pedagogies. A fifth section was taught by one of the authors as a control. The control section was taught using the faculty member's usual active-lecture approach based on the ASCE ExCEEd Teaching Model [8].

Early results of the application of the new statics curriculum showed promise specifically in terms of material retention [9]. In addition to taking a pre- and post- concept inventory [10] during the first and last week of the course, respectively, 67 students also completed a retention concept inventory. The retention concept inventory was taken one month (n = 17) or three and a half months(n = 50) after statics when the students enrolled in strength of materials. Analysis found there was no statistical difference between the post- and retention scores. This indicates durable learning occurred as the average retention of superficially learned material is typically 20 percent after four weeks [11]. Additionally, student self-reported interest in engineering increased as a result of the course in four out of five sections, with one section indicating their interest remained unchanged [9]. During the study the authors had hoped to also look for gender effects but the sample size was too small to observe an effect. One interesting result was the effect of faculty training; those sections taught by the faculty highly trained in the treatment technique showed an expected post-concept inventory score 12 points higher on a 100 point scale than those students taught by faculty less accustomed to active teaching pedagogies. Students in these same sections also reported the highest numbers in increased interest in engineering as a result of the course.

The intent of this work is to use an expanded data set from three additional engineering statics sections taught during the 2017-2018 academic year to determine if there is a gender effect on student knowledge gain and the self-perception of students on their own class engagement and interest in engineering. This work addresses the following research questions:

1. Does introducing non-lecture teaching techniques into engineering statics improve self-reported participation based on reported gender of the student?
2. Do non-traditional teaching techniques increase interest in engineering based on reported gender of student?

3. Do non-traditional teaching techniques increase material knowledge gain based on reported gender of student?

Methods

During the 2015-2016 academic year, five sections of statics were taught to primarily civil and mechanical engineering students: four sections in the fall quarter and one in the winter. The sections were taught by four different faculty members, referred to here as Professor 1 (female), Professor 2 (male), Professor 3 (male) and Professor 4 (female). The curriculum for these sections were based on the existing active-learning curriculum of Professor 1. The existing curriculum is based on the ExCEEd Teaching Model [8] and includes mini-lectures combined with physical demonstrations, directed questioning techniques, in-class problem solving and periods of group work. Twelve lessons in the existing curriculum were modified to include additional pedagogies including flipped, flipped-flipped, and hands-on learning activities with minimal to no lecture content. Full details of these modifications are described in an earlier paper [9]. Fourteen of the remaining class meetings used the existing active-learning curriculum and five class meetings were for review and testing. Three of the fall sections taught in 2015 and the winter 2016 section used the modified curriculum. Professor 1 taught one fall section using the existing curriculum as a comparison to determine if student learning or student self-perception was impacted by the different pedagogies.

During fall of 2017, Professors 1 and 4 taught a total of three additional statics sections using the modified curriculum. Table 1 includes a summary of the eight sections taught. Section C, taught by Professor 1, used the existing, non-modified, curriculum. Professors 2 and 3, who taught sections B and D, used the modified curriculum and were experienced with using physical models in the classroom but historically only taught by lecturing with minimal active-learning methodologies. All four professors attended weekly meetings to review the upcoming lesson plans and activities during the fall of 2015.

Assessments on the new curriculum were made using a concept inventory [10] administered to all students at the beginning and end of the quarter. In addition to the concept inventory, students were asked to complete a survey at the end of the quarter that asked them about their interest in the course, engineering and particular activities during the course. The survey was a series of Likert questions that ranged from (1) to (5) with 5 being highest rating and 1 the lowest. As an additional data point, the grade from the prerequisite physics course and grade in engineering statics were compared.

After initial analysis of the data collected, the need for additional grouping of the data was identified. In particular, the acknowledgement that both faculty who are trained in active-learning methods are female and the two faculty who have less training are male made it apparent that there might be an unmeasurable interaction between professor and student gender. Therefore, the data analysis took on two stages. In the first, difference in Professor Group was evaluated with Group 1 being the trained faculty (Professors 1 and 4) and Group 2 being the untrained faculty (Professors 2 and 3). The next step was to remove the 31 students enrolled in Group 2 and look at gender differences only for the 95 students in Group 1. For both stages of data analysis, paired sample t-test on variables of interest as well as analysis of variance to look for interactions between variables was performed.

Results
Section Demographics

Results presented come from eight course offerings of engineering statics taught during fall 2015, winter 2016 and fall 2017. Section C was included in this study as the authors found the method of active-learning taught by the same instructor had no observable effect on student knowledge gain or self-perception [9]. From all students enrolled in the 8 sections, a total of 126 completed all 3 surveys (pre- and post-concept inventory and engagement survey) and gave permission for results to be included for research. Of the 126 students included, 36 are female and 90 are male. The majority of the students (95) were enrolled in sections taught by Group 1. The breakdown of gender and enrollment by section can be found in Table 1. This table also includes the average incoming grade from the prerequisite force physics course where the average point value was found by assigning the standard 4.0 scale for A-F grades to the letter grade. Plus grades, e.g. C+ or B+, received an additional 0.3 points and minus grades, e.g. C- or B-, were reduced by 0.3 points. Students with advanced placement, AP, credit were assigned 3.5 grade points, which is the mean of a B+ and an A-.

Table 1. Section enrollment gender demographics along with average pre-requisite grade in force physics. Count limited to students who completed all assessment surveys and gave permission to use their data.

			All Students		**Female Students**		**Male Students**	
Section	**Instructor**	**Quarter Taught**	**Count**	**Avg. grade pre-req.**	**Count**	**Avg. grade pre-req.**	**Count**	**Avg. grade pre-req**
A	Professor 1	Fall 2015	21	2.96	10	2.51	11	3.36
B	Professor 2	Fall 2015	16	3.27	5	3.34	11	3.24
C	Professor 1	Fall 2015	17	3.10	2	2.20	15	3.22
D	Professor 3	Fall 2015	15	3.11	3	2.67	12	3.23
E	Professor 4	Winter 2016	7	2.49	2	2.40	5	2.52
F	Professor 1	Fall 2017	12	2.70	6	2.77	6	2.63
G	Professor 4	Fall 2017	18	2.87	3	3.47	15	2.75
H	Professor 4	Fall 2017	20	3.27	5	3.34	15	3.25
		All Sections	126	3.02	36	2.85	90	3.09

Participation

The results from the survey questions 'Overall, how do you rate this course in the following area: Your class participation' and 'Overall, how do you rate this course in the following area: Other students' participation' are shown in Figure 1. Results are presented for all students and broken apart by student reported gender. When considering all 126 students, 83% (105 students) answered ‘Medium’, ‘High’ or ‘Very High’ to their class participation and 88% (112 students) answered ‘Medium’, ‘High’ or ‘Very High’ to other students’ participation.

By gender, 94% (34 of 36) of female students rated medium or above when evaluating their own participation compared to 78% (71 of 90) of male students. Almost half the male students (47%) rated their own participation as ‘High’ or ‘Very High’ compared to 35% of female students, who were more likely (59%) to rate their own participation as medium. A greater percentage of female students than male students rated whole class participation at medium or higher (97% of females versus 86% of male students).

Overall, when converting the Likert scale to numeric values, the average answer of the 126 students included in the study is 3.3 for both questions (Figure 2). On average, male students rated their individual participation higher than female students rated themselves; the male average answer is 3.38 versus 3.25 for the female students. Both male and female students rated the overall participation of their classmates as 3.33 (‘Medium’). Although these results are encouraging, statistical analysis did not show any significant differences in these variables based on student gender.

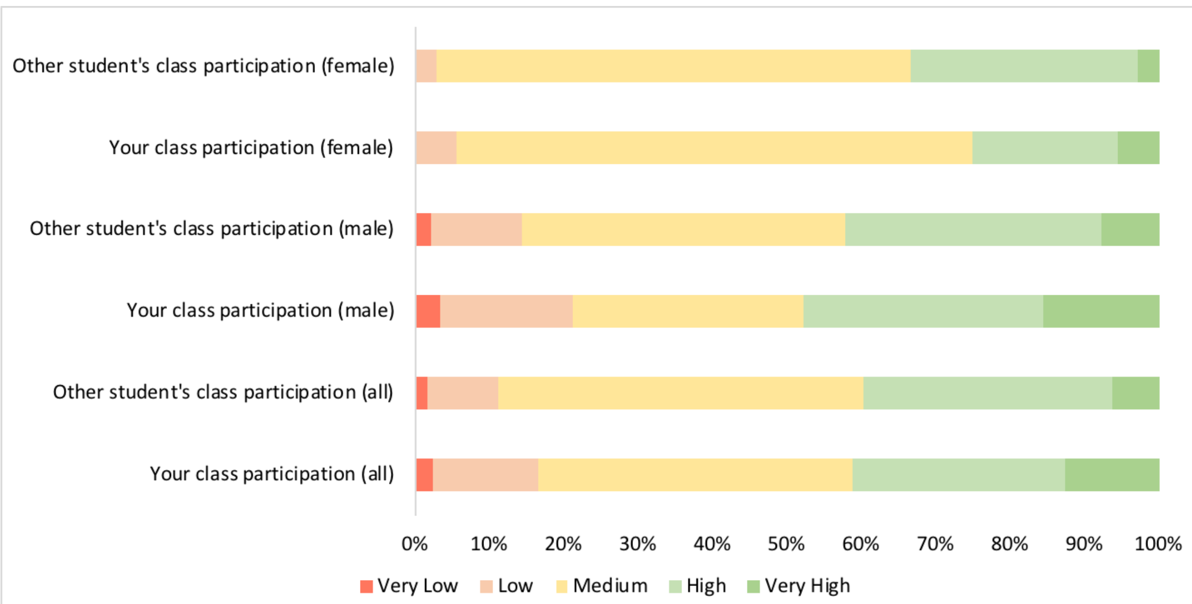

Figure 1: Summary of student response to post course survey questions about perceived class and self-participation. Survey was a Likert Scale ranging from Very Low (1) to Very High (5).

One of the most notable differences in perceived class and self-participation occurs between the students enrolled in the sections taught by the faculty trained in active pedagogies, Group 1, versus students enrolled with Group 2 faculty. Results from the survey responses aggregated by training type of faculty can be seen in Figure 2. Students in Group 1 rated their participation in the course ($M = 3.57$, $SD = 0.895$) significantly higher than those taught by Group 2 ($M = 2.68$, $SD = 0.832$), $t(124) = 4.894$, $p = 0.000$. Students enrolled with Group 1 also rated whole class participation ($M = 3.54$, $SD = 0.697$) significantly higher than students taught by Group 2 ($M = 2.71$, $SD = 0.783$), $t(124) = 5.566$, $p = 0.000$. These results suggest that students enrolled in sections where faculty are trained in active teaching methods, including student engagement, perceive that everyone in the class, including themselves, participate more than students in other sections. Although this result is not surprising, it is encouraging that the active-learning methods, when applied correctly, do work.

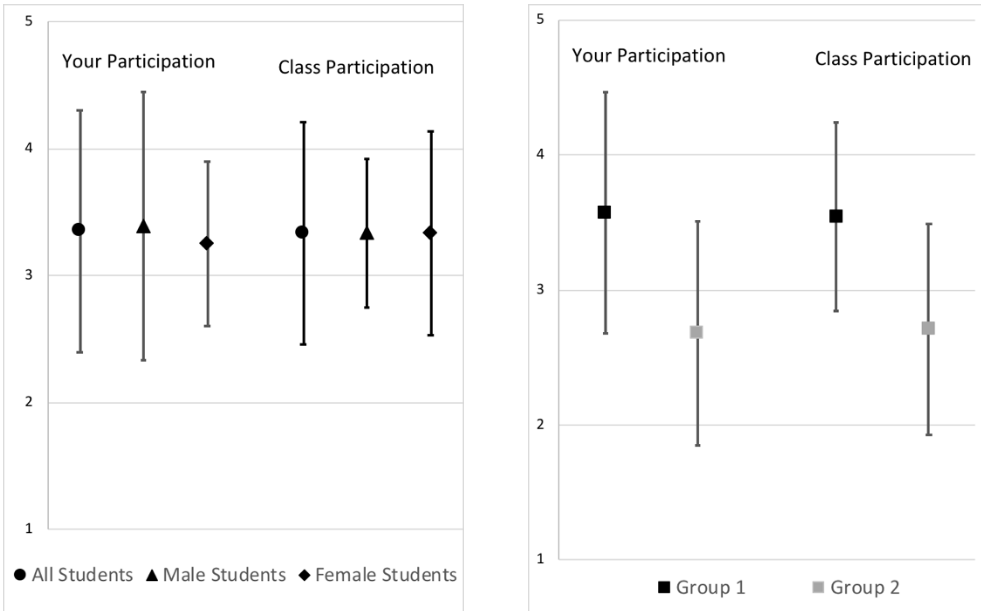

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Figure 2: Average student response with standard deviation shown as error bars to 'Overall, how do you rate this course in the following area: Your class participation' and 'Overall, how do you rate this course in the following area: Other students' participation' (a) for all students and separated by gender and (b) for students in Group 1 versus Group 2.

Interest in Engineering

Although there are many measures of a students' interest in engineering, in this case we asked students at the end of the course if the course contributed to their interest in engineering. Results for all students and results broken out by self-reported gender are presented in Figure 3. Fifty eight percent (74 of 126) of all students answered that the class increased or greatly increased their interest in engineering and results are similar when looking at male students (60%) and female students (55%).

When data is separated by Instructor Group, 67% (64 of 95) of the students by Group 1 faculty indicated their interest increased or greatly increased with no students in these sections indicating their interest in engineering decreased as a result of the course (Figure 4). In fact, students in Group 1 rated their interest in engineering ($M = 3.80$, $SD = 0.646$) significantly higher than those in Group 2 ($M = 3.23$, $SD = 0.805$), $t(124) = 4.037$, $p = 0.000$ (Figure 5). This finding suggests that active-learning, when executed properly, helps students engage in the course and major. When looking at all sections, 13.8% of female students (5 of 36) stated that their interest 'greatly increased' after the course but this number increases to 17.8% for female students in Group 1.

Male students answered 'greatly increased' at a rate of 10% for all faculty, regardless of training, but statistical analysis did not show significance in these differences between genders.

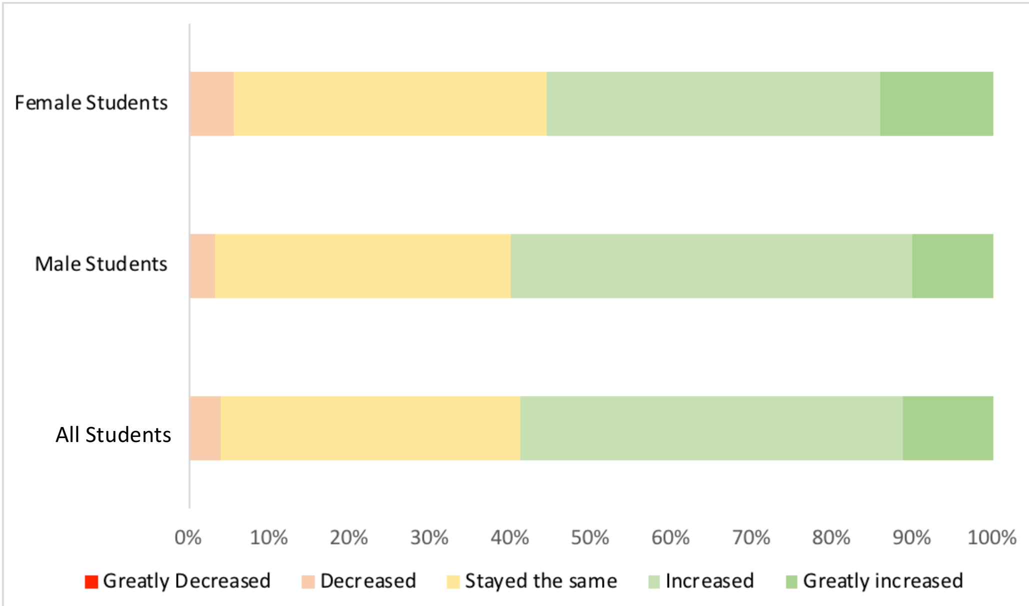

Figure 3: Survey results from survey question 'As a results of this class my interest in engineering' from all sections and separated for male and female students. Survey options were a Likert scale from Greatly Decreased (1) to Greatly Increased (5)

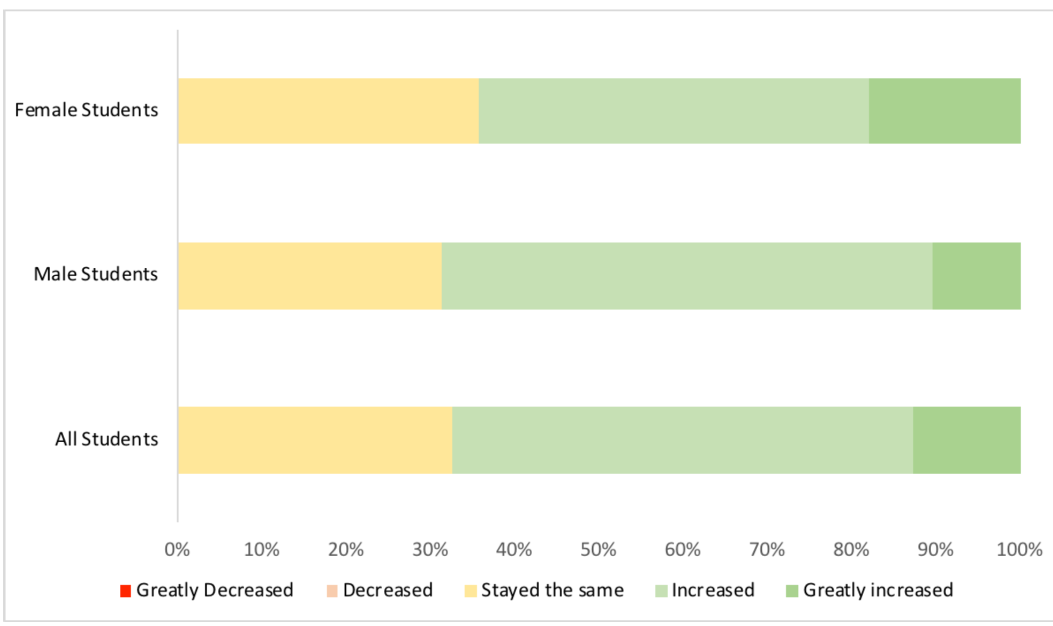

Figure 4: Survey results from survey question 'As a results of this class my interest in engineering' from sections taught by faculty members trained in active-learning techniques (Group 1)

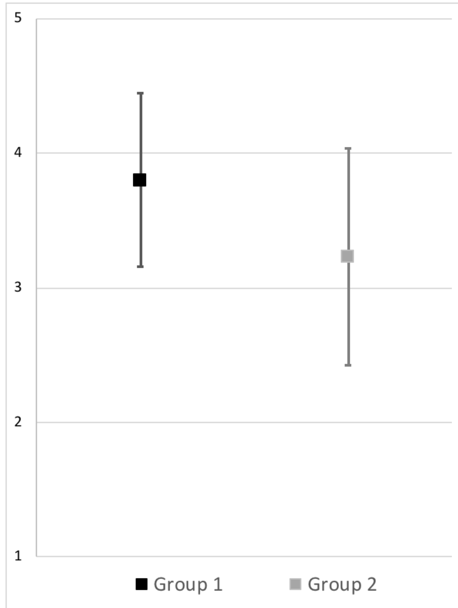

Figure 5: Survey results from survey question 'As a results of this class my interest in engineering' separated by Group.

Material Knowledge Gain

To measure material knowledge gain, student performance was evaluated on pre- and post-concept inventory scores and incoming grades in the prerequisite force physics course versus outgoing grades assigned in statics. Grades were reviewed to look for patterns rather than hard data points. When evaluating material knowledge gain and the impact on student gender of the active-learning curriculum, we first evaluated the difference between instructor type: trained (Group 1) and untrained (Group 2) before looking at student gender. The sections students enrolled in had no significant impact on incoming or final grade in the course (Figure 6a). A comparison of the average incoming pre-requisite grade in physics to the outgoing statics grade is shown in Figure 6a. The average incoming grade was 3.02 (just over a B) for all students and the final grade was 3.31 (B+). The incoming grade for students in Group 1 (M = 3.005, SD = .802) was not significantly different that the incoming grade for students in Group 2 (M = 3.194, SD = 0.713); t(124) = -1.17; p = 0.26. Similarly, the final grade for students in Group 1 (M = 3.33, SD = 0.672) was not significantly different than the final grade for students in Group 2 (M = 3.18; SD = 0.594); t(102) = 0.839, p = 0.404.

The pre- and post- concept inventory score for all students are shown in Figure 6b – for all students and separated out by faculty groups. The average score on the pre-concept inventory taken at the beginning of the course was 0.21 (out of 1.0) and at the end of the quarter, the average post-concept inventory score for all students was 0.46. The pre-concept inventory scores were not significantly different between the two groups – Group 1 (M = 0.2430; SD = 0.115) and Group 2 (M = .2406, SD = 0.156); t(124) = 0.094, p = 0.925 – an expected result as all students come into the course with similar background knowledge. However, the post concept inventory scores for students enrolled with Group 1 (M = 0.4841, SD = 0.216) were significantly higher than the post concept inventory scores for students enrolled with Group 2 (M = 0.397, SD = 0.211); t(124) = 1.993, p = 0.048.

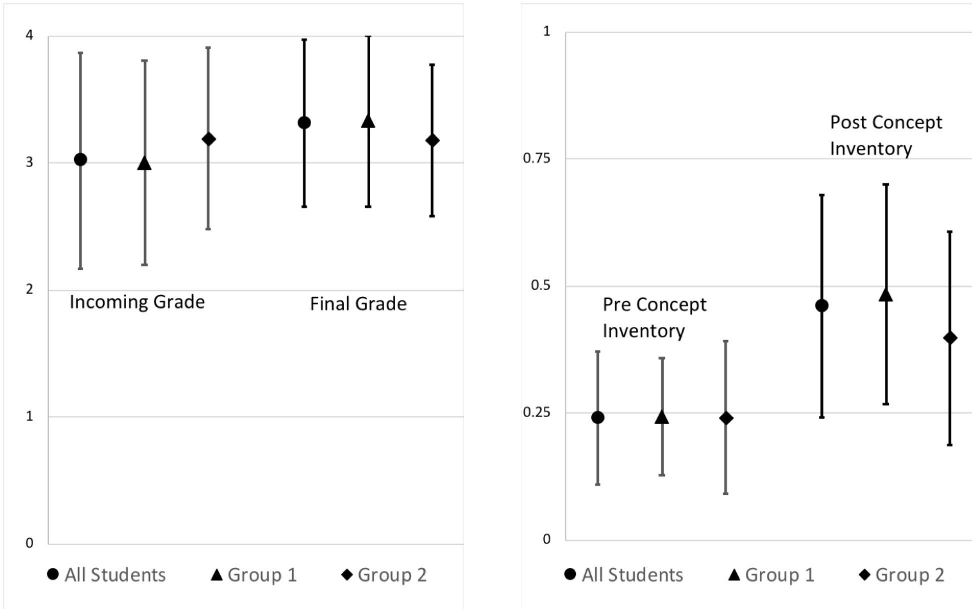

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Figure 6: (a) Average physics pre-requisite grades and statics grades, converted to 4 point scale, for all students in engineering statics separated by instructor training group. (b) Average pre and post concept inventory scores for the same groups. For both, group 1 has formal training in active teaching methods and group 2 does not. Error bars represent standard deviation for each data set.

To determine a difference in effect of the new curriculum on gender, the pre- and post- concept inventory and incoming and final grades of the 95 students enrolled in Group 1 were evaluated as a separate data set. This was done to isolate the students who likely had a more active-learning experience and to remove any potential confounding factor of the interaction of student and instructor gender.

There was a significant difference in incoming grade for male students (M = 3.14, SD = 0.736) and female students (M = 2.68, SD = 0.873); t(93) = 2.65, p = 0.01. However, there was not a significant difference in the final grade for the male (M = 3.37, SD = 0.668) and female (M = 3.23, SD = 0.68) students; t(86) = 0.913, p = 0.364. This result suggests that more active teaching methods helps female students catch up to their male peers. Similar results can be seen when a paired sample t-test is conducted on the scores for both the pre- and post- concept inventories in male and female students. The male students (M = 0.2655, SD = 0.111) have a significantly higher pre-concept inventory score compared to the female students (M = 0.1892, SD = 0.107); t(93) = 3.091, p =0.003. There is no significant difference, however, in the post-concept inventory scores for male (M = 0.5034, SD = 0.227) and female (M = 0.4413, SD = 0.184) students; t(93) = 1.280, p = 0.204. Figure 7 shows these results.

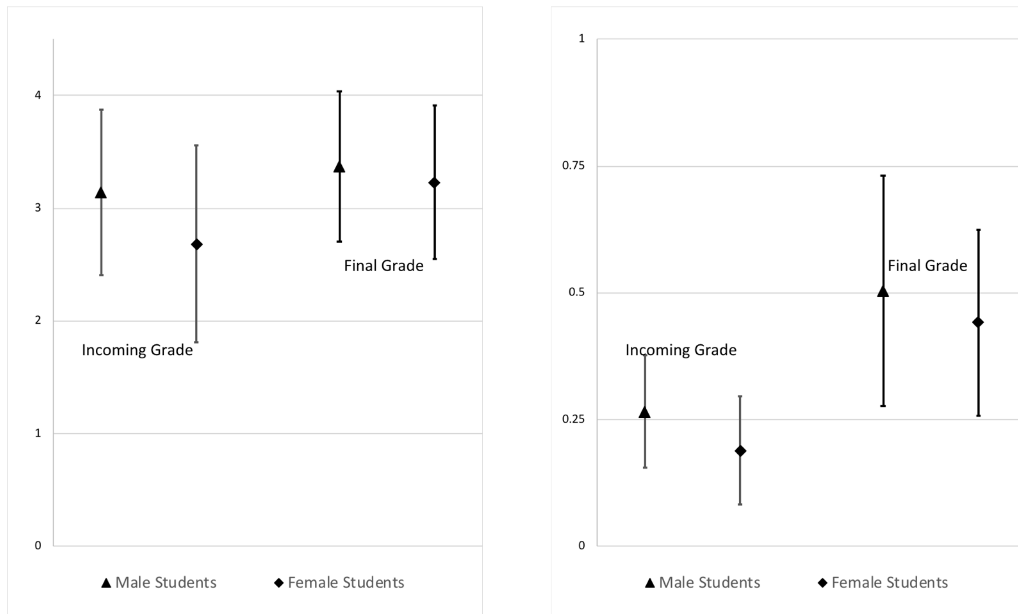

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Figure 7: Data from Group 1 students only. (a) Average physics pre-requisite grades and statics grades, converted to 4 point scale, for female versus male students in engineering statics (b) Average pre and post concept inventory scores for the same groups. Error bars represent standard deviation for each data set.

Discussion

The results on student perception of participation in class, both their own and others, clearly indicate that female students believed the course was active and student-centered with no female student indicating their own or other students' participation was low or very low. However, the female students were more likely to rate their own participation as medium while male students were more likely to choose high or very high. Student groups were either randomly assigned or self-selected during class time. As such it is not possible to determine the number of gender mixed groups and if the well-documented gender roles in group dynamics played a role in the students' perceptions or if this is a result of the female students underrating their contribution.

There was an interesting gender difference in how students rated participation depending on the pedagogy training of the faculty member. Males rated their own and others' participation more than 40% higher in the sections taught by the faculty trained in pedagogy (Group 1) while the female students only rated their own participation higher (15%) and thought other students' participation was the same regardless of their section. Discussions between all four professors at the end of the fall 2015 quarter identified a significant difference in the amount of student/faculty interaction during the student-centered activities. Professors 1 and 4 indicated spending more time checking in on groups as they were working and pulling the entire class in and out of the activities to have groups report out. Professors 2 and 3 indicated they primarily let students work together and had limited interaction. If the female students view straight lecturing as a highly passive form of teaching while male students less so, as indicated by Kardash and Wallace [7], any group or collaborative work may be considered more participatory by female students regardless of the faculty member's action during the assigned activity. This also reinforces Colbeck, *et al*, [3] findings that faculty interaction and feedback had the greatest effect on male students' self-perceptions while collaborative and group work was the most important for female students. However, given the small sample size included (8) for female students taught in Group 2, these results on female students' perception of collaborative learning offer an interesting question but are not conclusive.

The high numbers of students who indicated the course actually 'increased' or 'greatly increased' (58%) their interest in engineering is important and also in line with the work Colkbeck, *et al,*[3] who found active pedagogies, such as collaborative learning and instructor interaction, improved student motivation and confidence to be an engineer. The results are promising for a course that some consider a "weeder" course, especially considering another 37% of students indicated their interest remained the same. While the results for the combined 'increased' or 'greatly increased' responses were similar for male and female students, (60% vs 55%), it was of interest to note that female students were more likely to indicate their interest 'greatly increased'. The data also indicates that faculty training in active pedagogies will improve student interest as 67% of students taught by Group 1 indicated their interest in engineering 'increased' or 'greatly increased' and no student said it 'decreased' as a result of the course. The sections taught by Group 1 also saw a 29% increase in the number of female students who said their interest 'greatly increased". And while the overall interest by male students was improved, there was no difference in the percent of males who indicated the course 'greatly increased' their interest between Group 1 and Group 2 sections. This indicates the amount of faculty interaction and delivery techniques of the active lessons have an impact on improving student interest in a topic beyond just having a collaborative learning environment.

The influence of the student-centered pedagogies studied in this work on gender performance and self-perception were most apparent when looking at student performance. Female students saw greater overall gains in both their concept inventory scores and their incoming and outgoing grades. It should be noted that the grades are only considered as a point of interest and not a strong data point as the grades being compared were assigned in different courses and by a variety of professors both in engineering and physics. They were included in this work because of the consistent pattern found regardless of the instructor. Generally, the average statics grade was higher than the average prerequisite force physics grade with male students' grade increasing by 9.6% and the females' grades increasing by 13.7%, a 43% improvement over the males. As the course content between force physics and statics is not significantly different, it is theorized that the instructional methods may be affecting the results. As reported in the 2013-2014 HERI data, lecturing is the common teaching methodology used by SCU STEM faculty [12]. More than 70% of the STEM faculty at SCU report using lecture as their main form of instruction all or most of the time, as compared to 56% of all the SCU faculty and 51% of all reporting faculty nationwide. Based on these numbers it is likely the students received the pre-requisite instruction in a lecture style format, which would have a greater negative impact on the performance of the female students [4], [5]. The inclusion of active pedagogies versus lecture could also account for the significant disparity between the females' pre- and post-concept inventory gains versus the males' gains, with the males scoring 50% higher than the females on the pre-concept inventory but only 7.0% higher on the post.

Conclusion

This work used the results from eight sections of statics to determine if the use of active pedagogies and collaborative learning had a gender effect on student knowledge gain and student self-perception on class engagement and interest in engineering. The data collected included the results of student pre- and post-concept inventory scores, prerequisite and final statics grades, and a post-course survey. The work also unintentionally highlighted the importance of providing thorough faculty training in active pedagogies versus just providing untrained faculty with an active-learning curriculum.

Overall students found all sections to have a high level of class participation with female students perceiving more student participation in the class than male students. Female students were less likely than male students to indicate their own participation as high or very high. Female students' perceptions of engagement were not affected by the pedagogy training of the faculty but male students' perceptions were significantly affected with the sections taught by trained faculty considered more active. The majority of students indicated the class actually 'increased' or 'greatly increased' their interest in engineering with female students more likely to answer the class 'greatly increased' their interest, especially if taught by a faculty member with active-learning training. The greatest observed gender difference was in knowledge gains. Female student gains between the pre- and post-concept inventory scores were significantly higher than the male students regardless of the section.

Overall this work supports the idea that active-learning increases both student engagement and interest in engineering, which improves overall performance in the course for all students. For active-learning to reach its full potential, it is important that faculty implementing active-learning modules receive adequate training in classroom best practices.

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