The Impact of Supervised Homework Sessions and SAT-Math Scores on Academic Performance in an Advanced Undergraduate Course

Waterloo Tsutsui
School of Aeronautics and Astronautics
Purdue University
West Lafayette, IN, USA
wtsutsui@purdue.edu

Michael C. Loui
School of Engineering Education
Purdue University
West Lafayette, IN, USA
mloui@purdue.edu

***Abstract*—Ancillary learning opportunities outside the classroom take different forms such as peer-led team learning (PLTL) and supplemental instruction (SI). To gain the benefits of ancillary sessions with less overhead than PLTL and SI, we facilitated optional weekly supervised homework sessions for AAE 35200, an aerospace structural mechanics course for third year engineering students at Purdue University. In these sessions, a graduate teaching assistant used the assigned homework problems to demonstrate key concepts on structural mechanics. In order to understand the attributes of the participants, a survey was administered. Also, session attendance was recorded and compared against the exam and homework results. Based on the collected data during the Fall 2015 and Spring 2016 semesters, we have reached the following conclusions: a) attending the supervised homework sessions does not significantly affect the exam score, whereas the opposite is true for the homework scores and b) SAT-Math scores do not seem to have a strong influence on both the exam and homework scores.**

Keywords—ANCOVA; exam; homework; mechanics; SAT-Math

I. Introduction

This paper demonstrates the impact of supervised homework sessions on the academic performance of students in AAE 35200, an aerospace structural mechanics course for third-year engineering students, at Purdue University. Previously, we published the results of the preliminary study based on the data obtained during the Fall 2015 semester [1]. The intention of the present paper is to follow up the study based on the combined data from both the Fall 2015 and Spring 2016 semesters.

II. Literature Review

Our supervised homework session differs from the following two representative examples of learning opportunities outside the classroom: a) Peer-led team learning (PLTL) [2], [3], [4] and b) supplemental instruction (SI) [5], [6], [7]. For a description of our supervised homework session, please see the "Description of Course" subsection under "Course Context" below.

In PLTL, a peer leader leads the groups of 6 to 8 students to solve problems. The peer leader is a facilitator, not necessarily a subject matter expert. Thus, undergraduate students may serve as PLTL leaders. PLTL is a proven technique as Hockings et al. [8] concluded that the frequent participation to PLTL can improve the grades by about one-third of a grade point. SI, on the other hand, requires the subject matter expert to facilitate the discussion. SI can be taught as a group problem solving session.

There is little prior scholarship of teaching and learning (SoTL) research in mechanics education in advanced undergraduate or graduate courses. Brown et al. [9], [10] and Montfort et al. [11] investigated how students conceptually understand the state of stress based on the general mechanics problems, such as beam bending. So far, no SoTL research has been conducted on the mechanics education on thin-walled structures, such as aircraft, that were the main focus of AAE 35200 at Purdue University.

From the literature review, we found no previous study on the effectiveness of supervised homework sessions in mechanics courses, even though getting help from teaching assistants in the homework is a very common practice. Based on this knowledge gap, we generated our research question as follows: *What is the impact of attendance at the supervised homework sessions on students' academic performance in an advanced undergraduate mechanics course?*

III. Course Context

A. *Description of Course*

AAE 35200 is a three-credit structural mechanics course designed for third-year aerospace engineering majors. The course topics include an introduction to elasticity, torsion, bending, shear flow, and failure criteria. During the Fall 2015 semester, a total of 109 students registered for the course. The students were divided into two sections as follows: a) 62 students attended lectures three times a week on Monday, Wednesday, and Friday for 50 minutes per lecture and b) 47 students attended lectures twice a week on Tuesday and

Thursday for 75 minutes per lecture. During the Spring 2016 semester, a total of 51 students registered for the class. These 51 students attended lectures twice a week on Tuesday and Thursday for 75 minutes per lecture.

During Fall 2015, a senior-level professor taught the lecture, and an advanced Ph.D. student taught the supervised homework sessions as a teaching assistant (TA). During the Spring 2016, another senior professor taught the lecture, and the same TA taught the supervised homework sessions. The same TA also graded all exams, except for one of the three problems in the final exam in Fall 2015. The grader for the homework was also kept the same throughout the study. A master's student graded all homework during Fall 2015 and Spring 2016. The same textbook [12] was used during the two semesters, but some homework problems differed between semesters.

In the supervised homework sessions, the TA led the discussion on how to solve problems. The TA demonstrated key concepts and procedures that were necessary to solve the assigned homework problems. When time allowed, the TA also attempted to show alternative approaches to solve problems. For instance, when calculating shear flow in a closed stringer-web cross-section of an airplane wing, the cross section must be cut fictitiously to calculate the fictitious shear flow. Then the fictitious shear flow is combined with the constant shear flow in order to calculate the total shear flow. This process is akin to the principle of superposition in physics. In this problem, the TA provided the fictitious cut at several different positions and demonstrated that no matter where the fictitious cut was made, the final answer was always the same. Whereas PLTL and SI require the instructional staff to prepare additional materials, the supervised homework sessions do not because the staff have already prepared solutions to homework problems as a part of their routine tasks.

B. Description of Participants

Among the 109 students who took AAE 35200 in the Fall 2015 semester, 58 students consented to participate in the study (53% participation). Among the 51 students in Spring 2016, 39 students consented to participate in the study (76% participation). Please see the Methods section for further details on the possible reason on why the percentage of study participation was increased in the Spring 2016 semester.

Table 1 shows demographics of participants in Fall 2015 and Spring 2016. The largest category of the students were out-of-state male students who spoke English as their first language.

Table 1: Demographics of Participants (Fall 2015) [1]

Gender	Status	English Language Speaker	Number		Percentage	
			F2015 [1]	S2016	F2015 [1]	S2016
Female	In-State Domestic	Native	0	5	0%	13%
Female	Out-of-State Domestic	Native	4	1	7%	3%
Female	Inter-national	Non-Native	2	0	3%	0%
Male	In-State Domestic	Native	20	8	35%	21%
Male	Out-of-State Domestic	Native	24	20	41%	51%
Male	Inter-national	Native	2	1	3%	3%
Male	Inter-national	Non-Native	6	4	10%	10%

IV. METHODS

As a prerequisite for our study, we obtained the approval from Institutional Review Board (IRB) at Purdue University at the beginning of the Fall 2015 semester. The IRB required that students be free to choose to participate or not to participate in the study. The only requirement for participants was to answer a survey. The teaching assistant (TA) of AAE 35200 was also the primary researcher in the present SoTL study. To maintain the research integrity, we chose to keep the survey sheets inside the sealed envelopes until after the deadline to submit course grades in each semester. This practice eliminated any influence of research participation on students' grades, since the TA did not know who had consented to participate in the study. That is, the student attendance in the supervised homework sessions was independent of student participation in the research.

In Fall 2015 semester, the survey was conducted during the eighth week of the semester during the regular lecture. The survey contained both qualitative and quantitative questions. On the other hand, in the Spring 2016 semester, the quantitative survey was conducted during the first week of the semester during the regular lecture. Then, the qualitative survey was conducted during the eighth week of the semester during the supervised homework session. We chose to alter the timing for the surveys during the Spring 2016 semester because we intended to have as many participants as possible by advertising the study during the first week of the semester. That is, we learned from the Fall 2015 semester that the class attendance declined toward the middle of the semester; thus, many students did not answer the survey. Conducting the survey at the beginning of the semester maximized exposure to the potential participants since almost all students attended the lectures during the first week of the semester.

All demographics of participants and the standardized test scores (i.e., SAT-Math or ACT-Math score) were self-reported as a part of survey. The homework and exam scores were obtained from Blackboard Learn, a web-based application that Purdue University utilizes in order to keep track of students' semester progress. The attendance at the supervised homework session was recorded in the pre-printed spreadsheet that was circulated at the beginning of every supervised homework session.

The exam score from the Fall 2015 semester was calculated from the average grades of three exams. The homework score from the Fall 2015 semester was based on the average grades of 13 homework assignments. Similarly, the data from Spring 2016 was based on the average grades of three exams as well as the average of 11 homework assignments. Based on the SAT-Math score, we classified the students in three categories (Table 2) and analyzed the results. Then, we conducted analysis of covariance (ANCOVA), so we could statistically control for the effect of covariates, independent continuous variables.

Table 2: Classification of Participated Student based on SAT-Math Score

	Low SAT-Math	Medium SAT-Math	High SAT-Math
SAT-Math Scores	600 – 710	720 – 770	780 – 800
Number of Students Fall 2015 [1]	18	19	21
Number of Students Spring 2016	17	12	10

V. Results

A. Visualization of Experimental Data

We conducted our data visualization and analysis by using Minitab 17 statistical software. Figure 1 shows the frequency of supervised homework session attendance during the two semesters. The average (mean) evening session participation was 34.3% and 66.1% in the Fall 2015 and Spring 2016 semesters, respectively. The standard deviation was 24.7% and 26.3%, respectively. Significant increase in the session attendance from Fall 2015 to Spring 2016 was observed. We suspected that this could come from the positive reputation of the supervised homework session.

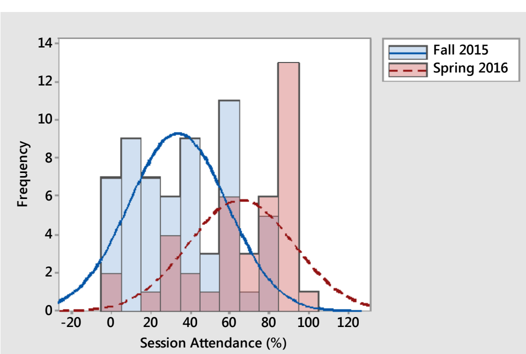

Figure 1: Frequency of Session Attendance

Figure 2 summarizes the attendance data in a whisker-and-box plot. For the Fall 2015 data, the first quartile, second quartile (median), and third quartile are 12.5%, 34.4%, and 56.3%, respectively. For the Spring 2016 data, the first quartile, second quartile (median), and third quartile are 50.0%, 78.6%, and 85.7%, respectively. The first quartile from Spring 2016 was almost as high as the third quartile from Fall 2015, which resulted in the same conclusion from Figure 1 that the attendance in the supervised homework session increased.

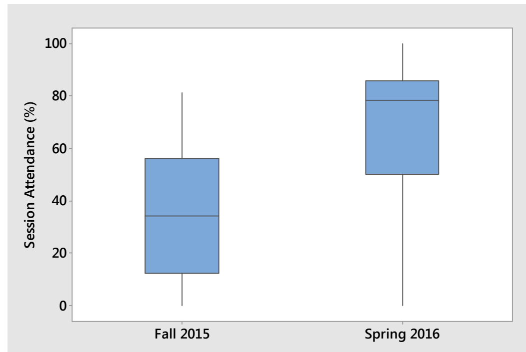

Figure 2: Percentage of Session Attendance

Figure 3 shows the distribution of the exam score. The average (mean) exam score was 85.7% and 81.0% during Fall 2015 and Spring 2016, respectively. The standard deviation was 7.8% and 9.16% during Fall 2015 and Spring 2016, respectively. Since the exam score distributions from two semesters had their own mean and standard deviation, it was impossible to simply combine (or compare) the raw data in order to analyze the data.

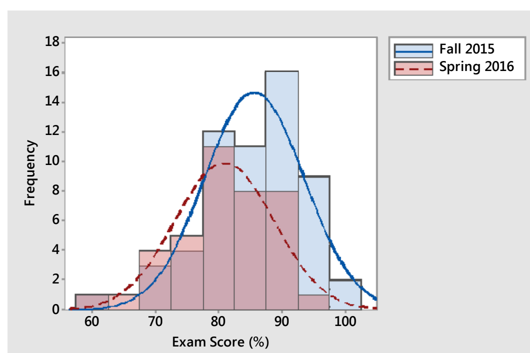

Figure 3: Frequency of Exam Score (%)

To further compare the two population samples for their mean values, we have conducted the two-sample unequal variance t-test (Welch's t-test) as shown in Table 3. Based on the p-value obtained for the exam score ($0.005 < 0.05$), we reject the null hypothesis (H_0), thus concluding that the statistical difference in the mean values appears to exist in the exam scores. For the homework score, on the other hand, there is no evidence to suggest that mean values of two distributions are different, statistically.

Table 3: Two-Sample Unequal Variance T-Test

	Exam	Homework
Hypothesis	H_0: $\mu_{F2015} = \mu_{S2016}$ H_1: $\mu_{F2015} \neq \mu_{S2016}$	
P-Value	0.005	0.554

Figure 4 also shows the exam results; however, the exam score was converted from percentage to z-score. We assumed that this approach would provide better method of combining and comparing the exam results from two different semesters. As the fit-line in Figure 4 indicates that the two distributions are placed on the top of each other without horizontal shifting by using the z-score of the exam results.

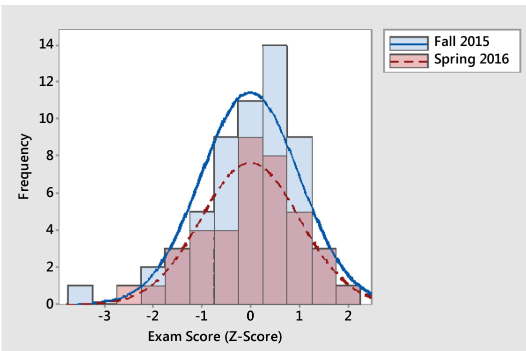

Figure 4: Frequency of Exam Score (Z-Score)

Figure 5 shows the distribution of the homework score. The average (mean) homework score was 91.7% and 92.9% during Fall 2015 and Spring 2016, respectively. The standard deviation was 10.9% and 9.2% during Fall 2015 and Spring 2016, respectively. Similar to the analysis of Figure 3, each data set has its own distribution with dissimilar mean and standard deviation; therefore, it was impossible to combine the raw data in order to analyze the data.

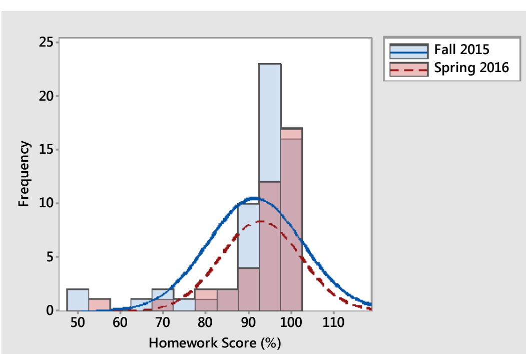

Figure 5: Frequency of Homework Score (%)

Figure 6 also shows the homework results, but the homework score was converted from percentage to z-score. Similar to the idea we demonstrated between Figure 3 and Figure 4, we assumed that this approach would provide better method of combining the homework results from two different semesters. The only caveat for the homework score was that the distribution does not appear to be normal unlike the exam score.

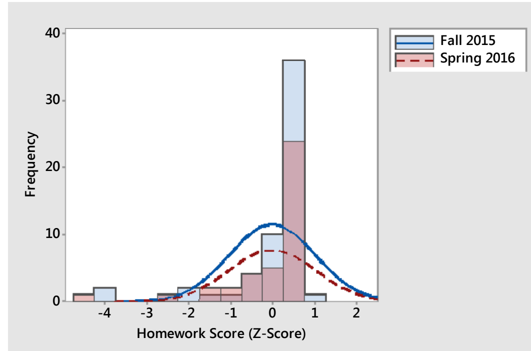

Figure 6: Frequency of Homework Score (Z-Score)

To this end, we investigated the normality of the collected data by using the Anderson-Darling, Ryan-Joiner, and Kolmogorov-Smirnov tests (Table 4). Based on the assumed confidence interval of 95%, any p-values less than 0.05 indicate the statistical significance. All three normality tests indicated that a) exam scores appear to be normally distributed and b) homework scores do not appear to be normally distributed. Furthermore, we investigated which distribution best fits the data for the homework score. However, we were unable to identify the best distribution since all p-values were smaller than certain values that are even smaller than 0.05 (Table 5). Therefore, for the purpose of research reporting, we chose to assume the homework scores were normally distributed.

Table 4: Normality Test P-Values

Normality Test	Exam		Homework	
	Fall 2015	Spring 2016	Fall 2015	Spring 2016
Anderson-Darling Test	0.147	0.475	< 0.005	< 0.005
Ryan-Joiner Test	0.045	> 0.100	< 0.010	< 0.010
Kolmogorov-Smirnov Test	> 0.150	> 0.150	< 0.010	< 0.010

Table 5: P-Values for the Identification of Homework Score Distribution

Semester	Lognormal	Exponential	Weibull	Gamma
Fall 2015	< 0.005	< 0.003	< 0.010	< 0.005
Spring 2016	< 0.005	< 0.003	< 0.010	< 0.005

B. Effect of Attendance at Supervised Homework Sessions

Figure 7 plots the exam scores against attendance at the homework sessions. The Fall 2015 and Spring 2016 distributions are almost identical, especially when comparing the linear regression fit equations that are shown below the plot. Figure 7 also shows the combined exam score of Fall 2015 and Spring 2016. The combined exam score reveals that the attendance at the supervised homework session was not significantly correlated with exam scores.

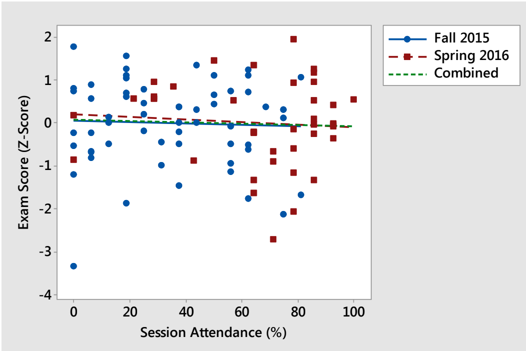

Figure 7: Exam Score (Z-Score)

Fall 2015: y = -0.001x + 0.05
Spring 2016: y = -0.003x + 0.21
Combined: y = -0.002x + 0.07

Figure 8 plots the homework scores against session attendance. It is easy to observe that both regression fits have the same tendencies. Figure 8 also shows the combined homework score of Fall 2015 and Spring 2016. The positive slope clearly indicated that the attending the homework sessions was positively correlated with homework scores.

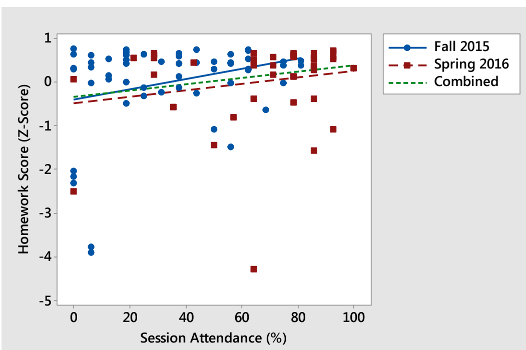

Figure 8: Homework Score (Z-Score)

Fall 2015: y = 0.012x - 0.40
Spring 2016: y = 0.007x – 0.48
Combined: y = 0.007x - 0.33

Figure 9 and Figure 10 were adapted from Tsutsui and Loui [1]. The data were obtained in the preliminary study during Fall 2015 for exam and homework scores, respectively. The preliminary study demonstrated that exam scores were not affected by the session attendance, whereas the opposite was true for the homework scores, especially for the students with low SAT-Math scores [1].

Figure 11 demonstrates that the students in Spring 2016 with high SAT-Math score benefit from attending the session for their exam scores, while the session attendance appears to have a minor negative impact on students with lower SAT-Math scores. Figure 12 similarly reveals that the students with high SAT-Math scores benefit from the session attendance for their homework scores more than those with lower SAT-Math scores.

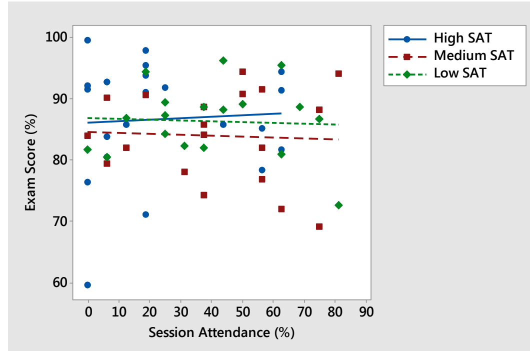

Figure 9: Exam Score Based on Session Attendance
Fall 2015 [1]

High SAT: y = 0.03x + 86.09
Medium SAT: y = -0.01x + 84.61
Low SAT: y = -0.01x + 86.90

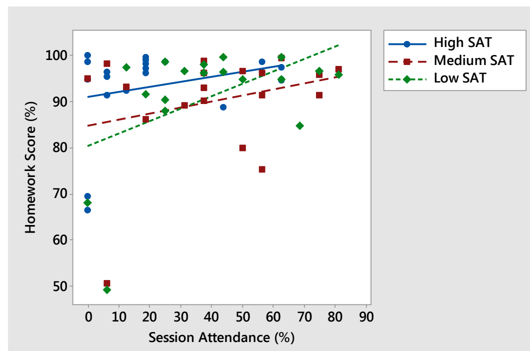

Figure 10: Homework Score Based on Session Attendance
Fall 2015 [1]

High SAT: y = 0.11x + 91.06
Medium SAT: y = 0.12x + 85.09
Low SAT: y = 0.27x + 80.40

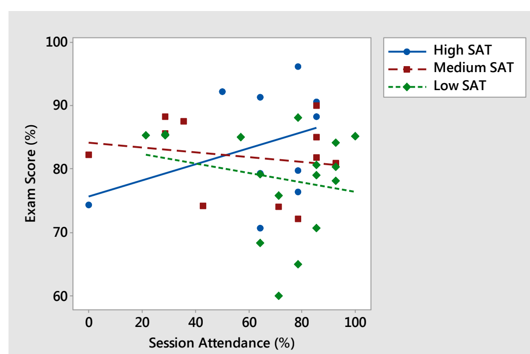

Figure 11: Exam Score Based on Session Attendance
Spring 2016

High SAT: y = 0.13x +75.80
Medium SAT: y = -0.04x +84.13
Low SAT: y = -0.08x + 83.95

C. Effect of SAT-Math Score

Figure 13 indicates the session attendance based on the SAT-Math scores. Both Fall 2015 and Spring 2016 data suggest that the students with lower SAT-Math scores attend the session more frequently than those with higher SAT-Math scores.

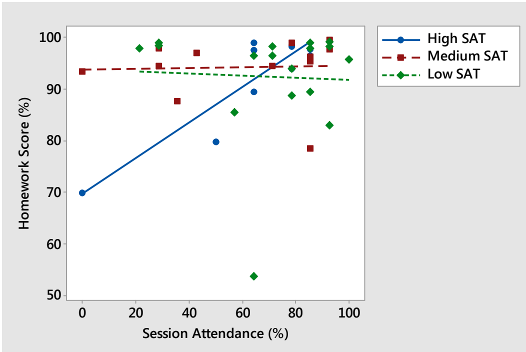

Figure 12: Homework Score Based on Session Attendance Spring 2016

High SAT: y = 0.34x + 69.69
Medium SAT: y = 0.01x + 93.84
Low SAT: y = -0.02x + 93.90

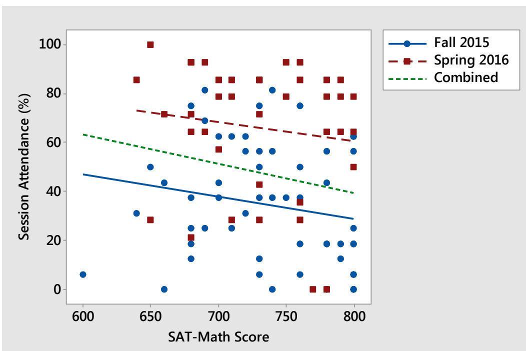

Figure 13: Session Attendance Based on SAT-Math Score

Fall 2015: y = -0.09x + 102.3
Spring 2016: y = -0.08x + 124.1
Combined: y = -0.12x + 133.9

Figure 14 and Figure 15 show the homework and exam scores based on the SAT-Math score. The slopes in all figures are small; therefore, the effect of SAT-Math score on homework and exam scores appears to be small.

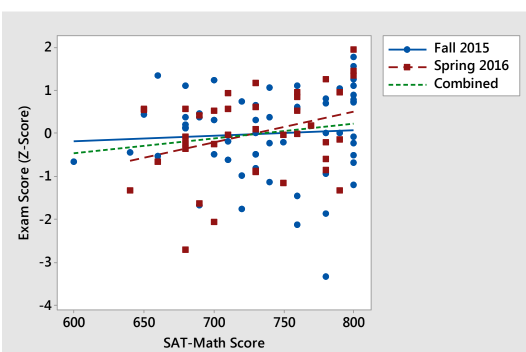

Figure 14: Exam Score Based on SAT-Math Score

Fall 2015: y = 0.001x – 0.98
Spring 2016: y = 0.007x -5.24
Combined: y = 0.003x - 2.54

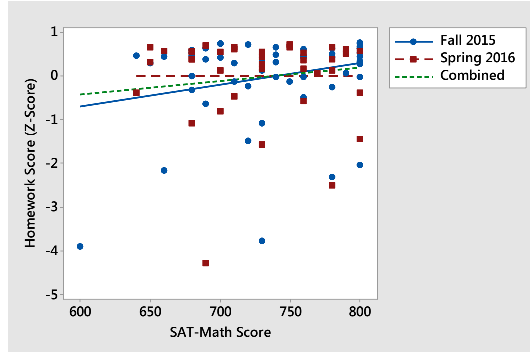

Figure 15: Homework Score Based on SAT-Math Score

Fall 2015: y = 0.005x – 3.67
Spring 2016: y = -0.0001x +0.04
Combined: y = 0.003x - 2.26

D. Analysis of Covariance (ANCOVA)

As far as the ANCOVA study is concerned, we have developed the regression models (Equations 1 and 2; Table 6) based on the experimental data from Fall 2015 [1].

<u>Fall 2015:</u> Adapted from [1]

$$\text{Exam} = C_1 + 0.56\ \text{SAT} - 0.18\ \text{Attendance} - 0.37\ \text{SAT*Attendance} \quad \text{(Equation 1)}$$

$$\text{Homework} = C_2 + 2.74\ \text{SAT} + 3.35\ \text{Attendance} - 2.94\ \text{SAT*Attendance} \quad \text{(Equation 2)}$$

Table 6: Discrete Variables, Number of Students (n), and Constants (C_1, C_2) for Regression Equations for Fall 2015 [1]

Discrete (Categorical) Variables			n	C_1	C_2
Gender	Status	Language			
0	0	0	0	89.55	94.02
0	0	1	0	99.65	90.60
0	1	0	4	92.84	96.83
0	1	1	0	102.94	93.40
0	2	0	0	80.87	98.98
0	2	1	2	90.97	95.60
1	0	0	20	84.03	89.44
1	0	1	0	90.43	81.51
1	1	0	24	87.31	92.25
1	1	1	0	93.72	84.31
1	2	0	2	75.34	94.40
1	2	1	6	81.75	86.46

Based on our previously-developed technique, we analyzed the experimental data from the Spring 2016 semesters and developed the regression models (Equations 3 and 4; Table 7).

<u>Spring 2016:</u>

$$\text{Exam} = C_3 + 3.27\ \text{SAT} - 0.35\ \text{Attendance} - 0.82\ \text{SAT*Attendance} \quad \text{(Equation 3)}$$

$$\text{Homework} = C_4 + 0.49\ \text{SAT} + 1.57\ \text{Attendance} - 2.75\ \text{SAT*Attendance} \quad \text{(Equation 4)}$$

Table 7: Discrete Variables, Number of Students (n), and Constants (C_3, C_4) for Regression Equations for Spring 2016

Discrete (Categorical) Variables			n	C_3	C_4
Gender	Status	Language			
0	0	0	5	83.47	95.84
0	0	1	0	86.03	89.60
0	1	0	1	82.70	97.68
0	1	1	0	85.27	91.40
0	2	0	0	71.51	101.80
0	2	1	0	74.07	95.56
1	0	0	8	82.66	91.54
1	0	1	0	85.23	85.30
1	1	0	20	81.90	93.38
1	1	1	0	84.47	87.10
1	2	0	1	70.71	97.49
1	2	1	4	73.27	91.26

The following section describes the response (dependent variables), factors (discrete independent variables), and covariates (continuous independent variables). The section has been directly adapted from [1].

Responses: Dependent Variables

Homework Score:
Expected homework score in percent (%)

Exam Score:
Expected exam score in percent (%)

Factors: Discrete (Categorical) Independent Variables

Gender:
0 = Female
1 = Male

Status:
0 = In-state domestic student
1 = Out-of-state domestic student
2 = International student

Language:
0 = English as a first language
1 = English as a non-first language

Covariates: Continuous Independent Variables

SAT:
Z-scores corresponding to the SAT-Math score

Attendance:
Z-scores corresponding to the supervised homework session attendance

P-values for the variables were recorded in order to identify the statistical significance of variables and their interactions (Table 8). Based on the assumed confidence interval of 95%, any p-values less than 0.05 indicate the statistical significance. From the result, SAT-Math score (0.014), attendance (0.021), and the interaction of between SAT-Math and attendance (0.044) has the statistical significance.

Table 8: P-Values for Discrete and Continuous Independent Variables

Variables	P-Values			
	Exam		Homework	
	F 2015 [1]	S2016	F2015 [1]	S 2016
SAT	0.634	**0.014**	0.082	0.769
Attendance	0.864	0.772	**0.021**	0.321
Gender	0.055	0.832	0.169	0.384
Status	0.071	0.304	0.611	0.792
Language	0.220	0.756	0.519	0.562
SAT*Attendance	0.734	0.526	**0.044**	0.107

The multiple R-squared values were recorded in order to evaluated the fit of the regression line (Table 9). Based on the results, our regression model can explain approximately 15 to 30% of variation in the exam and homework scores.

Table 9: Multiple R-Squared

Semester	Exam	Homework
Fall 2015	20.13%	29.64%
Spring 2016	30.85%	16.47%

VI. DISCUSSION AND IMPLICATIONS

There are significant differences in the session attendance between the Fall 2015 and Spring 2016 semesters. That is, the average session attendance nearly doubled from Fall 2015 to Spring 2016 (Figure 1 and Figure 2).

Each sample population has its own mean and standard deviation. More specifically, the mean and standard deviation of academic scores (i.e., exam and homework) in percentage were different between Fall 2015 (Figure 3) and Spring 2016 (Figure 5). Therefore, combining and comparing the unprocessed raw data in percentage does not seem to be the best practice. For this reason, the z-scores were calculated and plotted against frequency (Figure 4 and Figure 6). Then, we used z-scores to represent the final exam and homework results from the two semesters (Figure 7 and Figure 8).

With the combined Fall 2015 and Spring 2016 data, exam scores are not significantly influenced by the session attendance (Figure 7), whereas the opposite is true for the homework score even though the regression coefficients are not very large (Figure 8). Moreover, exam scores are not significantly influenced by the session attendance in any of the three SAT-Math groups in Fall 2015 (Figure 9), whereas the opposite is true for Spring 2016 (Figure 11).

Homework scores are affected by the session attendance significantly, especially for the low SAT-Math group in Fall 2015 (Figure 10) and for the high SAT-Math group in Spring 2016 (Figure 12).

The coefficient of the interaction term in Eq. 2 is -2.94, whereas the coefficient in Eq. 4 is -2.75. These results suggest that the attendance has a greater benefit for students with low SAT-Math scores in both semesters. This result contradicts the separate analyses of the low, medium, and high SAT-Math groups in Section V-B. One potential explanation for a contradiction in data is the outliers distorting the results. We did not remove any outliers from the experimental data.

As a byproduct of the study, we observed that students with low SAT-Math scores tend to attend the session more frequently than the students with high SAT-Math scores (Figure 13). Furthermore, SAT-Math score does not seem to have a strong influence on both the exam score and homework score as the small regression coefficients of 0.003 and 0.003 were observed for the combined Fall 2015/Spring 2016 for the exam score (Figure 14) and homework score (Figure 15), respectively. For the exam score, even though Table 8 indicates the p-value of 0.014 (< 0.05) for Spring 2016, the regression coefficient 0.007 is small (Figure 14). That is, even if SAT-Math has a statistically significant influence on exam scores, the effect is likely to be small.

VII. CONCLUSIONS AND FUTURE DIRECTIONS

We studied the effectiveness of our supervised homework session on the academic performance of the research participants. We found that attending the session helped the low SAT-Math students to do well in the homework scores during Fall 2015, but not so much in Spring 2016. We felt that one of the reasons for the contradiction in data originated from outliers. Furthermore, participating in the session did not help the exam scores. However, if we can come up with the way to quantify the similarities and differences between the homework and exam problems, we might be able to use this value as an additional independent variable. As a byproduct of the research, we found that the SAT-Math score was not a great predictive measure for the exam and homework scores.

One potential future direction is to pay attention to the type of distribution. In our study, we assumed that all scores are normally distributed. However, in the case of homework score, the average was skewed to one side, which may necessitate the need to use an alternative distribution. A possible countermeasure is to transform the non-normal data into normal data using the Box-Cox power transformation, so that the data analysis can be performed with a greater accuracy in ANCOVA.

Another potential future direction is to incorporate the hours that students spent on the outside the classroom as an independent variable. Even if students do not attend the supervised homework sessions, they may still spend many hours outside the classroom. Thus, if we know how many hours the students spent studying outside the classroom, we would be able to control for student effort.

ACKNOLWEDGMENT

This work was supported by the Dale and Suzi Gallagher Professorship in Engineering Education at Purdue University.

REFERENCES

[1] W. Tsutsui and M. C. Loui, "The Effectiveness of Weekly Supervised Homework Sessions in an Aerospace Structural Mechanics Course," in ASEE 2016 Annual Conference & Exposition, New Orleans, L.A., 2016.

[2] M. C. Loui, B. A. Robbins, E. C. Johnson and N. Venkatesan, "Assessment of Peer-led Team Learning in an Engineering Course for Freshmen," International Journal of Engineering Education, vol. 29, no. 6, pp. 1440-1455, 2013.

[3] L. T. Tien, V. Roth and J. A. Kampmeier, "Implementation of a Peer-Led Team Learning Instructional Approach in an Undergraduate Organic Chemistry Course," Journal of Research in Science Teaching, vol. 39, no. 7, pp. 606-632, 2002.

[4] W. K. Born, W. Revelle and L. Pinto, "Improving Biology Performance with Workshop Groups," Journal of Science Education and Technology, vol. 11, no. 4, pp. 347-365, 2002.

[5] T. J. Webster and K. C. Dee, "Supplemental Instruction Integrated Into an Introductory Engineering Course," Journal of Engineering Education, vol. 87, no. 4, pp. 377-383, 1998.

[6] R. Jacquez, V. G. Gude, A. Hanson, M. Auzenne and S. Williamson, "Enhancing Critical Thinking Skills of Civil Engineering Students through Collaborative Learning Methods in Supplemental Instruction," Proceedings of the 2007 American Society for Annual Conference & Exposition, pp. AC 2007-907, 2007.

[7] C. Blat, S. Myers, K. Nunnally and P. Tolley, "Successfully Applying the Supplemental Instruction Model to Sophomore-level Engineering Courses," ASEE 2001 Annual Conference & Exposition, pp. 6.911.1 - 6.911.12, 2001.

[8] S. C. Hockings, K. J. DeAngelis and R. F. Frey, "Peer-Led Team Learning in General Chemistry: Implementation and Evaluation," Journal of Chemical Education, vol. 85, no. 7, pp. 990-996, 2008.

[9] S. Brown, D. Lewis, D. Montfort and R. Borden, "The Importance of Context in Students' Understanding of Normal and Shear Stress in Beams," ASEE 2011 Annual Conference & Exposition, pp. 22.1471.1 - 22.1471.12, 2011.

[10] S. Brown, K. Findley and D. Montfort, "Student Understanding of States of Stress in Mechanics of Materials," ASEE 2007 Annual Conference & Exposition, pp. 12.1318.1 - 12.1318.14, 2007.

[11] D. Montfort, S. Brown and D. Pollock, "An Investigation of Students' Conceptual Understanding in Related Sophomore to Graduate-Level Engineering and Mechanics Courses," Journal of Engineering Education, vol. 98, no. 2, pp. 111-129, 2009.

[12] C. T. Sun, Mechanics of Aircraft Structures, 2nd Edition, Hoboken, N.J.: John Wiley & Sons, 2006.