

AC 2010-890: ENGAGEMENT IN AN UNDERGRADUATE HEAT TRANSFER COURSE OUTSIDE OF THE CLASSROOM

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Engagement in an Undergraduate Heat Transfer Course Outside of the Classroom

Abstract

This paper describes a curriculum and a course format for teaching assistant-led sessions aiming to foster student interest and increase engagement in an introductory undergraduate heat transfer course. Evidence of engagement from records of participation in optional extra credit assignments and optional teaching assistant-led sessions are presented. These data indicate that increases in participation in optional activities are correlated with increases in course performance.

Introduction

Heat transfer instruction is common to many undergraduate mechanical and chemical engineering departments throughout the country and the world, and the available coursework material and teaching practices in this particular discipline are among the most mature in these departments. Heat transfer plays a central role in modern societal needs, in particular energy conversion processes such as the combustion of fossil fuels, which is responsible for a large fraction of green house gas emissions.

Astin and Pace have suggested that increases in student involvement and quality of effort are associated with increases in learning.^{[1],[2]} Based on this theory and the importance of the subject matter we formulated the research question, “Does out-of-class engagement in heat transfer lead to increases in learning as measured by course performance?” Answering this question would allow educators to make more informed decisions about how to encourage learning.

There is an extensive history of pedagogical research on student engagement, much of which has made progress on defining the concept of *engagement*. There are many different aspects of student engagement in university courses as engagement stands at the crossroads of interest, involvement, excitement, choice, attitude, behavior, and opportunity. Pace used the term *quality of effort* and, in his view, “quality of effort describes voluntary behavior. It reflects initiative. It describes the strength and the scope of personal investment that students are making for their own higher education.”^[3] Astin used the term *involvement* and considered the involved student to be someone who “devotes considerable energy to studying, spends a lot of time on campus, participates actively in student organizations, and interacts frequently with faculty members and other students.” He also states that “the extent to which students are able to develop their talents in college is a direct function of the amount of time and effort they devote to activities designed to produce these gains.” Astin suggests that “greater use of active rather than passive modes of instruction” would increase students’ level of involvement.^[2] More recently Chen et al. determined that student engagement is affected by faculty in the classroom and suggested that future studies of engagement should investigate faculty-student interactions.^[4] Here, we look into engagement through the effort that students put forth outside the classroom which may be a proxy for their initiative or involvement in the course.

While there have been many attempts to quantify the impact of student engagement in a variety of disciplines, such as literature^[5], math and science^[6], and at a variety of educational levels from elementary school^[7] to high school^[8] to college^[9, 10], we were not able to identify any focused work on the question of engagement and heat transfer learning. We do note that there has been recent research to better understand the misconceptions in learning heat transfer.^[11]

The present work contributes to the field of engagement research by investigating the correlation between course performance and engagement with the material outside of class. This paper outlines the creation of a curriculum that encourages student engagement in heat transfer through example problems and classroom activities during the teaching assistant-led sessions. The data we collected representing engagement outside of the classroom and learning includes: attendance during class, self-reported time spent on homework, and grades (including overall course grades). Next, we describe our methodology for data analysis followed by our findings that illustrate the correlations between indicators of engagement outside the classroom and course performance. This paper concludes with recommendations for fostering engagement in undergraduate courses and plans for future work. Our results linking course performance with completion of extra credit assignments will spur further study of how to best encourage learning in heat transfer courses.

Course Background

The introductory heat transfer course held in Fall 2009 had three required components: an in-class component, an at-home component, and a laboratory component. In addition, there were optional components that students could choose to pursue including attending the teaching assistant-led sessions or completing extra credit assignments. There were 61 students enrolled in the course, and 60 students agreed to participate in this engagement study.

There were two lectures each week given by a professor for an hour and fifteen minutes duration. The professor's teaching style consisted of a traditional lecture format, although there were occasionally departures from this format. The professor did not lecture to the board while writing constantly, but turned to the class to discuss most of what was presented. This allowed the professor to easily see if students had raised their hand with a question. In addition, the professor often asked questions of the students. Unlike the common call of "Any questions?" which is usually met with the blank stares of lost or confused students, this professor would ask specific questions of students such as "What do you think causes this?" or "Can anyone tell me why this occurs?"

The homework assignments included lists of readings and problem sets assigned at the beginning of the course indicating the sections of the book that were to be covered during each lecture and the due dates for the weekly problem sets. Each problem set included three to five problems from the text book and an extra credit problem also assigned from the book.

The laboratory component was carried out by teams of students and consisted of three laboratory experiments and one design competition. Individual lab reports were turned in after each experiment and team reports were turned in with the design competition. The course also had one midterm exam in week five of the course and one final exam that was given a week after the

completion of the course. The final exam also offered extra credit that was not included in the final exam grade, but is included in the number of total extra credit points earned.

Optional teaching assistant-led sessions (TA sessions) were offered twice a week. The same material was covered each week in the two one-hour sessions led by the same teaching assistant. The TA sessions were held in the same room in which the class lectures were presented. The TA sessions were offered on Thursdays and Fridays with the homework assignments turned in on Wednesdays. Because the TA sessions were held before many of the students had started the homework assignment due the following week, the students were on similar standing coming into the sessions. The discussion of curriculum development in this paper refers to curriculum designed for these TA sessions.

Extra credit points were offered for completing extra homework problems and additional exam problems. These extra credit points were not included in the grades assigned for homework and not included in the overall grade for the course. During the first lecture, the professor explained that the extra credit problems were optional and points earned from them would not be added directly into the grades for the course. Each extra credit problem was assigned a number of points based on the perceived difficulty of the problem. Fairness in the opportunity to work on the extra credit on the final exam was assumed because roughly 90 percent of the class chose to turn in the exam before the time limit was reached.

Methodology

Challenges with quantification

This work attempts to identify how indicators of engagement outside of the classroom—attendance at the optional teaching assistant-led sessions, completing the extra credit assignments, and time spent working on homework— influence course performance. While these measures of engagement may be correlated with course performance, we cannot draw any conclusions about causality. In addition, there is a challenge in quantifying engagement. Recording attendance at the TA sessions only indicates the decision to attend the session and not the reasons for coming (which may range from a high level of interest in the course material to feeling obligated); while not a measure of interest, attendance is a measure of the involvement of the student. Similarly, the increases in time spent on homework (which Astin suggested correlates with increases in learning) may be due to interest in the material, but also may be due to a lack of interest, lack of focus, or lower “quality of effort” while completing the assignments.^{[2],[3]} The current study is constrained by the measures used to record only the students’ behaviors and not their attitudes towards the curriculum.

Methodology for designing the TA session curriculum

The curriculum for the TA-led sessions was designed to increase levels of interest and to encourage engagement with carefully chosen content and presentation in sections and homework assignments selected considering the context of the problem and the skills required. This is based upon Dewey’s work on interest and effort which suggests that students’ interest is gained by choosing content and activities that are relevant to students’ skills and experiences.^[12] The curriculum includes active learning components as suggested by the active learning literature to provide a chance for students to talk and listen, read, write, and reflect in class.^[13] Informal

cooperative groups as described by Smith et al. were utilized to promote in-class engagement as well.^[9] Several principles of effective teaching and learning were also incorporated to try to boost engagement: encouraging faculty-student interaction, using active learning techniques, and encouraging students' motivation to learn.^[14]

TA sessions were designed to reinforce the material presented in the lectures, to provide the students with additional tools to complete the homework assignments, and to create a lasting understanding of the fundamentals of heat transfer that students would carry with them years after the class was completed. In achieving these goals, there was much flexibility in what material was presented and how it was presented. In order to connect students of different interests and backgrounds to the material, concepts were presented from multiple angles using different descriptions of phenomena, referencing the history of heat transfer and the context in which the fundamental equations were discovered, and outlining the physics behind the equations. To further the interest of students and provide relevance it was pointed out (when appropriate) that analyses conducted in class may be the same or different from analyses that may be carried out on the job. Finally, in-class examples were presented that used heat transfer to solve problems that were relevant to other interests of the students in situations such as automotive applications, global warming, skin and muscles, manufacturing, and cooking.

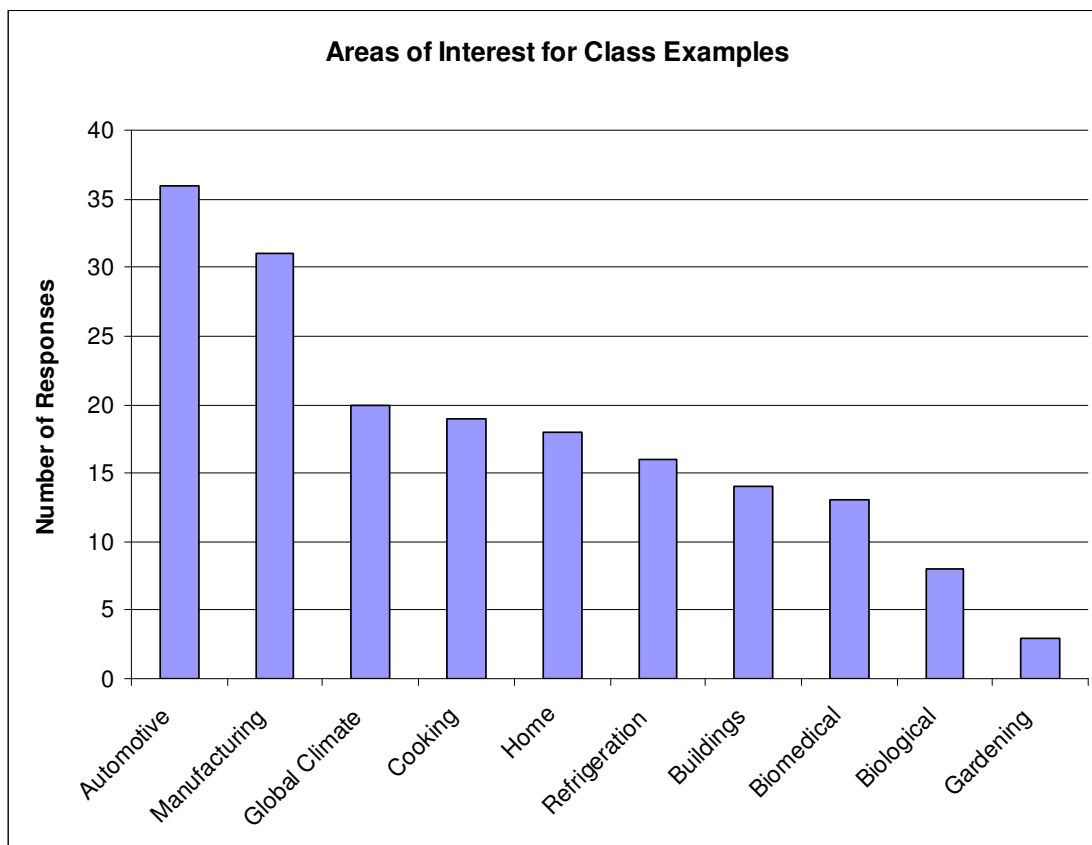


Figure 1. Results from survey on the first day of class indicating the areas students are interested in learning more about through examples.

Interest areas for class examples were determined from a 10-minute survey administered during the last 10 minutes of the first lecture meeting. Students were asked to indicate from a list the three topic areas in which they would be most interested in seeing examples. The results are shown in Figure 1. After the survey was administered, the in-class examples were chosen to align with the topics identified by the students as interesting.

Class activities were based on the active learning literature suggesting that courses include time for students to talk and listen, read, write, and reflect during class.^[13] Some of the activities used in the TA sessions include think/pair/share exercises, quick writes, and class discussions. The informal cooperative learning groups that were formed during the think/pair/share activities allowed for greater classroom involvement. Activities provided time for students to recall what they knew about a topic or reflect on the problem solving process; this provided opportunities for students to solidify their conceptual understanding of heat transfer and to identify portions of the material that they understood and portions of the material that they needed to revisit. In one class activity, for example, students acted out the behavior of molecules within a temperature gradient to better understand the randomness associated with diffusion. Other class activities included mini-lectures and group questioning in which the teaching assistant would ask questions such as “what do we need to know first?” and “how can we determine that value?” to lead the class through a heat transfer problem.

The material presented during TA sessions was adapted “real-time” during the session based on feedback from the students. Feedback was solicited at the beginning, middle, and end of the TA sessions by asking students to indicate if they understood the previous lectures, were confused by any part of what was presented in the TA session, and if they had any suggestions about the concepts presented. A large part of the curriculum involved balancing the wants of the students (e.g., procedures to complete the homework problems) with the goals of the teaching team (e.g., teaching the tools needed to complete the homework and do well on the final and midterm and instilling a lasting understanding of heat transfer that includes the basic mechanisms and assumptions underlying the equations and procedures taught during the course).

Homework and extra credit problems were selected to follow from material that would be covered in the lectures and supported by the assigned reading from the textbook. They were chosen for their context so that students would be provided with information about the possible applications of the skills that they were learning.

Methodology for data collection and analysis

Data that demonstrated engagement outside of the classroom, specifically outside of attending the required lectures, were collected and compared to measures of course performance. Attendance at optional TA sessions, time spent on homework, and completion of the extra credit assignments were collected as indicators of engagement. Indicators of course performance, grades on homework assignments, laboratory assignments, exams, and in the course overall, were collected for comparison with the indicators of engagement.

Students attending the TA sessions were asked to sign in at each class in order to keep track of the number of sessions each student attended. Students were asked to sign in when they arrived to the session, even if they arrived after the session began. The sign-in list was also used to help

the teaching assistant learn the names of the students and for calling on students to answer questions.

TA session attendance was measured in increments of 1, for each session attended. No students attended both a Thursday and a Friday session of the same week. The maximum number of sessions attended was 10; the average for all of the students in the class was 3.6. The distribution of the number of sessions attended can be seen in Figure 2. Twenty percent of the class did not attend the TA sessions at all. This may be due to feeling as though they understood the material sufficiently to not need extra help or due to expectations that these optional sessions really were optional and that doing well in the class would not require attending them.

The attendance pattern of students also indicates, as seen in Figure 2, that many students attended only one TA session. It is possible that these students did not find the TA session interesting or felt that it did not meet their needs.

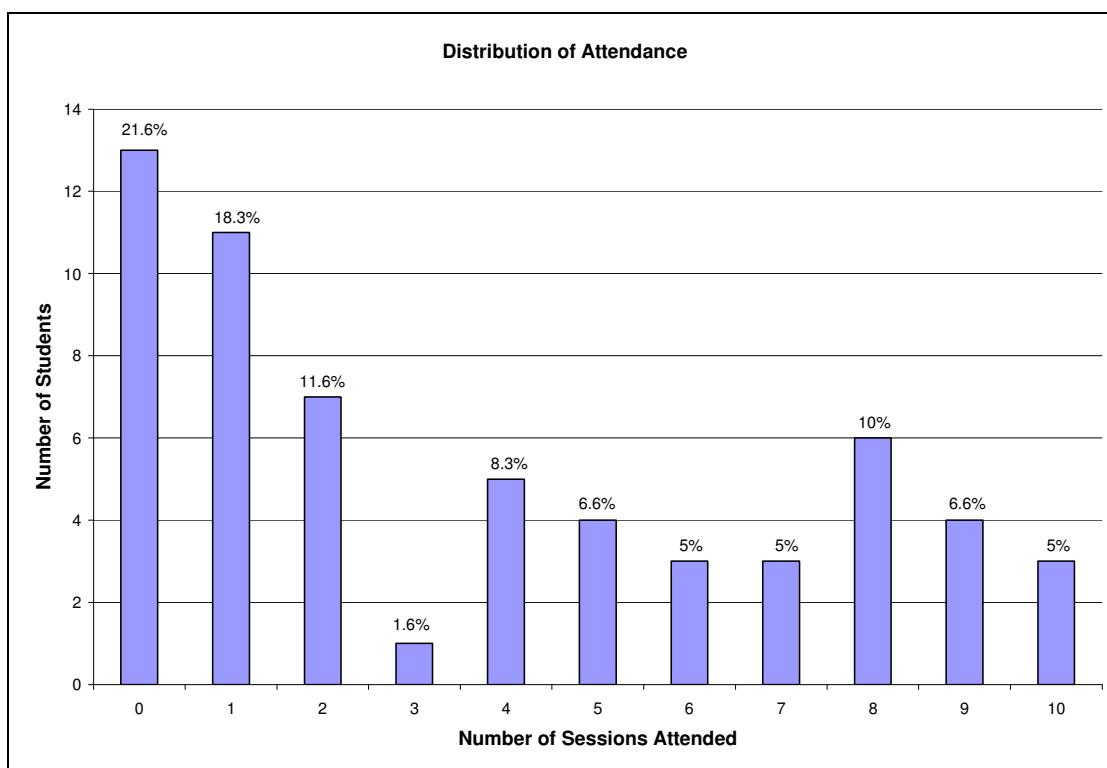


Figure 2. Distribution of the total number of TA sessions that students chose to attend. Percentages indicate the portion of the whole class in each category.

While total student attendance at the lectures remained near 100 percent for the duration of the course, attendance at each week's TA sessions varied between 20 percent and 55 percent. Figure 3 shows the total attendance at the two TA sessions each week. After the high attendance during the initial weeks of the course, there was a spike in attendance at the TA sessions before the midterm (week 4) and before the final (week 10). Students may have become busier with projects, exams, and outside activities towards the end of the course thereby accounting for the decline in attendance. Another explanation for the declining trend in attendance may be that students lost interest in the course as the course progressed.

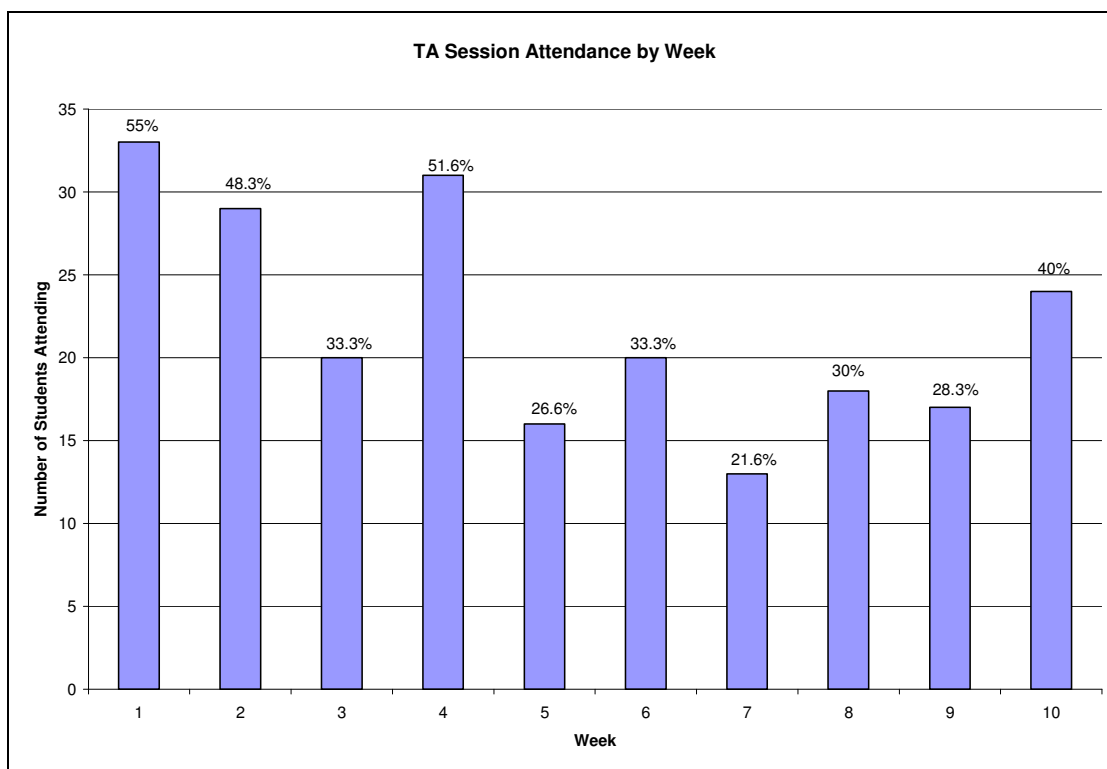


Figure 3. Total attendance at the two TA sessions each week. Percentages indicate the portion of the whole class attending each week.

The students were asked at the beginning of the course (and reminded by e-mail and in class several times throughout the course) to report the number of hours that they spent on each homework assignment. While some students provided half hour increments, most students responded in hour increments. Figure 4 presents the average of the times reported by students. Roughly half of the class reported the number of hours they took to complete the homework on each assignment; the percentage of responses on each assignment is noted in Figure 4. Responses came from a different set of students each week, so student responses were weighted by the difficulty of the problem set as determined from the average time to complete the assignment by the six students who reported times on all assignments. While the homework assigned at the beginning of the course included a reading list and a list of problem sets, we believe that most of the students reported only the time that they took to complete the problem sets. Some of the variation in times reported may be due to differences in the interpretation of what comprises homework. While we are unsure if some students considered time spent reading the book, reviewing notes, and going to office hours as time spent doing homework, we assume most students did consider time spent working on homework extra credit problems. It is important to remember that these are self-reported estimates of the amount of time the homework took and may be inflated or deflated or simply poor estimates. Some time outside of class was spent working on laboratory assignments and studying for exams, and that was not included here.

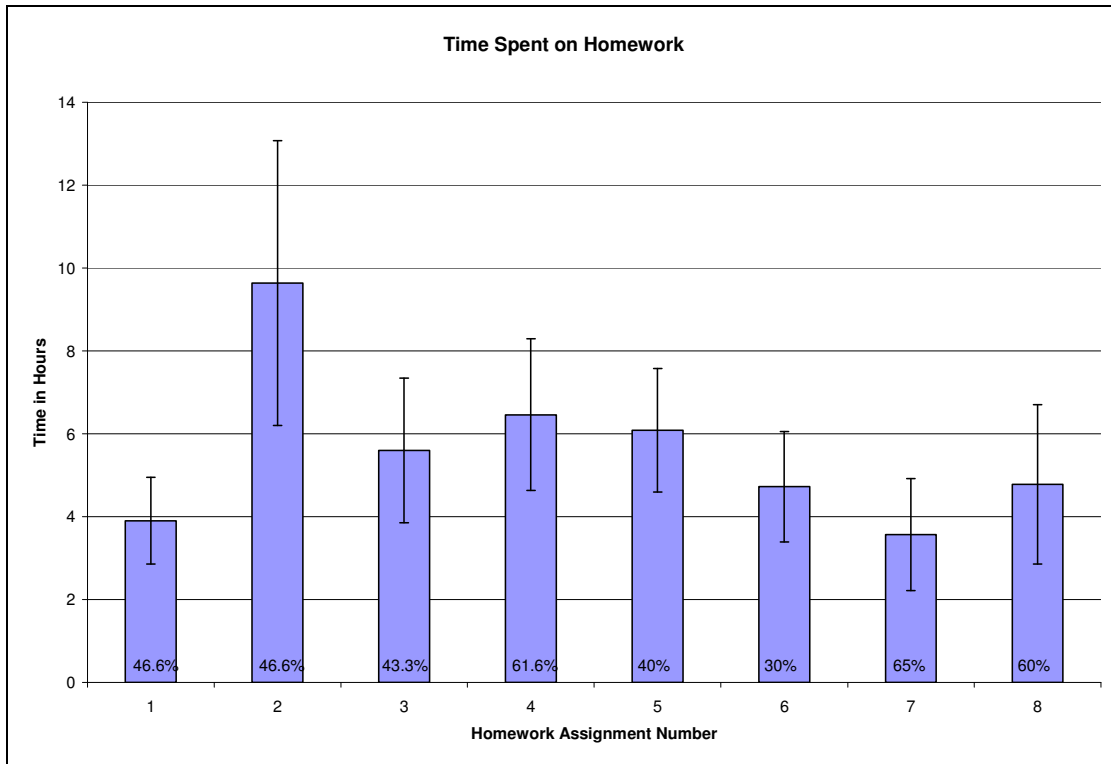


Figure 4. Average time spent on each homework assignment. Percentages indicate the portion of the class who responded. Bars represent standard deviation of the times reported on each assignment.

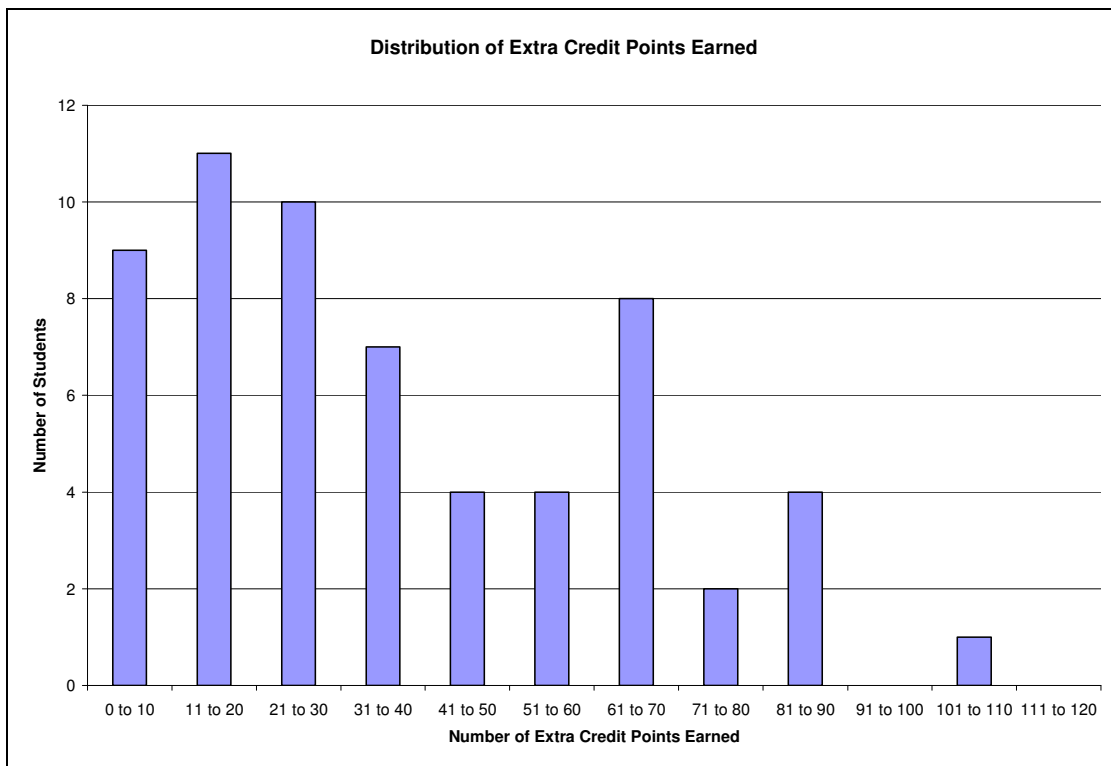


Figure 5. Distribution of total extra credit points earned by students.

Extra credit points were offered for solving an extra homework problem on each homework assignment and one extra problem on the final exam. The extra credit points were not added into the homework or exam grades. The maximum number of extra credit points possible was 120; the class average was 38. The distribution of extra credit points awarded can be seen in Figure 5.

Grades on homework assignments, laboratory assignments, midterm, and final were collected and compiled into an overall course grade. The overall course grade was calculated as 25 percent of the homework average plus 20 percent of the lab report average plus 20 percent of the midterm grade plus 35 percent of the final exam grade. Points awarded for extra credit were recorded but not included in the grades for each student.

The comparison of the indicators of outside-of-class engagement with course performance variables was completed using bivariate and partial correlations. Statistical significances are indicated in the results sections by p-values. A p-value less than 0.05 indicates a statistically significant correlation, a p-value less than 0.01 indicates a highly statistically significant correlation, and a p-value less than 0.001 indicates a very highly statistically significant correlation.

Results and Discussion

In investigating the measures of outside of class engagement, the analyses indicate a positive correlation between extra credit points earned and TA session attendance with a p-value of 0.004. Neither extra credit points earned nor TA session attendance correlated with the average amount of time spent doing homework as seen in Table 1.

Pearson Correlations between Measures of Out-of-class Engagment			
	Extra Credit Points Earned	TA Session Attendance	Average Time on Homework
Extra Credit Points Earned	1		
TA Session Attendance	.363**	1	
Average Time on Homework	-0.076	-0.07	1

*p<0.05, **p<0.01, ***p<0.001

Table 1. Correlation matrix with 3 outside of class engagement variables.

This finding may suggest that the three measures should not be lumped into a larger “engagement” variable. For our analysis, these measures are considered separately using bivariate correlations. However, attending TA sessions and completing extra credit assignments may both indicate a larger involvement in the course or increased engagement. Partial correlations were utilized to try to tease apart the more influential factor, attendance or extra credit.

In taking a closer look at our measures of course performance shown in Table 2, there are significant positive correlations between overall grade and each of the components of the overall

grade: homework grades, lab grades, midterm grades, and final exam grades. This is expected, as the overall grade is simply a linear combination of the other grades. Positive correlations between all of the other grades in the class were found as well. While lab reports, problem sets, and exams may be measuring very different components of understanding heat transfer, students who do well in one area are seen to do well in others, and students who do poorly in one area appear to be also more likely to do poorly in the other areas.

Correlations between Measures of Course Performance					
	Homework	Midterm	Lab Reports	Final Exam	Overall Grade
Homework	1				
Midterm	.480***	1			
Lab Reports	.424***	.477***	1		
Final Exam	.481***	.620***	.550***	1	
Overall Grade	.657***	.853***	.663***	.891***	1

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 2. Correlation matrix with course performance measures.

The data also indicate that students who complete extra credit assignments are more likely to do well on homework, the midterm exam, lab reports, the final exam, and in the course overall as indicted in Table 3. Attending TA sessions is positively correlated with homework grades and positively but weakly correlated with overall grades also seen in Table 3. Interestingly, time spent on homework is not significantly correlated with any of the course performance measures.

Correlations between Measures of Engagement and Measures of Course Performance					
	Homework	Midterm ^a	Lab Reports	Final Exam	Overall Grade
Extra Credit Points Earned	.501***	.412***	.333*	.443***	.560***
TA Session Attendance	.394**	0.193	0.212	0.203	.313*
Average Time on Homework	-0.098	-0.141	0.014	-0.115	-0.192

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

^a Midterm grades were correlated with average time spent on homework before the midterm, extra credit points earned before the midterm, and TA session attendance before the midterm.

Table 3. Correlations between average time spent on homework and course performance measures.

The reason why time spent on homework is not correlated with increases in course performance may be twofold; students who are interested in the material and understand it well may be likely to spend more time on the extra credit and discussing the finer details of the problem set. However, disinterest or confusion about the material may also lead to spending longer amounts of time on the homework especially if students are not staying focused or are having to refer to other sources such as the text book for help.

Table 1 shows that extra credit scores and TA session attendance are positively and significantly correlated. Because of this relationship, it is unclear if the correlation between homework grade

and both attendance and extra credit as well as the correlation between overall grade and both attendance and extra credit (shown in Table 3) reflect actual relationships between attendance and these grades or a secondary result from the trend of attendance increasing with increasing extra credit points earned. Partial correlations make these relationships more clear. By looking for a correlation between attendance and homework grade while holding extra credit constant, we see if the relationship is really between attendance and homework grade or if that relationship was significant only because attendance and extra credit were correlated. The same can be done with overall grade. We therefore repeated the process while holding attendance constant and looking for a correlation between extra credit and each homework and overall grade.

The partial correlations shown in Table 4 indicate that the extra credit points earned positively and significantly correlated with both homework grades and overall grades when holding TA session attendance constant. However, when we control for extra credit points earned, attendance is not significantly correlated with overall grade and only moderately correlated with homework grade. This suggests that the correlation between overall grade and attendance is due to the correlation between attendance and extra credit and does not reflect a significant relationship between attendance and overall grade. The partial correlation between attendance and homework grades does show that attending the TA sessions has a positive impact on homework grades when controlling for extra credit completion.

Partial Correlations with Attendance and Extra Credit			
Control Variable		Homework	Overall Grade
TA Session Attendance	Extra Credit Points Earned	.418***	.504***
Extra Credit Points Earned	TA Session Attendance	.263*	0.142

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4. Partial correlations relating extra credit and attendance to homework grades and overall grades while holding attendance and extra credit points earned constant, respectively.

Conclusions and Future Work

The correlations presented in this paper suggest that our measures of outside of class engagement are not equally correlated with measures of course performance. Of the three measures of engagement referred to here---TA session attendance, extra credit points earned, and time spent on homework---we find that TA session attendance and extra credit points earned are significantly correlated. This implies that time spent on homework is perhaps measuring something other than the factor that TA session attendance and extra credit points seem to be getting at, engagement. Scores on lab reports, problem sets, and exams were all correlated with one another, implying that they do, in fact, measure components of the same underlying idea, understanding heat transfer.

From the data analyzed here, the average time that students spent doing homework did not appear to be correlated with course performance. Additionally, attending the TA sessions was only moderately correlated with increased performance on homework assignments.

Completing the extra credit assignments was positively and significantly correlated with all of our measures of course performance. Before we suggest requiring all students complete the extra credit assignments, we should note that it is unclear from this study as to what caused the increases in course performance. We are unable to determine if the increases in performance were due to completing the extra credit or due to other characteristics held by the group of students who self-selected to complete the assignments.

We are interested in investigating further the connection between engagement and optional participation. We plan on conducting following-up interviews with students from the course who attended many of the sessions to see what affected their choice to continue attending. We also intend to interview students who attended only one or two sessions to see why they chose to stop attending. Similarly, we will follow-up with students who completed much and little of the extra credit assignments to gain further insight into the decisions made about completing extra credit assignments.

The strong relationship between completing extra credit assignments and course performance leads to questions about the role of extra credit in a course. Future work may investigate whether the positive correlation with course performance is due to completing the extra credit assignments or due to some other factors held by the students who choose to do the assignments. Future work may also try to understand the impact of extra credit when integrated into the class in various ways.

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