AC 2012-3902: EXAMINING AND INFLUENCING HOW STUDENTS PREPARE FOR ENGINEERING CLASSES

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Examining and Influencing How Students Prepare for Engineering Classes

Abstract

A common stigma that students often associate with an engineering degree is enduring an excessive workload. In fact, recent studies suggest that this perception is one of the primary reasons many students leave engineering majors and pursue other studies. This claim is also confirmed almost uniformly across all core engineering courses when students report on end of course surveys that they do not have enough time in their schedule to complete their assignments. As an educator, however, these claims are viewed from an admittedly critical perspective, especially after witnessing first-hand, frustratingly at times, poor study habits, weak time management skills and unacceptable daily preparation levels for class. In fact, this contradiction is highlighted further by a unique departmental policy requiring students to anonymously report how much time they spend preparing for each lesson. Each year, students report that they are actually spending on average just half the amount of time per lesson that is both expected and also used to design course requirements. So is it really fair, or even accurate, to label engineering with an "excessive workload" compared to other disciplines? As an educator, the potential to positively influence this apparent contradictory stigma and obvious source of frustration for both student and teacher forms the primary motivation of this study.

This work examines how engineering students actually spend their time preparing for class and how we as teachers can positively influence it. The first objective investigates the true nature of student preparation. We explore if students actually complete or at least review assigned readings and what encourages them to do so. We evaluate how graded events drive student preparation and how much time is truly being spent preparing for class. The second objective evaluates certain teaching methods that reportedly enhance student preparation and learning. As a pilot study, our primary method requires students in a previously open-book-exam heat transfer course to rely on their own daily summary notes for all graded events. Students submit a summary outline from the reading within the front half of a sheet of paper for each lesson. Only sheets demonstrating completion of the assigned reading are approved and given back to students where additional notes can be written within the remaining space on the sheet of paper. Most importantly, this document serves as the student's ***primary*** reference on examinations. Initial results show this method is administratively simple to implement and class preparation time, along with completion rates of assigned readings are noticeably higher compared to other core engineering courses. We feel this study will be of interest to educators in any technical field looking for a simple, "self-motivating" tool to enhance student preparation and learning.

Introduction

Heat Transfer, as many advanced technical engineering courses, is a challenging course to teach. It is also a tough course for students to take. Many students often consider it to be one of the tougher courses they take in the mechanical engineering curriculum. The nature of the subject requires synthesis and application of many fundamental concepts from physics, mathematics and

past engineering courses-particularly thermodynamics and fluid mechanics. Sound pedagogy is certainly a premium when teaching such a course, but perhaps even more important is the nature in which students regularly prepare for class. In fact, recent studies suggest that the majority of student learning in engineering courses (approximately two-thirds) actually occurs outside of the classroom.[1] In addition to this, as students enter their senior year, they ought to be expected and encouraged to develop disciplined professional habits for lifelong learning.

A challenge to this sort or rhetoric however lies with recent trends in engineering enrollment. Studies suggest that students may be leaving engineering because the work load is too severe. In addition to curriculum difficulty and low grades, work load was a primary factor reported among a survey of 120 engineering students across five institutions that decided to leave their engineering major to pursue other studies.[2] A more recent article from the New York Times ("Why Science Majors Change Their Minds-It's Just So Darn Hard") cites roughly 40 percent of students who start out as engineering and science majors end up switching to other subjects or eventually fail to get their degree.[3] The President of the United States along with industry groups have called on colleges to graduate 10,000 more engineers along with 100,000 new teachers with majors in STEM-science, technology, engineering and math. Among a handful of other reasons that contribute to high attrition rates, the article points out that American students, particularly gifted students with above average admission scores, likely cruised through high school without developing disciplined habits. This is both troubling and in sharp contrast to students in China and India who focus relentlessly on math and science.

As an engineering educator, this is an important and sensitive issue, particularly when implementing a teaching method aimed to enhance student preparation outside of the classroom that may be perceived as punitive in nature. Studies suggest however (ref. NY Times article) that this sort of teaching approach is exactly what our students need to both get through the rigors of an engineering degree and also compete on a global scale where recent trends show that our students are lagging behind. It also suggests that mechanisms to monitor the work load, particularly how much time students are actually spending on course work should be collected, monitored and analyzed. This information can not only be used to design and structure a course, but also communicate positive expectations for students; especially if preparation time is low or data trends suggest problematic procrastination.

The overall strategy of this study is to provide an approach to both monitor and enhance daily student preparation. Several studies have been conducted that outline strategies for motivating students to complete reading assignments.[4,5] Quizzes, assigning study questions, posing non-threatening discussion questions in class on the reading and even dismissing the class completely if students arrive unprepared are generally accepted strategies to encourage reading and class preparation. In all cases, there seems to be one common theme: students tend to regularly prepare for a course when it actually makes a difference (often in their grade or personal embarrassment). The methods applied here are for an undergraduate heat transfer course taken by seniors, but the focus is actually not on explicit teaching methods used in the classroom. In fact, the results of this study can be applied to any course, and is not even necessarily restricted to engineering courses. The primary method examined in this study is a novel technique taken from literature termed "survival cards."[6] This technique was reported in an undergraduate mathematics course and was shown to increase reading in the text from 10% to 90%. Students

are required to submit a survival card at the start of each lesson. Only satisfactory cards that demonstrate adequate preparation are accepted. Cards are returned to students before examinations so that additional notes can be written in the remaining space. Only approved survival cards are used for reference on examinations.

This technique was implemented for one semester in an entire heat transfer course. This is compared and contrasted to other common techniques used in the same course over the course of two separate semesters-specifically online homework quizzes or "lesson surveys" and daily announced quizzes at the start of each class. In addition, survival cards are compared to student performance in another mechanical engineering course similar in scope (thermo-fluids) where no special method is implemented aimed to motivate and enhance student preparation. Results from an end of course survey from both students in the course using survival cards and the control course are reported.

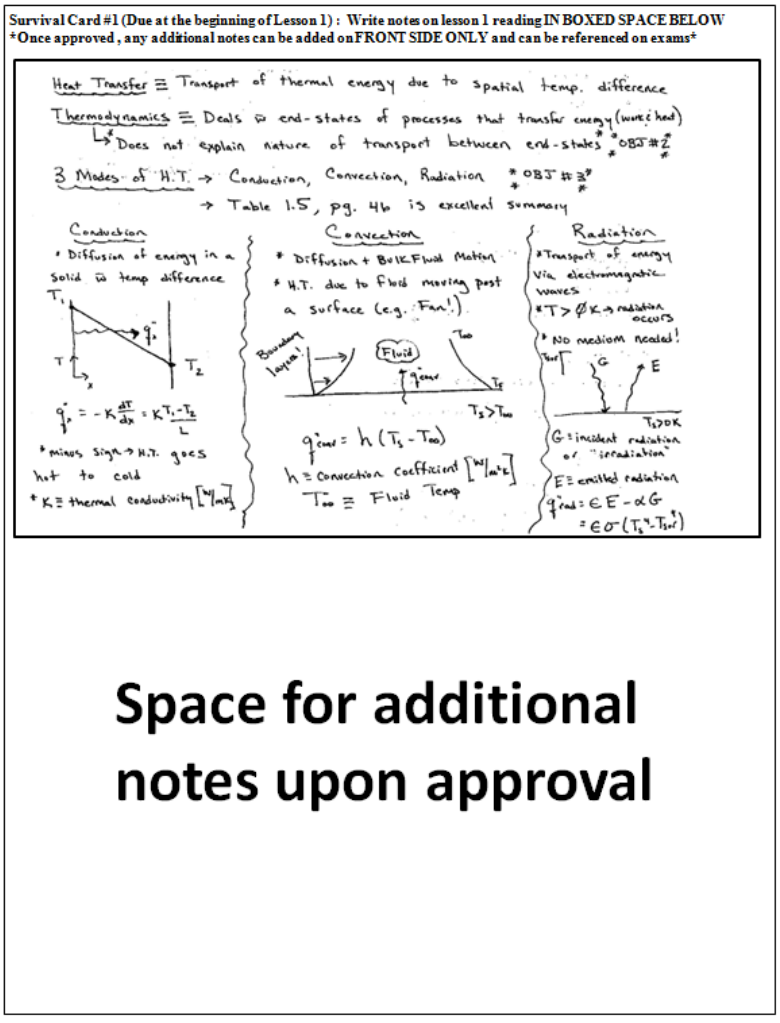


Figure 1-Sample Survival Card

OVERVIEW OF METHODS TO ENHANCE CLASS PREPARATION

Three separate methods were implemented in a heat transfer course over three separate semesters with an overall intent to enhance class preparation. The frequency of homework assignments is also reported for each method. Time data was collected daily by asking students to anonymously record how much time they spent preparing for each lesson.

The first two semesters utilized daily online homework quizzes and announced daily in-class quizzes respectively. The online quizzes included five multiple choice questions covering the main concepts from the reading that could be completed by the student at any time before the start of the lesson and were automatically graded by the online Blackboard system. The daily in-class quizzes included one or two questions that also covered the main concepts on the reading and were taken at the start of every class lasting no more than five minutes. All possible quiz questions were given to students at the start of the course to emphasize the concept of true "announced" quizzes with no surprises. The final method is the focus of this study and is compared to the previous two methods with respect to student preparation time and qualitative assessment from both the students and instructor.

This method is termed "survival cards" and requires the student to prepare summary notes on the lesson's reading to be turned in at the start of every class. These notes are then quickly reviewed by the instructor and if it is evident that the student completed the assigned reading, they are visibly approved (initialed) and returned to the student before the next examination. The student can then write anything they wish in the remaining space and only approved survival cards serve as the primary reference on examinations. An example survival card is shown in Figure 1. This same image is handed out to students during the first lesson to explain the survival cards policy and also demonstrate "what right looks like."

RESULTS

Table 1 summarizes the results for each semester where a different method was used to enhance student preparation. In addition, a 4 year historical average is provided for comparison of results. It should be noted that the GPA refers to the average GPA of the sample just prior to starting the course where a method is employed. The number of homework assignments is reported since a strong correlation is noted with respect to reported time data fluctuations. The average term end examination (TEE) grade for each sample is reported since the TEE is securely maintained and not changed from semester to semester. This provides a somewhat consistent metric for comparison of class performance from semester to semester. Time data was collected anonymously at the start of every class and the number reported in Table 1 is the average time spent on a daily basis for the respective sample.

Results from the sample using survival cards shows a dramatic increase in time preparing for class compared to the other two methods and the historical average, but is still well below the 120 minute rule of thumb (2 hours of prep for every 1 hour of class). Students spent almost 30% more time preparing for class when using survival cards. One would think that this would equate to better performance on the final examination but interestingly it did not. The class average on the term end examination (TEE) was a historical low. It is not exactly clear why this occurred.

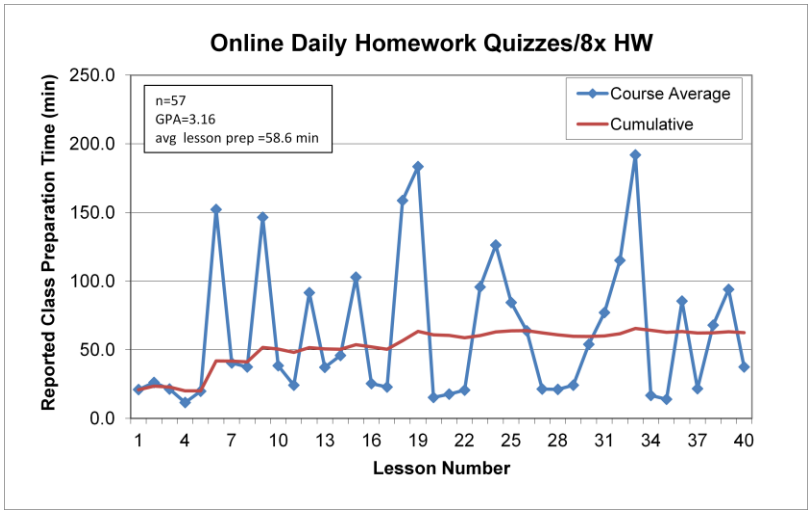
Table 1-Summary of samples analyzed with class preparation enhancement methods

Method	Sample Size (n)	Homework Assignments	GPA	TEE Average (%)	Average Prep Time (min)
Online Quizzes	57	8	3.16	82.9	58.6
In-Class Quizzes	35	14	3.15	85.0	53.5
Survival Cards	49	10	3.05	79.0	76.2
Historical Average (4yrs, 8 semesters)	349	NA	3.25	84.3	58.8

Two primary factors likely include a historically low class GPA for this course as well as the risk/reward nature of survival cards. As many studies show, course performance often correlates directly average course GPA. The added risk/reward inherent to the survival card policy may have been a factor since those that worked diligently throughout the semester had the benefit of having copious reference notes on the exam and performed very well, while those that did not were eventually penalized by not having the same amount of reference material. Another possible explanation that was not fully explored in this study is if preparation time may be better spent working example problems versus studying background information from the reading assignment. This approach could easily be implemented in the survival card policy and may especially benefit lower performing classes.

Figure 2 shows the results of daily time averages reported for each sample. The peaks in each figure coincide almost precisely with the lesson that homework assignments were due. For each figure, you will find that the number of peaks correlates almost exactly with the number of homework assignments for that semester. Additional peaks correlate with other graded events such as in class examinations or the design problem due date. Not surprisingly, this quantifies student's natural tendency to procrastinate. It also shows that students tend to only put forth effort into preparing for the course when it counts for a grade. The time reported in the valleys of Figure 2 is the most revealing for each method and is the primary explanation as to why survival cards were able to have such a higher class preparation time. The average times, especially for in-class quizzes when nothing was due on the syllabus were always close to zero. In contrast, when nothing was due for class using survival cards, students consistently spent at least 20 to 30 minutes completing the reading and filling out their survival card as opposed to doing nothing. This is perhaps the highest pay off for use of survival cards-to enhance student preparation when nothing is due for class. This allows students to keep up with the material and also come to class with at least a familiarity and working knowledge of the lesson which will likely lead to enhanced long term retention.

To better measure the effectiveness of using survival cards as a method to enhance student preparation, a comprehensive survey was given to students at the end of the course. The same survey was also given to a thermo-fluids course in the mechanical engineering curriculum to serve as a control sample that did not employ any special method to influence class preparation. Table 1 summarizes the sample size, average GPA's , average reported prep time by students that elected to take the survey and the actual time data for the entire course that the samples came from. The average GPA and class preparation time is what the students reported on the survey. Also annotated is the actual average GPA and class preparation time for the entire course for



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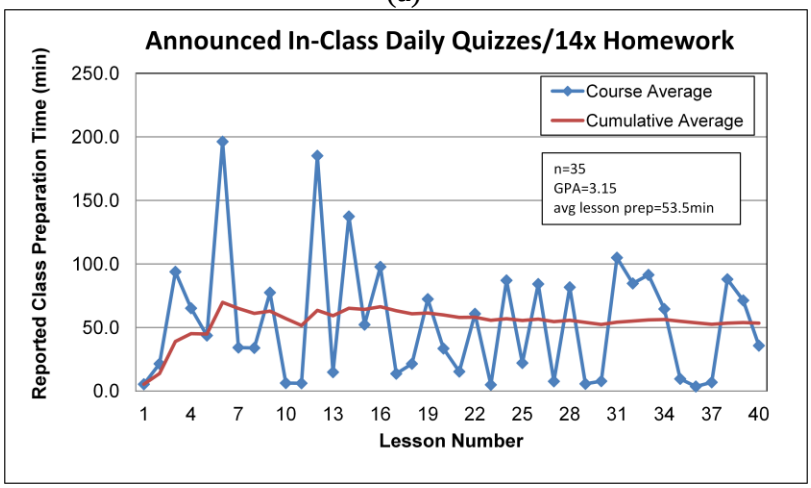

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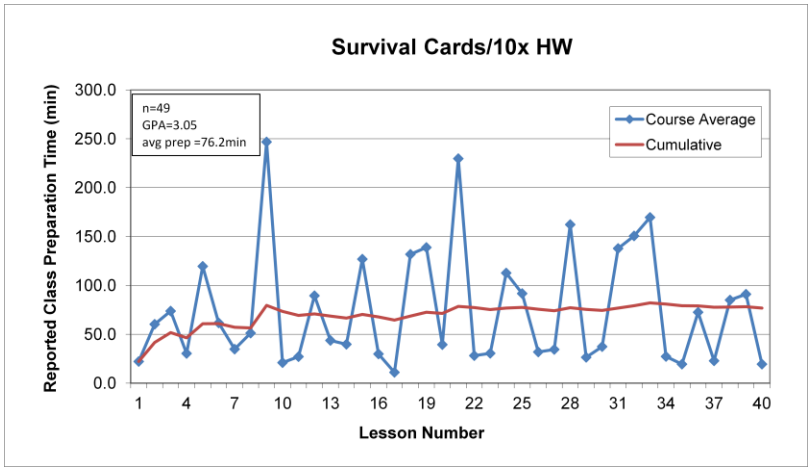

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Figure 2-Time data reported for three separate semesters of the same heat transfer course

comparison to what the students reported in the survey. Since this survey was taken on a volunteer basis, the students inclined to take it, especially for the control course not surprisingly have a high average GPA. The average GPA for the course using survival cards is also slightly higher than the average reported previously which suggests the students with the lower GPA's probably elected not to take the survey. As a result, this data set as a whole is a general reflection of better performing students. Interestingly, average preparation time that students reported on the survey is significantly lower than the actual time reported for the entire course. This is likely due to students not considering the high peaks in time data before graded events are due. Instead, their perceived time spent on class is likely a reflection of classes when nothing special was due.

Table 2-Summary of students surveyed

Sample Surveyed	Sample Size	Average Reported GPA	Actual Course GPA	Average Reported Prep Time (min)	Actual Course Prep Time
Control course	54	3.41	3.23	36.1	63.0
Course using survival cards	39	3.1	3.05	43.3	76.2

Encouraging students to complete lesson reading assignments, especially in technical engineering courses, is a common challenge for educators. Survival cards clearly cause students to utilize the course textbook. A recent study surveying college bookstores showed that about 20 percent of students do not even buy books![7] The reason that students do not complete the reading when they actually own the book is quite simple-they don't see any difference why they should or should not.[8]

The survey focused on assessing how many students are actually completing reading assignments, their general approach and their perceptions of whether it is beneficial or not. Figure 3 is a measure of how often the students used their textbook when preparing for class. Some teachers would probably be happy even if the students opened their textbook on a regular basis and quickly reviewed the material prior to or even after class. Results show a sharp

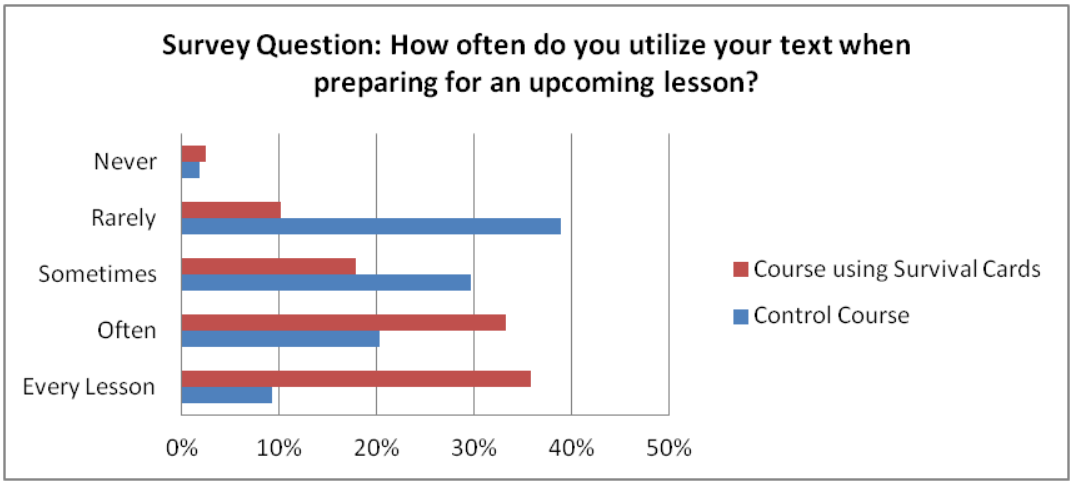

Figure 3-Text utilization when preparing for class

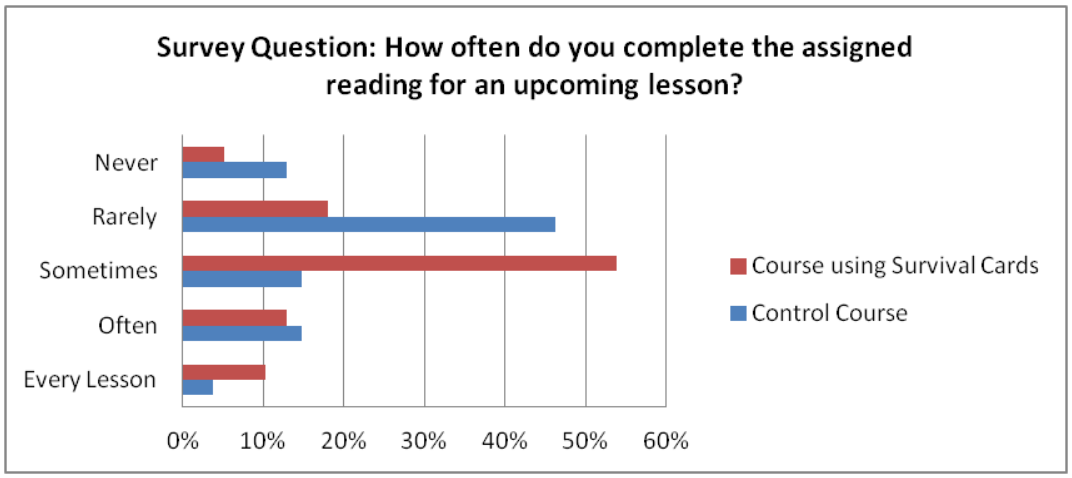

Figure 4-Reading completion rates

contrast between students required to complete survival cards versus those that did not in the control course. Approximately 41% of the students in the control course rarely or never utilized their text versus just 13% of the students using survival cards. Figure 4 measures how many students actually completed the reading assignments and just under 60% of students in the control course rarely or never completed the reading compared to just 23% of the students using survival cards.

Figures 5 and 6 explain the nature of student preparation outside of graded homework. The approach students take to completing reading assignments is generally similar, with slightly more students (67%) using survival cards that demonstrate active reading habits which are often essential to comprehend technically dense material. This is an objective of implementing the survival card technique, however it is not clear whether more students are active readers because of it. A surprising result from Figure 6 is how few students utilize lesson objectives to prepare for class. For both courses surveyed, detailed lesson objectives are painstakingly published for

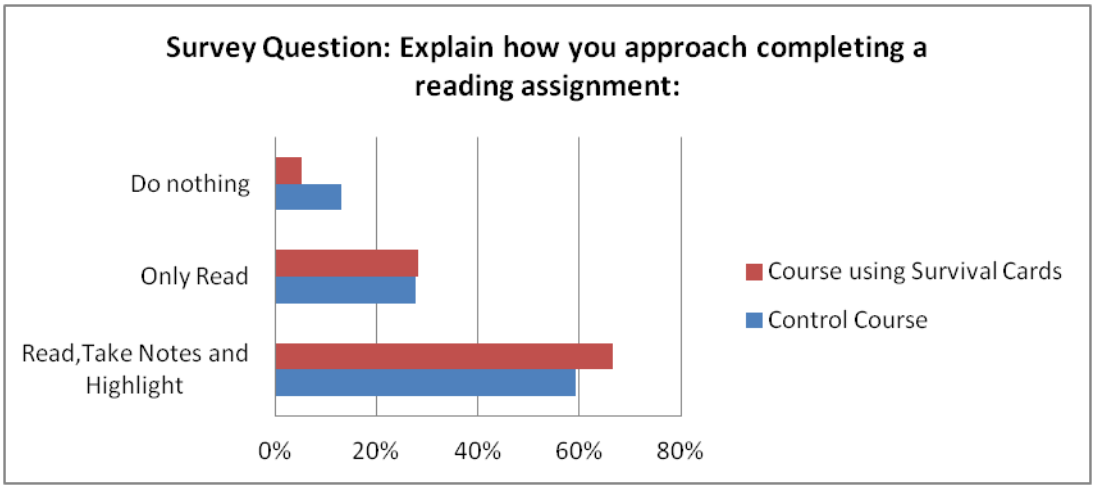

Figure 5-Student approaches to completing reading assignments

every single lesson that the class meets. Examinations are also directly written from these lesson objectives. In other words, students are essentially told in detail what they are responsible for every lesson (and therefore each exam). On average, almost half of the students from both courses never even pay attention to published lesson objectives! Students could easily benefit from studying lesson objectives by focusing their time during routine preparation and also reviewing prior to examinations. This could be easily influenced in the classroom by simply encouraging and reminding students about the importance of lesson objectives.

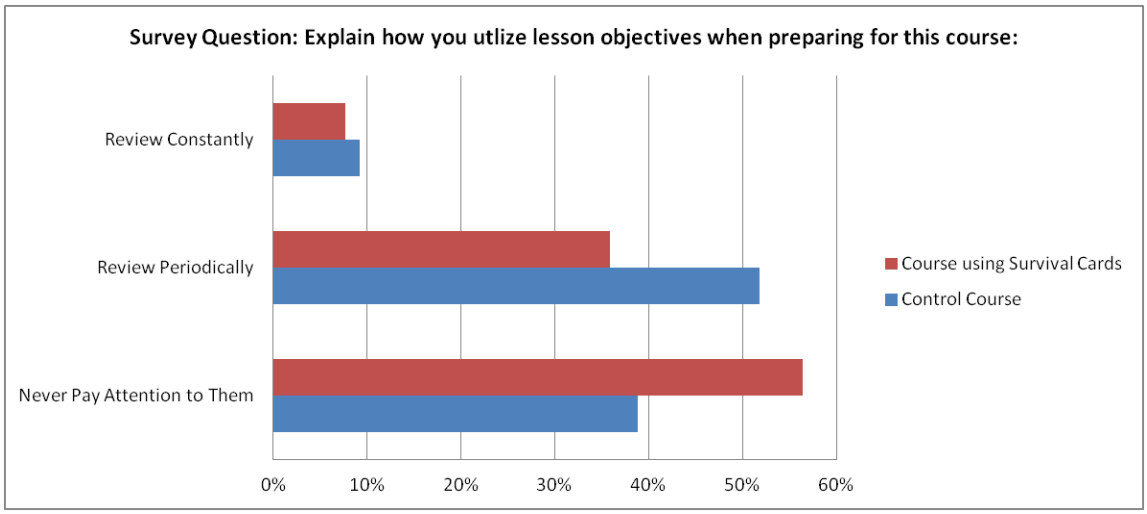

Figure 6-Student utilization of lesson objectives

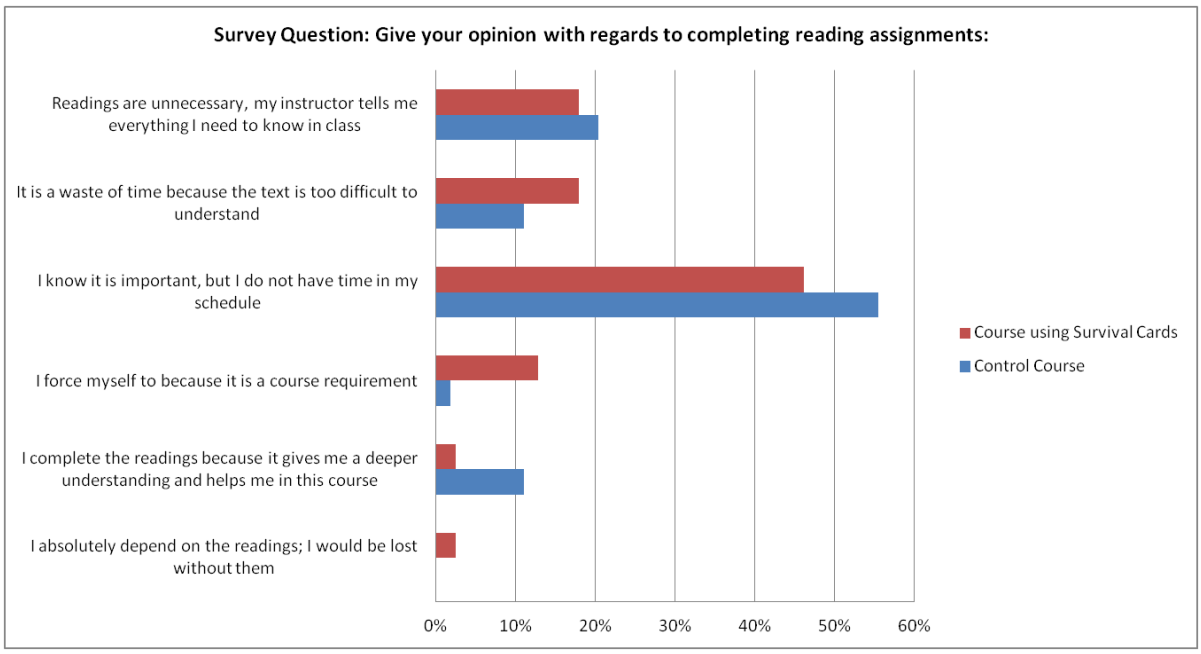

Figure 7-Student opinion of completing reading assignments

The final survey question (Figure 7) provides some insight into how students perceive the importance of reading assignments. The data is in general agreement between the samples with students citing not having enough time in their schedule as the primary reason for failing to complete reading assignments. It is not clear however if the competing demands are from other courses, external demands imposed by the institution or possibly other factors such as social pressures. Approximately 10% more students complete readings because it is a course requirement which is likely due to the survival card method. Interestingly, this percentage is still low (13%) which may suggest as the course progresses, many students may still not see the importance or value of completing reading assignments, even with the survival card requirement.

As a final qualitative form of assessment, students were asked in the survey to give their general opinion of the survival card method. Approximately 67% felt that survival cards enhance their preparation and learning outside of the classroom, while the rest (approximately 33%) said they did not think it was a good tool or that it needed to be changed. In a similar, more specific question, 28% of students felt that survival cards should be sustained as is and were an excellent tool, while 54% thought it was a good concept but needs some refinement. Approximately 18% of students felt that the method was not helpful and should be removed. Of those that felt the method should be refined, below are some of the commonly themed remarks:

It is great for the concepts that will be on exams, but I feel that there should be a reference card for the course because there are just too many equations.

Have a number of key equations and variables pre written on them so that we may focus our reading and notes around them.

It is a good idea but it gets a little much to do every lesson. Sometimes it just feels like I'm not learning anything just writing down the equations.

Allow students to use the book on exams as well. This will force them to use tabs and highlighting. It will also help students know where to reference things at in the book such as tables and figures.

Have them due at the end of class, instead of before.

I think that having the opportunity to submit a survival card for use as a reference on an exam is good but requiring them daily and often grading them ends up hurting me more than helping because that is the first thing to go if I have a lot of work to do for other courses the night before.

It is a good method especially for the tests because then it forces the students to open the text and actually figure out what the tables and charts as well as each equation means.

They are a good idea to get people to do the readings, and study the text, but I do not think that they should replace the text itself. I feel that learning to use engineering text books as a tool is the best way to demonstrate proficiency in a subject.

I feel that the survival cards would be better tool for taking notes in class and then going back to the book to write down equations that were not covered or examples that may be helpful.

Provide more guidance for what should be on them.

Sometimes I feel that the number of survival cards on any given test can be slightly overwhelming, but certainly manageable. I think the real problem will be cumulating all of them for the TEE. Having 30+ survival cards on the TEE seems as though it can be more detrimental than helpful.

If they were graded every time I would probably even spend more time on them. Sometimes I don't spend a lot of time on it because I feel that I will take the chance of having it not be graded. In addition, when they are graded they are graded fairly easily.

At times the material covered by a single survival card is too lengthy. It results in just copying down key equations (highlighted in the text) and generally skipping the readings thus missing important concepts. I would suggest having lessons where there are no survival cards due to help relieve some of the repetitive nature of them and focus more on concepts rather than key equations.

I think that they are overall good, but I do believe there needs to be some standardized reference card. Sometimes the survival cards seem worthless. However, they are good because they actually make me read some.

CONCLUSIONS

A method to enhance student preparation was successfully carried out in a senior level mechanical engineering course. This method is an overall effective approach to improve student preparation (i.e. complete reading assignments) as well as monitor preparation effort; however it may need some refinement depending on the course that it is being implemented in. As a warning, this technique may not seem too popular among students at first. However many will eventually learn the value of regularly preparing for class. With regards to implementation, it is highly recommended on the first day of class to provide a sample survival card filled out and a brief discussion of the policy. It may be worth considering more creative, positive incentives rather than punitive consequences (no reference material) to get more buy-in from students, especially for a course that is suited to be open-book. As an example, one modification could be allowing students to use their text on exams and if a certain number of survival cards are approved (e.g. 70%), they can use a one-page open note source on exams in addition to their text. It may also be worth considering how you want your students to focus their time preparing for class. For example, in certain courses it may be more beneficial for students to work problems versus spending time trying to comprehend background material and theory from a text. This should be addressed in the policy and revisited periodically throughout the course. As a final administrative note, depending on the class size, reviewing survival cards may become too laborious if the instructor to student ratio exceeds 1:50.

Specifically, the following conclusions can be drawn from this study:

- Influencing students to regularly prepare for class is possible with a relatively simple, self motivating technique called survival cards
- Students spent almost 30% more time preparing for class with the survival card technique compared to online homework quizzes and in-class quizzes on the reading
- Course examination grades may be lower due to the inherent risk/reward of the survival card policy
- Approximately 37% more students completed reading assignments for lessons as a result of using survival cards
- Even with a motivational policy to enhance preparation, approximately only one out of every two students allow other demands to take priority despite understanding the importance of reading and preparing for class
- The majority of students (82%) feel that survival cards are a good teaching tool, but it needs some refinement in implementation
- Providing positive incentives of completing survival cards, rather than punitive consequences (decreased reference material on exams) may be a better approach for more buy-in from students

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