Student Experiences and Preferences for Equation Sheets

Dr. Diane L Peters P.E., Kettering University

Dr. Peters is an Associate Professor of Mechanical Engineering at Kettering University.

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Abstract

Many instructors allow students to use equation sheets on tests, either provided by the instructor or constructed by the student. The length and format of such sheets varies, with some instructors providing or allowing more material than others, based on personal teaching philosophy as well as on the specific subject matter in the course. In this paper, equation sheets are examined in the context of a senior-level mechanical engineering course. Students were asked to fill out a survey and share their equation sheets from the specific class. In accordance with the approved IRB protocol, no personally identifiable information was collected, and students had the option to give a copy of their equation sheet to another instructor for safekeeping until the final course grades were submitted if they were concerned about identifying information that might be in it. Due to the small number of students in the course, data analysis relies heavily on qualitative data rather than statistical analysis. While the study is small in scope, it gives student perspectives on the helpfulness of different types of equation sheets, and provides insight to instructors when deciding on their own policies for equation sheets in their classes.

Introduction

Many professors, when discussing the tests they plan to give in a particular class, hear the question: “Do we get an equation sheet?” These documents may sometimes be colloquially referred to as “crib sheets” or “cheat sheets” as well. Whatever the name may be, their purpose is to assist students by providing equations to them on a test, to reduce the burden of memorization. This is often an expected practice, as engineering features many different equations, tables of data, and constants that practicing engineers can easily look up, and it allows students to focus their study time on the most important things, i.e., learning how to appropriately use the equations, data, and constants. These equation sheets are made up by the professor at times, at other times students have the option to make up their own, and some instructors use a hybrid approach where they supply some information but allow students to make up their own equation sheets as well.

Equation sheets appear as a topic, in passing, in many different papers, although they may not be the primary focus of those papers, and in fact may be mentioned very briefly (e.g., [1], [2], [3], [4], [5], [6], [7], [8], [9], [10], [11], [12]). One work mentioned them as not being allowed on a specific assessment [13], and a few mentioned specific lengths or other requirements. A single page of equations was allowed in [14], [15], and [16], with [16] specifically indicating that the equation sheet was produced by students and was restricted to only equations, not example

problems or definitions, although in that case students were also provided with material from the FE reference manual. The FE reference manual was also used as a resource in [17], although in that case the accompanying equation sheet was produced and supplied by the instructor. A two-page instructor-provided sheet was provided in the work described in [18], and instructor-provided equation sheets of unspecified length were called out in [19], [20], [21], [22], [23], [24], [25], [26], [27], [28], [29]. Students were allowed to make their own equation sheets in the work cited in [30] and [31]. Advantages and disadvantages of student-produced versus instructor-provided equation sheets are not well studied, although in [32] a student specifically mentioned that preparation of the sheet assisted in studying. However, in [33], the possibility of a student forgetting to write down an equation needed on their equation sheet and thus not having it on the test was raised.

Some research has addressed deeper questions of equation sheets, their advantages, and their possible down side, with [34] indicated that students trying to transfer knowledge from calculus to physics and later to engineering relying heavily, perhaps too heavily, on equation sheets. In [35], a student reflection mentioned looking on the equation sheet to find something with the right variables in it to use for a problem. Equation sheets, even when made up by the student, were seen as a source of authority in [31], and [36] also speaks of students' heavy reliance on equation sheets to solve problems. The possibility of over-reliance on equation sheets was noted in [37] as well, and to a lesser extent in [38], with [39] describing them as a possible source of knowledge in problem-solving but not making any judgments on whether they are good or bad. Overall, despite their frequent use in the classroom and the many passing mentions of them in the literature, there is no well developed body of knowledge on equation sheets, either from the student or the faculty perspective.

Methods

The study was conducted by means of a survey, implemented via a Google Form, with the link for that form sent to all students in the researcher's Dynamic Systems 1 course sections. In accordance with the protocol approved by the IRB, no identities were collected, nor was identifying information requested. The survey did ask students to supply a copy of their equation sheet, but they had two options for how to do so. In one option, they simply uploaded it to the form. However, considering that some students might be concerned that the professor would remember their handwriting if they saw the equation sheet immediately after grading their tests, students were given a second option. In that option, they assigned a code name of their choosing to the equation sheet, and gave the code name in the survey. They could then give the equation sheet with that code name attached to another professor, who had agreed to hold any equation sheets given to them until after the term had ended and supply them to the researcher at that time. No students chose that option, however.

While the number of responses was tabulated for quantitative data, the data analysis focused primarily on the qualitative data, with the comments providing a wealth of insight into students' thoughts and attitudes. In addition, eight of the nine responses included an equation sheet, and these eight were analyzed. The analysis focused on key topics covered, the length of the sheet, whether or not color was used on the equation sheet, and whether it was handwritten, typed or

computer generated, or some combination.

Findings

The survey had a low response rate, with only nine students out of a total of 65 responding, for a response rate of 13.8%. This may be due to concerns over their handwriting being recognized on the equation sheet, or simply due to students being busy and not seeing the benefit in answering the survey. While this results in an inability to do any serious statistical analysis of results, qualitative analysis of the equation sheets in question is still of value, and the general trends in the quantitative questions is suggestive of things that should be further investigated. Each question, along with its results, is given here individually. Due to the very small number of responses, no cross-correlations were analyzed.

Q1: Thinking about tests where you are allowed to use an equation sheet of some form, what do you think is the best approach?

This question presented students with six options, with a chance to elaborate on their answer. The choices presented were

1. I prefer when the professor provides an equation sheet, and students do not prepare anything of their own for the test.
2. I prefer that the professor provides some resources, but also students are allowed to prepare some materials of their own.
3. I prefer that the professor does not provide anything, and students prepare their equation sheet.
4. My preference depends strongly on the class itself.
5. My preference depends strongly on the professor.
6. My preference depends strongly on both the class and the professor.

Six students chose the option “My preference depends strongly on both the class and the professor.”, two chose “I prefer that the professor does not provide anything, and students prepare their equation sheet.”, and one chose “My preference depends strongly on both the class and the professor.” Four students chose to elaborate on their answer, as given below.

> Student 2: I think the best is when a student needs to prepare their own equation sheet but the professor offers a review session which highlights any important topics/equations that should be included
>
> Student 3: Oftentimes creating my own equation sheet equates to study time. However, basic things like quadratic formula, lagrange, etc., which are not the primary focus of the course, should be provided
>
> Student 7: I cannot trust an equation sheet provided by a professor because for the first test I forgot he was giving an equation, so I memorized the equation when I

didn't need to because the equation sheet was great. the next test also had a given equation sheet that was absolutely useless, like half of the equations that I wanted.

Student 8: I think it is best when students are provided with certain resources (basic equations, basic information like constants), and know that ahead of time. However they can also prepare more advanced notes such as how to derive from a basic equation, or more advanced forms of equations. I think this is a good balance between preparing for the test (inadvertently studying) and not having to worry about very basic information that may not fit on one or two sides of an A4 sheet with lots of other information.

Q2: What do you think is the best length for a student-created equation sheet?

This question probed students' views on the ideal length of a student-created equation sheet, with three options provided as well as an "other" choice. These choices were

1. One 3" x 5" notecard
2. One sheet (single side) of 8.5" x 11" paper
3. One sheet (both sides) of 8.5" x 11" paper

Six students indicated that the best length was one sheet (both sides) of 8.5" x 11" paper, one indicated that they thought one sheet (single side) of 8.5" x 11" paper was best, and two students chose the "other" option. One of them said that "It depends on the class, but typically 1 side of an 8.5" by 11" peice (sic) of paper." The other stated, "I don't think it matters, what ever you think you need will be put on it no matter the size".

Q3: If a professor is providing some resources, what should they provide?

The next question asked students about what resources they would like professors to provide. This question allowed students to choose multiple options, if desired, and had an "other" option provided. The options given were

1. Tables of physical properties and/or mathematical transformations (e.g., Laplace transforms, trig identities, etc.)
2. Key equations
3. Checklist of things to remember to check

Seven students chose "Tables of physical properties and/or mathematical transformations (e.g., Laplace transforms, trig identities, etc.)", five chose "Key equations", four chose " Checklist of things to remember to check", and one chose "Other". The student who chose "Other" did not elaborate there, but was one of the four students who elaborated on their answer. The students' free responses are given below.

Student 2: Transforms and other tabular knowledge is best when provided so the student doesn't have to waste space ensuring they have it all and the professor can make sure that information that is actually needed is included for the exam

Student 4: Anything that lets me know what to study so I'm not blind-sided by something on the test. Like giving 40 problems to 'study' when they take about 30 minutes each, then only giving 4 on the test with no questions on concepts.

Student 7: if they are not allowing an equation sheet, they better be providing one. memorizing equation sucks

Student 8: Two sides of one A4 sheet provides the best amount of space for students without needing to cram things onto a page like a notecard (bad vision = bad notecard...) I also think that providing things like basic properties (LaPlace table, trig identities, thermo tables, properties of air, important constants, and potentially SOME basic forms of equations) allows the student to focus on course specific knowledge when preparing, and not memorizing trig identities... I know I prefer when this basic information is given, so I do not stress about remembering math, and rather can focus on the important content of the course I am preparing for.

Q4: How do you go about making your equation sheet(s), when student-created equation sheets are to be used? Please describe your process for selection of information and how you organize it.

This question was an open-response question, investigating what students' processes are for producing equation sheets when they are making up their own. The student responses were as follows:

Student 1: If I know absolutely nothing about what will be on the test, I go through my notes and try to put down the main ideas / equations I might need. If I can expect the topics on the test than it narrows it down even more and I am able to put what I need and feel more confident without having to memorize. I usually put a box around each topic on my equation sheet.

Student 2: When making my equation sheets for classes I: 1) Write out all of the information that may be relevant ie. review notes, lectures, and textbooks for content/equations relevant to the exam

2) Organize the information by topic and ""use case""

3) Handwrite equation sheet from organized information from step 2 "

Student 3: I go through each class example day-by-day and pick common equations and formulas used in the classwork

Student 4: I usually look over class notes and lectures, if recorded (because some professors don't record), and go through chapter-by-chapter and write down any equations we used in class or in problems. Then I go through and add anything I feel I will forget because of the stress of the exam.

Student 5: I start by reviewing notes, highlighting key equations and points. I then work through example problems to ensure that the equation sheet is adequate, and to verfiy (sic) that no other material needs to be added.

Student 6: I look through lecture notes and pull the key concepts from each class period.

Student 7: I go through the notes and practice problems and write down what looks/is important

Student 8: After checking what content will be covered, I read through my notes completely once, and sometimes other resources given by the professor.

Then I go ””chronologically”” by topic that we cover in class and section my equation sheet as such. I try to fit the most important equations, along with notes of important concepts to remember when working with said equations, as well as any rules (different damping ratio value meanings and what damping they result in).

I either put a basic equation and how to derive it (this was more useful in Fluids), or the already derived forms of equations (dynamics/solids and similar classes).

Student 9: I just read down all my notes from the class and pull relevant equations we used onto my sheet of paper

Q5: To what extent do you feel the process of making an equation sheet helps you study?

The next question addressed students' experiences with the production of equation sheets and their studying for tests, and asked them to give a rating on a five-point scale, where five indicates that it helps a great deal and one indicates that it does not help at all. Eight students gave a rating of four, while one gave a rating of five, for an average of 4.11.

Q6: Do you work with other students when making up equation sheets for a test?

Students had the option of choosing "Yes", "No", or "Sometimes". Most students worked alone, as shown in Figure 1.

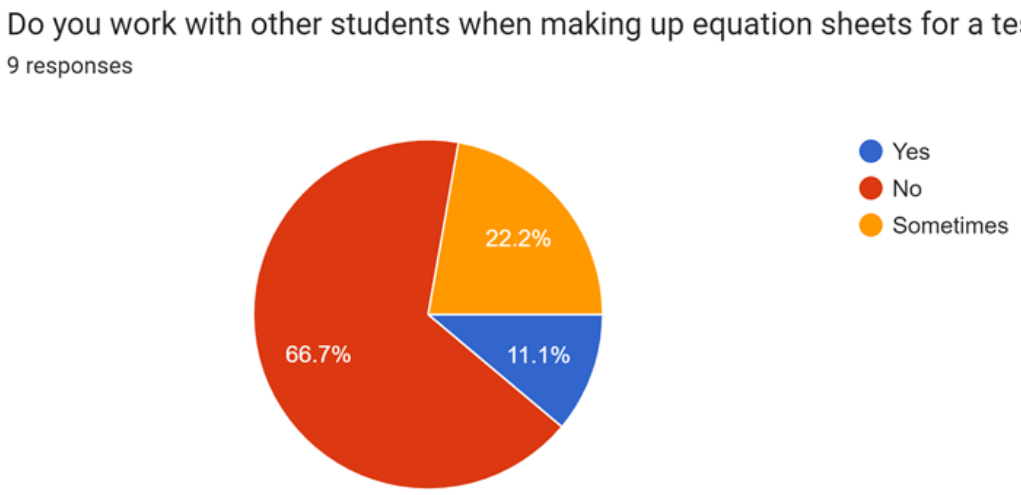

Figure 1: Students Working with Others on Equation Sheets

Q7: Do you prefer to hand-write your equation sheets or to generate them electronically and then print them out?

Students were then asked about their preference in how to produce their equation sheets. They were given three options, in addition to an "Other" option; these options were:

1. I prefer to hand-write them.
2. I prefer to generate them electronically.
3. I have no preference.

Five students preferred to hand-write them, two preferred to generate them electronically, and one reported no preference. One student selected "Other", and stated that their preference was "They are "hand-written" on my tablet, then printed. I try not to type." Students were further asked to explain their preferences, and the responses given were as follows:

> Student 1: Hand writing although takes longer, it is easier and quicker when making changes. I can also fit more on the sheet.
>
> Student 2: Handwriting helps me remember what I have and where it is better than a typewritten sheet. In the event that I need to include "tabular data" I type those sections to ensure neatness and compactness that handwriting usually doesn't afford.
>
> Student 3: When i write electronically, i learn less and get distracted
>
> Student 4: I don't have a preference; I just do whatever is easiest so making tables is easier on computer but if there are a lot of equations then using paper is easier because I don't want to use word or Google docs for that.
>
> Student 5: I take my notes electronically. Electronically genergated (sic) equation sheets are easier to read than hand written equation sheets.
>
> Student 7: It helps me remember what is on the equation sheet better and its faster than finding a printer
>
> Student 8: Hand writing (technically re-writing) my notes and equations helps me solidify what is important. It also helps me remember some equations or info without even needing to look at the sheet. It is a nice review of things covered earlier in the term.

Q8: Thinking about the MECH 330 Test #1 specifically, how effective do you think your equation sheet was at helping you perform on the test?

This question was an open-ended one, with students able to describe their views on the effectiveness of the equation sheet in this specific class. Responses indicated that the equation sheets students produced were quite effective, with the effectiveness varying on different parts of the test.

> Student 1: My equation sheet was effective as I knew where everything was on my sheet that I needed.

Student 2: The equation sheet had a minor impact on my test success primarily just information on the coefficients of damping and the sizes of xdot=ax+Bu matrices.

Student 3: Moderately so. Moreso (sic) for the multiple choice portion

Student 4: It helped me some but a lot of the stuff I wrote down was not relevant and I forgot some stuff.

Student 5: I think my equation sheet was very effective.

Student 7: I would have had to put many more hours into studying to memorize the things I put on it

Student 8: I definitely forgot to put some things on it that would have been nice, however overall it greatly helped me review concepts and methods.

Student 9: I feel it helped a lot, other than the potential for forgetting an equation, which I actualy (sic) did, it was extremely helpful especially for the extra credit portion

Q9: Is there anything else relevant to your views on or experience with equation sheets that you'd like to share?

Student 1: I like when professors give sheets that not only have key equations, but label the equations and what topic to use them for. It makes it easier when some equations carry over to other topics. I also like when the professor gives us the sheet and then we can add anything extra to help us get through problems efficiently to make time for more difficult problems.

Student 3: If I am behind on the class / dont (sic) understand it fundamentally, a bunch of equations on a notecard will not help me. Equation sheets should be a vehicle to study, but not so much that the performance of an exam depends on them.

Student 4: I like bigger equation sheets because I don't like to write small, like on a notecard; it makes my hand cramp a lot.

Student 5: When professors provided equation sheets that are in adequate (sic) it increases my stress level when studying and taking the test. When in a testing enviroment (sic) is easy to miss write a formula due to the stress.

Student 7: Why can't all my professors be like you.

Student 8: Completely student made equation sheets are usually a good tool to study.

Completely professor made equation sheets allow students to know what to expect on the exam.

A mix of both is, I think, the best way to be prepared for an exam while also getting study-time by creating your own.

A nice thing that I have seen is that some professors provide a nice equation booklet AND allow students to add their own notes. This isn't always ideal, but it was nice.

Analysis of student equation sheets

In analyzing the eight provided equation sheets, it was found that most of the students did not use the full space allocation. In this class, students were allowed to use any notes they could produce on both sides of one 8.5" x 11" sheet of paper. The equation sheets were categorized by whether they used approximately one-quarter of the space or less (half a page), between one-quarter and one-half of the space, between one-half and three-quarters of the space, or between three-quarters and the full space allocation. Results are shown in Table 1.

Table 1: Space Usage on Equation Sheets

Space Usage (percentage)	Number of Students
0 - 25%	0
25 - 50%	3
50 - 75%5	2
75 - 100%	3

Next, the content of the equation sheets was examined. In this class, students were not subject to restrictions on what could be on the sheets, as long as they produced it themselves; in other words, they could not simply use screen captures from the professor's notes that were posted on Blackboard, but could choose to re-write those notes themselves if they wished. It was found that the content of the sheets could be categorized into four key areas: equations, graphs and diagrams, definitions and procedures, and example problems. The number of equation sheets with each type of content is shown in Table 2. As one might expect in an engineering course, equations appeared on all of the sheets, with other content varying by students; the second most common type of content was definitions and procedures.

Table 2: Content of Equation Sheets

Type of Content	Number of Students
Equations	8
Definitions and Procedures	7
Graphs and Diagrams	3
Example Problems	2

Most of the equation sheets were completely handwritten, with seven of them produced entirely by hand. One equation sheet combined typewritten material and handwritten material, with none of them completely typed or computer generated. Two of them, the one containing some typewritten material and one of the completely handwritten sheets, utilized color; the remainder were written in a single dark color (black pen or a standard gray pencil).

Discussion

In examining the findings from this study, it was found that students seem to have a strong preference for equation sheets that they have a part in producing, and that they see value for their

study process in producing them. Many of them report that they go through their notes as they produce the sheet(s), which also serves as a part of their review. Both the reported content that they would like professors to provide when they are given an equation sheet, and the analysis of their own sheets, suggests that equations are a major item that they expect and need to have, in order to avoid the need to memorize them. They do acknowledge, however, that it is possible to forget equations on their own sheet, which argues in favor of the professor having some role in producing the sheets. As one student noted, this also helps students to know what to expect on the exam, as it shows what the professor believes is important.

Additional content that students find useful is definitions and procedures, followed by graphs and diagrams, as displayed on the sheets that were analyzed. The relative usefulness of graphs and diagrams can be expected to depend very heavily on the specific course, with some classes relying much more heavily on graphical data than others, and thus the content of these sheets is not necessarily generalizable to all classes. The relative scarcity of example problems on the sheets suggests that students do not usually find examples helpful on the test itself; this may align with one student's comment about equation sheets not helping if they do not understand the course material to begin with.

Most of the students feel that the length of the sheet should be both sides of one piece of 8.5" x 11" paper; however, the majority of them did not use that full length in their sheets, with five of the eight sheets analyzed using less than 75% of that space (i.e., 1.5 pages of length or less). This suggests that having the extra space has the purpose of making sure that they do not run out of space, and that there is no need to write extremely small, in line with one student's comment about the concern over a small notecard and bad vision.

These results suggest that professors who allow equation sheets in their classes should engage students in the process of producing them, both so that they know where to find material (in line with some students' comments about knowing where everything was) as well as due to the impact on their own studying. Some of them may put limitations on what can be produced on those sheets, e.g., disallowing example problems, as was noted in the literature; however, as few students put these problems on their sheets, this is not a limitation that is likely to be of much concern to students. This also aligns with the study procedure for the Fundamentals of Engineering (FE) exam. As noted in the literature, a few professors allowed the use of material based on the FE reference manual, which contains items such as equations but does not allow example problems.

Limitations

In applying these results to their own classes and teaching practices, one significant limitation of the work is the small sample size in the study, which does not allow for large-scale statistical analysis of the quantitative data gained from the survey. Furthermore, the work is limited by the specific population of students who opted to respond to the survey. In a question asking about student scores on the specific test for which the equation sheets were produced, all but one of the respondents reported that their exam grade was 90% or higher, with the one student whose test score did not fall into that range scoring between 80 and 90%. This is not a representative population, with no students who scored in the C range or below filling in the survey. Therefore,

the conclusions reached may change in a future study that includes a more academically representative sample. A further limitation is that the study was conducted in the context of a single class; while some of the questions were more general, the specific equation sheets examined were all from that one single class.

Future Work

A larger, more comprehensive study should be conducted, with the goal of gaining a clearer picture of students' experiences with equation sheets. Such a study should include a greater variety of classes, which would capture different types of course content. In addition, a concerted effort should be made to recruit participants who fall into all ranges of academic achievement.

An additional study could be conducted to learn about faculty perspectives on equation sheets. At this time, no comprehensive study has been performed that would provide data on what resources faculty typically provide to students, what they allow students to produce or provide for themselves, or what their attitudes are about what should or should not be provided and why. Such a study would also be a useful addition to the literature.

Conclusion

Despite the limitations in this work, it is a useful beginning at obtaining a clear understanding of equation sheets and other exam references that are created or provided by students or professors. While much work remains to be done, the information in this study suggests ways in which professors can use equation sheets for exams to enhance student learning and help prepare students for their future studies and careers, in which their focus will be on the use of material and not the memorization of equations. As future work is conducted, it can further inform faculty on how to best structure their policies on equation sheets and exam resources to achieve the goals of their courses.

Acknowledgments

Professor Kristy Brinker-Brouwer is thanked for her assistance in serving as a conduit for students to anonymously submit their hardcopy equation sheets.

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