A Quantitative Case Study on Students' Strategy for Using Authorized Cheat-sheets

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***Abstract*—Traditional formal tests are usually given in a time-limited, closed book/notes style because instructors believe this approach measures students' learning. Nonetheless, other researchers argue that there are better alternatives and allowing students to use authorized cheat-sheets is one of them. The most important reason for allowing cheat-sheets is to help students to focus more on greater understanding and deeper learning. However, some researchers have questioned the efficacy of authorized cheat-sheets in formal exams. While it might be true, in some cases, that authorized cheat-sheets function like "crutches" in exams, we should not ignore that they are also learning tools. To make the cheat-sheets, students need to read the class material, process information actively, and select, organized, prioritize the content for the cheat-sheets. Our earlier research showed that in an undergraduate engineering course, the quality of students' cheat-sheet is strongly positively correlated with the students' performance on the exams. Moreover, the quality of the cheat-sheets improved through the sequence of exams during the semester and the students' grades did likewise. In this research, we collected more than 300 cheat-sheets from two sections of a graduate course on the same subject as our previous research. The class design of the graduate level course is similar to the undergraduate one but it covers more conceptually difficult topics at a greater depth including theory and proofs. We use the same cheat-sheet rating scheme and compare the quality of graduate students' cheat-sheets with the undergraduate students' on multiple dimensions including density, organization, number of sample answers, number of formulas and number of graph representations. We discovered significant differences between the graduate and undergraduate students' use of and how to best create authorized cheat-sheets and formulate useful directives.**

Keywords—authorized cheat-sheet; examination; cheat-sheet quality; learning strategy

I. INTRODUCTION

Authorized cheat-sheets (some researchers prefer to call them "authorized crib sheets") refer to additional notes that a test taker is allowed to create beforehand and use in the formal exam. By definition, instructors make regulations for the authorized cheat-sheets such as they must be hand-written or are limited to one side of a standard paper. If there are no restrictions, then an exam with cheat-sheets is essentially an open note exam which is another alternative to open book or cheat-sheets.

Some instructors and researchers have reported findings which support the efficacy of a cheat-sheet policy. Allowing students to use cheat-sheets in formal exams can reduce test anxiety of students [1], which thereby, can increase the validity of exams [2]. Anxiety related to formal exams among students is common. Memorization for exams that require formulas is a proven source of this anxiety [3]. The essence of mathematics-related, single-correct-answer exam questions and time stress during exams can further exacerbate the anxiety [4]. Researchers report that students who have difficulties remembering formulas had less anxiety when they were provided "safety nets" such as cheat-sheets [2].

Another advantage of cheat-sheets on formal exams is that students could concentrate more on learning and understanding the material [2]. Since there are restrictions on cheat-sheets, e.g. they must be hand-written within a given size, test takers have to learn, evaluate and prioritize the material [5]. This cheat-sheet preparation process itself requires test takers to do the reading, actively process the information, choose which material to keep on cheat-sheets and how to organize the information [6, 7]. This cheat-sheet preparation process should, and our results show does, help test takers with meta-cognition and subsequent performance in the exams.

Some instructors and researchers, on the other hand, are not positive about authorized cheat-sheets. A common criticism of authorized cheat-sheets is that, after being relieved from excessive memorization, students do not take the second step to focus on higher level learning. Instead, they study less than they would without cheat-sheets [8]. For this research, we also collected the time students reported they spent on preparing content for and then making the actual cheat-sheets.

Another common challenge to authorized cheat-sheets is that test questions will be more difficult or focus more on higher order thinking. Hence, authorized cheat-sheets do not help grades as much as students expect [9]. Some researchers also reported that more students stopped using cheat-sheets as the semester progressed [8]. In this research, on the reverse side of each cheat-sheet, we collected students' rankings of its usefulness for learning and for doing well on the exam and we analyze this data.

II. BACKGROUND AND METHODOLOGY

We collected cheat-sheets and exam grades from two sections of a 500 (graduate) level computer networking course at North Carolina State University. We carried out a study on

students' usages of authorized cheat-sheets last year on the undergraduate computer networking classes. Though the undergraduate and the graduate classes are taught at significantly different levels, they were taught by the same instructor with similar class policies. The classes had common materials but the graduate class included probability, performance modeling and proofs, more in-depth explanations and more systematic reasoning.

A. Class setting and data collection

There were 111 students in this graduate course. The two sections were taught in the same semester by the same instructor. There were 59 students in the undergraduate classes.

The class configurations of the graduate and undergraduate classes were similar in many aspects:

- There were two midterms and one final exam spaced at approximately ⅓, ⅔ and the end of the semester.
- Each midterm exam had approximately 20 questions split roughly evenly between computation, explanation, and more subtle why problems.
- Midterm 1, 2, and Final tested the knowledge covered in their respective 1/3 of the class but the final was comprehensive and had about 35% review material.
- The midterm exams were allocated 85 minutes and the final exam 180 minutes.
- The computation questions frequently reflected homework questions but were significantly different.
- There were subtle why problems which students had not seen in their homework to test understanding.
- The exams were designed to use the full exam periods.
- Students were allowed one signed hand-written single-sided cheat-sheet (8½ × 11 paper) for each midterm exam. They could also bring the first two cheat-sheets to the Final.
- The graduate class had more theory, proofs, and harder problems.

The students were required to submit their cheat-sheets with the exam papers. The teaching staff marked all the cheat-sheets with special pens so that students had to use the same cheat-sheets in the comprehensive final exam. The class policy prohibited backfill of earlier cheat-sheets, which was enforced by our cheat-sheet markings. Students turned in all cheat-sheets with the final exam. The final was not returned but a few (8) graduate students retrieved their cheat-sheets for use in future courses. We collected 323 cheat-sheets in total.

Students in the two graduate sections took the identical midterms together and there was a two-day gap between their final exams. The teaching staff created two distinct final exams. It turned out that the medians of grades for the final exams from the two sections were nearly the same. The exams for the undergraduate classes and the graduate sections were of comparable difficulty considering the level of the students. For consistency, in case the exams were not really of the same difficulty and to make the results comparable between the undergraduate and the graduate classes, we normalized exam grades by scaling to the same median (85) of undergraduate class 1 exam 1 just as we did in [5]. For example, the median grade for graduate midterm exam 1 was 87. To make the grades comparable, we modified the grades for the graduate midterm exam 1 for this research by multiplying each grade by 85/87. The grades on the midterm exams were always 100 points and the finals were 125 (graduate) and 150 (undergraduate). On all of these exams, there were a few points of extra credit possible. The scaling put all of the exams on the same grade scale. However, it must be noted that the scaling and extra credit did produce some grades over 100.

Additional information we collected from the graduate class included:

- dates they started making notes preparing for the cheat-sheets
- dates they started preparing the cheat-sheets
- number of hours they spent preparing the cheat-sheets
- on 5-point Likert scale, how useful they thought the cheat-sheets were as a learning tool
- on 5-point Likert scale, how useful they thought the cheat-sheets were in the exams.

These questions were printed on the reverse side of the cheat-sheets. Students could answer most of those questions before the exams except for the last one. After we collected the cheat-sheets, all responses to these questions were tabulated. Invalid answers were removed; e.g. one student claimed that he started preparing a cheat-sheet on Jan. 1st 2015 but this course was offered in fall semester.

B. Cheat-sheet rating scheme

For this work, we continued to use the five features of our previous successful cheat-sheet rating scheme [5] but please note that the scales have shifted to be all positive:

- density scale 1 - 3
- organization scale 1 - 3
- number of sample answers scale 0 - 1
- number of formulas scale 0 - 1
- number of graphs scale 0 - 1.

Density was tagged using the Likert Scale, namely, from "very sparse" to "very dense". However, the rating of organization was more subjective so the rating in Likert Scale was harder. So we rated organization in three different levels, namely "well organized", "moderately organized" or "poorly organized". For the remaining three features, we did not rate them but counted the numbers of sample answers, formulas, and graphs. The "best" cheat-sheet score possible is 9.

Cheat-sheets were rated by the two course TAs. One worked as TA for this course for three consecutive academic years and the second was a TA only for this graduate course. A training phase was done to make sure they had similar rating standards.

The training was on the cheat-sheets from the first midterm of one section (52 total). The Cohen's Kappa on rating density and organization was 0.69 and 0.91 between those two TAs.

After tagging the cheat-sheet density, we did exactly as we had done for the undergraduate course and assigned 1 to "very dense" and "very sparse", 2 for "somewhat dense" and "somewhat sparse", 3 for "moderate density". The graduate course covered more material but we still argue that cheat-sheet is a memory aid so students do not need to write down complete information as long as they have a good understanding of the material. From our past teaching experience and observations on cheat-sheets collected, students with a solid grasp of a topic tend to write down key words or important aspects for the topic instead of a complete discourse. Really dense cheat-sheets do not indicate a good understanding. Also, students, on average, start to prepare the cheat-sheets one or two days before the exams thus creating a very dense cheat-sheet could take too much time away from exam preparation. We also gave low scores to very sparse cheat-sheets because they indicated that the students either did not have enough time to prepare for the exam or were not able to find the important topics to write down. This could also indicate that students did not make notes on the important topics earlier.

We assigned 1, 2 and 3 to "poorly organized", "moderately organized" and "well organized" cheat-sheets respectively. A poorly organized cheat-sheet indicates the student did not have a clear idea on how to organize the information effectively or how much content (s)he would have on the cheat-sheet. Poorly organized cheat-sheets also make material harder to access during the exam and potentially makes the student more anxious.

A cheat-sheet receives 1 point if it contains fewer than twice the median number of sample answers. If the median number of sample answers is 0 for that exam, then cheat-sheets having 0 or 1 sample answers received 1 point. We found that the students who wrote down many sample answers usually performed poorly in the exams. Though we give students answer keys to all the homework questions, using the homework answer keys as the main study material was not encouraged by the teaching staff. A student cannot understand or have enough depth or breadth of coverage if (s)he relies mostly on homework answers on cheat-sheets. Plus, we never repeated any homework question on exams.

We also assigned 1 point if a cheat-sheet contains fewer than twice the median number of formulas or complete graph representations. In the graduate class, more formulas (roughly twice as many as the undergraduate class) were taught in lectures, but we argue that the students with good understanding do not need to refer to *basic* formulas. If a student needs to refer to the cheat-sheet for the simplistic and intuitive formulas repeatedly during an exam, (s)he may not have enough time to finish. In the graduate class, more than 100 graphs were presented due to the coverage of performance modeling. Knowledge was needed on a deeper level and most graphs were not useful in exams. Too many graphs also limited space for other topics. If no cheat-sheet is submitted, then the total cheat-sheet score is a 1 and is recorded as such.

For each exam, we divided the students into two groups: more competitive students (MCS) group if their exam grades were at the median score or above and less competitive students (LCS) group if their grades are below the median.

III. Data Analysis and Experiment Results

Now we analyze the data collected for this research and compare it with the data we collected earlier from two undergraduate classes on the same subject. Fig. 1 and 2 show the distribution of the exam grades and cheat sheet scores of the graduate class and undergraduate classes. Exam grades and cheat-sheet scores are distributed in a nearly normal fashion. However, the undergraduate exam grades and cheat-sheet scores have more variance than the graduate class.

All grades given are raw scores normalized by the same median value of 85. Graduate grades should be higher and less dispersed due to the grading structure of A B C for passing. We see that is the case. In addition, we also find that on average the graduate students got higher cheat-sheet scores. This indicates that the graduate students may have better ideas on how to use the cheat-sheets on the exams or are just more motivated.

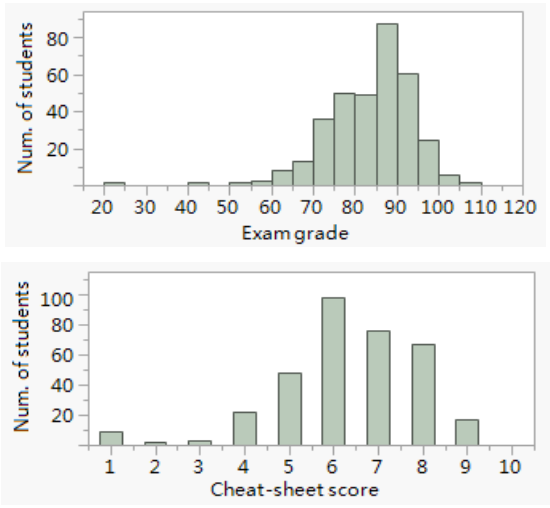

Fig. 1. Distribution of exam grades and cheat-sheet scores for graduate class

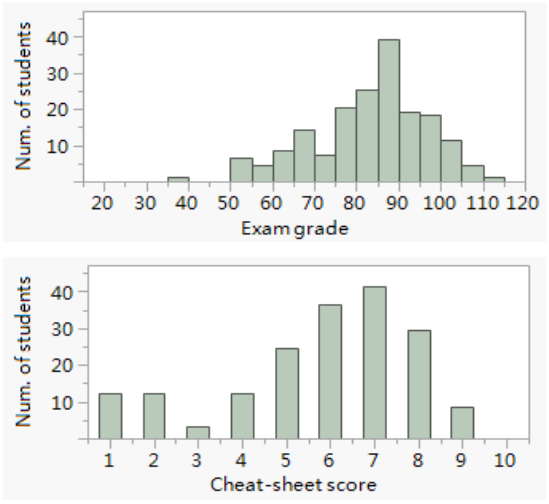

Fig. 2. Distributions for exam grades and cheat-sheet scores for undergraduate classes

A. *How docheat-sheet scores related to the exam grades?*

We now determine if there is any difference in the cheat-sheet scores between the MCS and LCS groups, and if there is a difference, how are cheat-sheet scores related to exam grades.

We used the Student's t-test to determine if there was any difference between the cheat-sheet scores from MCS and LSC groups. The first half of TABLE I shows the results for the graduate class. The p-values we got from Midterm 2, the Final and all three exams together are all smaller than 0.05, indicating that we are confident that the population of the cheat-sheet scores of the MCS group was different than the population of the cheat-sheet scores of the LCS group. The average cheat-sheet scores show that the students who got higher exam grades in the graduate class also created better cheat-sheets. Another interesting finding is that, though the difference on the cheat-sheet scores between those two groups was not significant in Midterm 1 (p-value is 0.0733), in the later two exams, the difference between the average cheat-sheet scores of the MCS and LCS groups became larger. This indicates that students in the graduate class who did better in later two exams continued to improve their cheat-sheet strategy but students who scored worse did not improve their cheat-sheets much.

We also compared the data from graduate class with undergraduate class. There were small differences between the average cheat-sheet scores between MCS groups in graduate and undergraduate classes (0.13 in Midterm 1, 0.34 in Midterm 2 and 0.37 in Final). This means both graduate and undergraduate MSC groups were able to plan and use their cheat-sheets well and create cheat-sheets of good quality. Similar improvement on cheat-sheet scores on MSC group was also found in undergraduate classes. This means the students in MSC groups from both graduate and undergraduate classes continued to improve the cheat-sheets through the semester.

The undergraduate LCS group created much worse cheat-sheets than the graduate LCS group (the difference on the average cheat-sheet scores are 1.55, 0.88, 1.10 for Midterm 1, 2 and the Final respectively). This is largely accounted for by the 24 undergraduate cheat-sheets that were not submitted or had little content (1 and 2 scores respectively). Later, we will discuss more about the difference between graduate and undergraduate students on using the cheat-sheets.

Since we found for the graduate class, the MCS group, on average, created better cheat-sheets than the LCS group, we then examined the correlation between the quality of cheat-sheets and students' grades. In [5], we showed exam grades were positively correlated to the cheat-sheet scores in undergraduate classes. Ideally, this should also be true for graduate students.

We performed linear regression analysis to investigate the relation between exam grades and cheat-sheet scores. Fig. 3 and 4 show the linear regression fit lines for graduate and undergraduate classes.

From Fig. 3 and 4 we find that for both levels of students, their exam grades are positively correlated to the cheat-sheets scores. The students who created better cheat-sheets tended to perform better in the exams as well.

TABLE I. COMPARISON ON CHEAT-SHEET SCORES FOR DIFFERENT STUDENT GROUPS

Class level	Group	Avg. Cheat-Sheet Score Midterm1	Avg. Cheat-Sheet Score Midterm2	Avg. Cheat-Sheet Score-Final
Graduate class	MSC	6.00	6.88	7.46
	LCS	5.55	6.06	6.02
	p-value	0.0733	0.0041	<0.0001
Urgd.classes	MSC	6.13	6.54	7.09
	LCS	4.00	5.18	4.92
	p-value	0.0006	0.0059	<0.0001

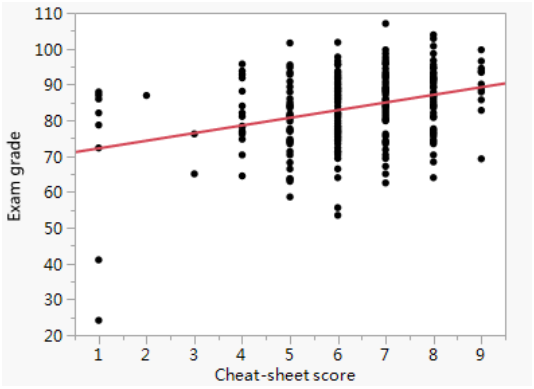

Fig. 3. Linear regression result between student's grades and cheat-sheet scores on all exams in graduate class

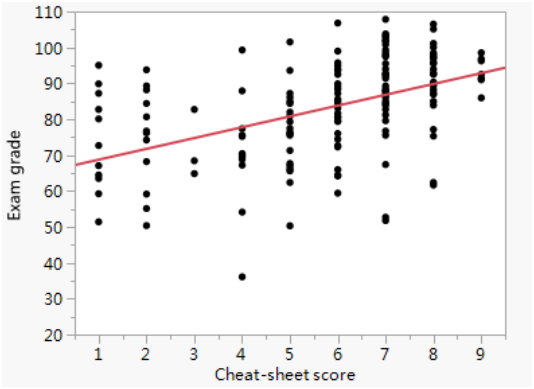

Fig. 4. Linear regression result between student's grades and cheat-sheet scores on all exams in undergraduate classes

To get a better understanding of the difference between the correlations of graduate and undergraduate students, we compared parameters from the linear regression fit lines from Fig. 3 and 4. We also calculated Pearson's correlation between exam grades and cheat-sheet scores for both graduate and undergraduate classes. The results are shown in TABLE II.

From TABLE II, we find that even though the cheat-sheet scores are positively related to students' grades in both levels, the slope for undergraduates is higher, so improvements in cheat-sheet quality may result in larger improvements in the exam grades. The R-square value from undergraduate class is

also higher, which means that for the undergraduate classes, the changes of the cheat-sheet scores better explain the grade changes. Pearson's correlation also shows this: for the undergraduate class, the students' grades are more correlated to the cheat-sheet scores.

TABLE II. COMPARISON ON LINEAR REGRESSION RESULTS

Class Level	Intercept	Slope	R-Square	Pearson's Correlation
Graduate class	70.04	2.14	0.11	0.34
Urgd. classes	65.74	3.01	0.23	0.48

TABLE II shows that cheat-sheet quality has a greater positive correlation with undergraduate students' grades than with graduate students' grades. This influence is in both the likelihood and improvement – if an undergraduate and a graduate student both improve their cheat-sheet quality by one point, the undergraduate student is more *likely* to get an improvement on the exam grade, and is expected to have a *larger* grade improvement than the graduate student.

We believe there are several reasons that the cheat-sheet is more effective for the undergraduate course. First: graduate students have a more varied background and some have had related courses or working/research experience. Graduate students did not spend as much time on preparing cheat-sheets because they know the material better. Second: graduate students are more determined to get higher grades. They spend more time on class material, discussing the homework questions with each other and also, they are more motivated to learn from other sources, like MOOCs. Third: the exams in the graduate course are deeper and more subtle and the cheat-sheet is less helpful. These partially explains why the cheat-sheet quality affects exam grades less in the graduate class.

B. *How do students' usage of graphs, formulas and sample answers differ?*

Now we examine the use of graphs, formulas and sample answers and how they are related to students' exam grades. We compare graduate and undergraduate classes to see if the students made use of this information in similar ways. TABLE III shows the number of graphs, formulas and sample answers for graduate and undergraduate classes. We see graduate students used more graphs and formulas and fewer sample answers. The difference on the number of formulas can be explained by the depth of topics covered in graduate class: it covered more theoretical details and reasoning as well as probability and performance modeling.

We see in TABLE III that graduate students wrote fewer sample answers than the undergraduates. This means that graduate students, overall speaking, did not find sample answers particularly helpful (note decrease over the exams). Graduate students are better able to solve problems given the facts needed and adjust to the exam configurations.

TABLE III. COMPARISON ON USAGE OF GRAPHS, FORMULAS AND SAMPLE ANSWERS ON CHEAT-SHEETS BETWEEN DIFFERENT LEVEL

Class Level	Exam	# of Gaphs		# of Formulas		# of Sample Answers	
		avg	*median*	*avg*	*median*	*avg*	*median*
Graduate class	Midterm1	2.59	2	14.74	14	1.03	1
	Midterm2	4.07	3	15.69	15	0.47	0
	Final	4.70	4	10.05	10	0.4	0
Urgd. classes	Midterm1	1.98	2	9.51	10	3	1
	Midterm2	2.65	2	3.04	3	1.77	1
	Final	1.57	1	6.64	7	1.07	0

To compare students' grades and their use of sample answers on the cheat-sheets, we superimpose the distributions of the students' grades and those using cheat-sheets sample answers (at least 1) (as shaded area) in Fig. 5 and 6.

Comparing Fig. 5 and 6, the undergraduate students across all grades relied on sample answers much more than graduate students. The graduate students, on the contrary, used fewer sample answers and those who performed well usually did not need any sample answers. For both graduate and undergraduate classes, we found that the LCS groups used more sample answers than MCS groups.

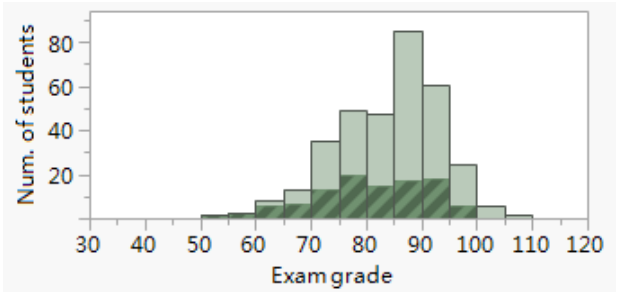

Fig. 5. Distribution of students' exam grades and the students who used sample answers in graduate classes

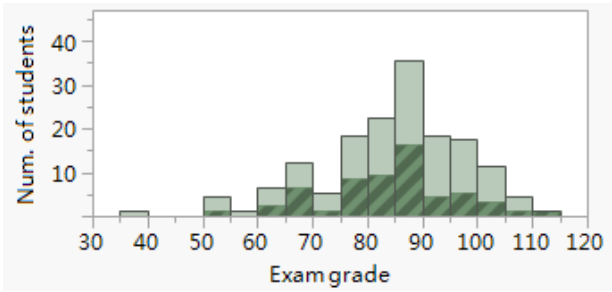

Fig. 6. Distribution of students' exam grades and the students who used sample answers in undergraduate classes

Now we look at students who used too many sample answers, i.e. rated 0 points with more than twice of the median number of sample answers. We have seen both graduate and undergraduate students create full pages of sample answers but do poorly on the exams. Therefore, we further created the histograms which show the grade distribution of the students who used too many (rated 0) sample answers on their cheat-sheets (as shaded area) in Fig. 7 and 8.

Fig. 5, 6, 7 and 8 show some stronger students, both graduate and undergraduate, used sample answers but students using too many, rated 0, seldom performed well. This bolsters our argument that students should not use the homework answer keys as the main study material for exams.

We found different trends in graduate and undergraduate classes concerning graph representations: the number of graphs used by graduate students increased through semester but in undergraduate classes, this number increased between Midterm 1 and 2, but dropped for the Final. In addition, the graduate students also tended to use more graphs.

To see which students used more graphs, we again used superimposed histograms of students' grades and students who used at least one graph representation in their cheat-sheets (as shaded area). The results are shown in Fig. 9 and 10.

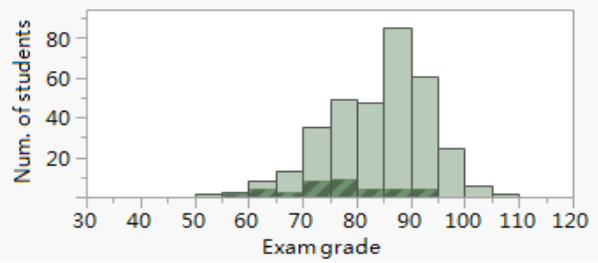

Fig. 7. Distribution of students' exam grades and the students who used too many sample answers in graduate class

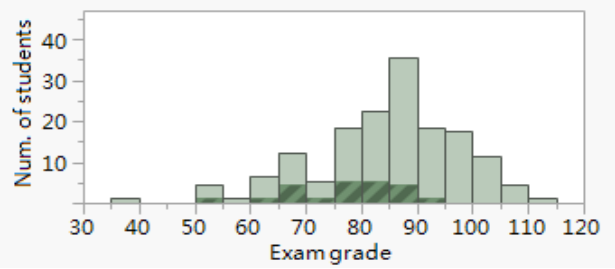

Fig. 8. Distribution of students' exam grades and the students who used too many sample answers in undergraduate classes

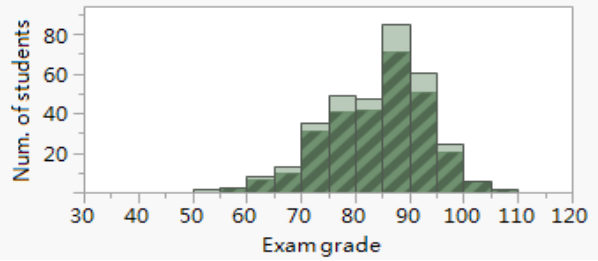

Fig. 9. Distribution of students' exam grades and the students who used graph representations in graduate class

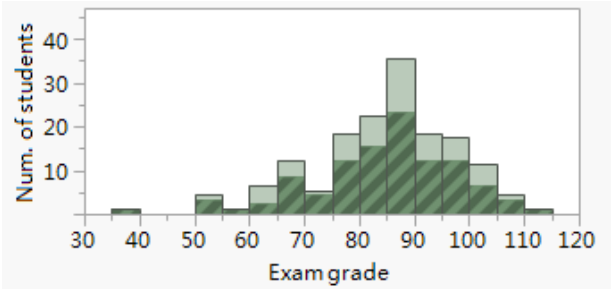

Fig. 10. Distribution of students' exam grades and the students who used graph representations in undergraduate classes

We see that a higher percentage of graduate students used graph than undergraduates. This indicates undergraduate students may find using graphs on their cheat-sheets less helpful than using pure text. Since we did not "penalize" cheat-sheets unless there were excessive graphs, we examined the distribution of the students who used too many graphs (more than twice the median). Fig. 11 and 12 show the students' grade distribution and the distribution of "too many graphs" students (the shaded area) for both graduate and undergraduate classes.

We do not see any difference between the grades of "too many graphs" students and the other students. We made the "too many graphs" one group and the other students the second group, and ran the t-test on their exam grades. We found those groups did not have any significant difference in either the graduate class or the undergraduate classes (p-value was 0.73 in the graduate class and 0.68 in undergraduate classes).

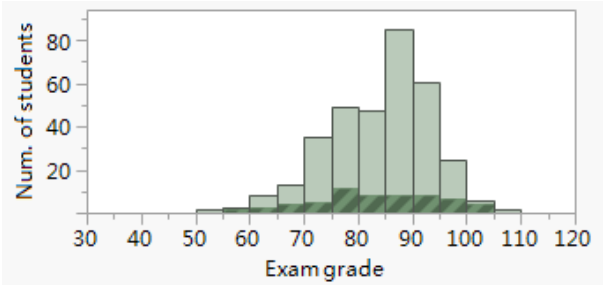

Fig. 11. Distribution of students' exam grades and the students who used too many graph representations in graduate class

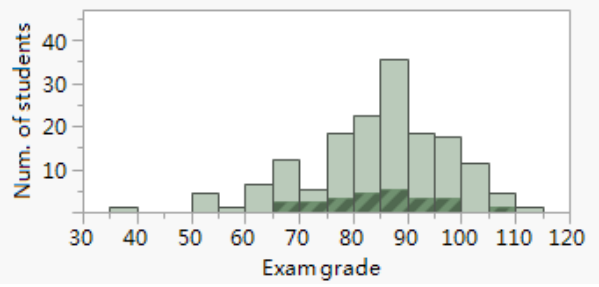

Fig. 12. Distribution of students' exam grades and the students who used too many graph representations in undergraduate classes

C. Who appreciates the cheat-sheet class policy more?

In last semester's graduate class, we first asked survey questions on students' attitude toward the cheat-sheet policy. We asked students if they felt that the cheat-sheets were 1) useful

learning tool and 2) useful tool in taking exams. The survey used the 1-to-5 Likert scale with 1 -"strongly disagree" and 5 - "strongly agree". TABLE IV shows the students' attitude toward cheat-sheet policy in graduate class.

Clearly students, on average, agreed that the cheat-sheets were useful in both learning and taking exams. This finding was higher than we expected. There were almost no low-level recall questions, so students cannot rely solely on cheat-sheets to do even average on exams. This finding disagrees with Dickson and Miller's finding that cheat-sheets were only helpful for factual questions [8]. Though we did not ask students in the survey why they appreciated the cheat-sheets policy, we did receive a few students' comments as shown in Fig. 13.

In the 323 graduate cheat-sheets, 23 indicated that the they-"strongly disagree" or "disagree" that the cheat-sheets were good learning tools and 27 indicated they-"strongly disagree" or "disagree" that the cheat-sheets were helpful on exams (answers of 1 or 2 on the Likert scale). Those who did not appreciate the cheat-sheet policy were a mix of MCS and LCS students. Though those students created slightly worse cheat-sheets (average cheat sheet scores were 6.14 versus 6.37, we found their exam grades were not significantly worse than the rest of the class. We hypothesize that part of these were students who had strong computer networking backgrounds and cheat-sheets did not help them learn nor help them much on exams.

D. What do early birds do?

In the graduate class, we also asked students about how much time they spent preparing the cheat-sheets. Three questions were asked were: 1) on what date did they started to take notes for the cheat-sheets 2) on what date did they started creating the cheat-sheets and 3) how many hours did they spend creating the cheat sheets. TABLE V shows the reported time students spent preparing cheat-sheets.

From TABLE V, we find that most students started to create the cheat-sheets the day before exams. This is consistent with other observed student behavior. Students started to make content notes for the cheat-sheets at least several days earlier than the exams. Some of the students even claimed that they started to make notes for the cheat-sheets from the first day of class. The average time that students spent creating the cheat-sheets (a little more than 10 hours) was a little longer than we expected, but this was probably partly learning and partly exam preparation.

TABLE IV. STUDENTS' ATTITUDE TOWARD CHEAT-SHEET POLOCY IN THREE EXAMS IN GRADUATE CLASS

Exam	Avg. Usefulness for Learning	Avg. Usefulness for Exam
Midterm1	3.95	3.87
Midterm2	4.18	4.05
Final	4.10	4.05

> "The cheat sheet for me is my final study tool. It helps me recap the information and fill in any holes that are missing."
>
> "Because I lost some of the points on Midterm Exam 1 just because of not having a complete cheat sheet."

Fig. 13. Part of students' comments on cheat-sheet policy

TABLE V. TIME SPEND ON PREPARING CHEAT-SHEETS

Exam	Avg. Cheat-Sheet Prep. Days	Median	Avg. Content Prep. Days	Median	Avg. Cheat-Sheet Prep. Hours	Median
Midterm1	2.08	1	9.68	4	10.7	6
Midterm2	1.88	1	8.88	3	12.03	8
Final	2.56	1	6.37	3	12.05	10

Fig. 14 plots students' grades against the number of days before exams they started to make cheat-sheets notes. Making notes during class and while reading the textbook was encouraged by the instructor. But from Fig. 14, we see that LCS students who claimed that they started to take notes very early did not do well on the exams. For the MCS group, the students who made notes earlier tended to do slightly better than the others.

Fig. 15 shows there was almost no correlation between the number of days before the exam the students started to create cheat-sheet and their exam grades. However, only 1 of 7 failing students started to prepare more than one day before the exam.

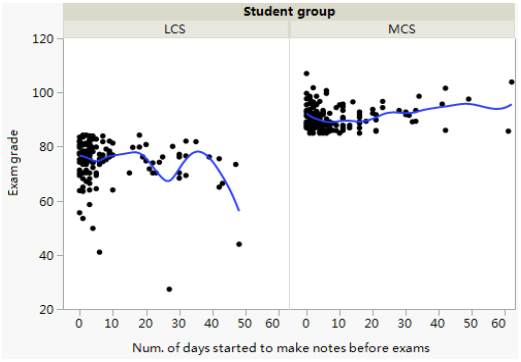

Fig. 14. Distribution of students grades against the number of days they started to make notes for cheat-sheets before exams

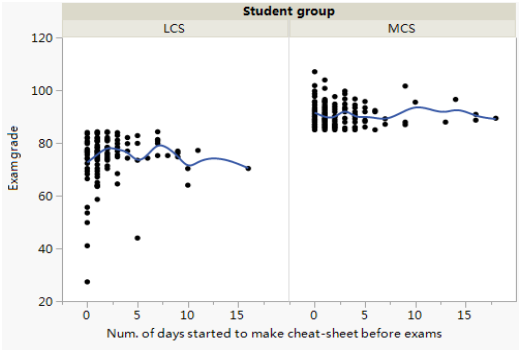

Fig. 15. Distribution of students grades agains the number of days they started to make cheat-sheets before exams

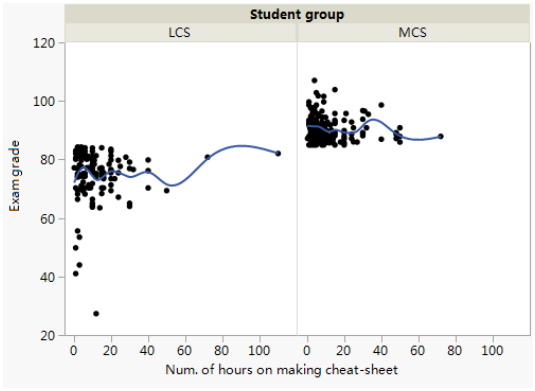

Fig. 16. Distribution of students grades agains the number of hours they spent on making cheat-sheets

We also asked how many hours students spent making the cheat-sheets and we investigated the influence of cheat-sheet preparation time on students' grades. Fig. 16 shows the distribution of students' cheat-sheet preparation time and their grades. We found that there was no significant correlation between them but again almost all failing students spent less than 2 hours preparing cheat-sheets.

The three tests in this section show that, overall speaking, the students' exam grades are not related to when they started to take notes for cheat-sheets, when they started to make the cheat-sheets, or how much time they spent to do so. These findings remind us that a cheat-sheet is, first of all, a tool for memory aid and motivation for students to learn. As educators, we can encourage students to make good use of this tool, but devoting excessive time to cheat-sheets does not really help students do better on exams.

IV. Conclusions

In this study, we collected 323 cheat-sheets from a graduate computer networking course and used data analysis to reveal how the cheat-sheets were related to students' exam grades. We also compared those cheat-sheets with 155 cheat-sheets we collected a year earlier from undergraduate classes on the same subject to see how the use of cheat-sheets differs between graduate and undergraduate students. Our research showed that:

- for both graduate and undergraduate classes, students who created better cheat-sheets also did better in exams;
- cheat-sheet quality better correlates with undergraduate students' grades than graduate students' grades;
- undergraduate students tend to write down more sample answers as part of their cheat-sheets;
- for both graduate and undergraduate students, too many sample answers does not help them do better;
- graduate students tend to draw more graphs as part of their cheat-sheets;
- students agree that the cheat-sheets were helpful both as learning tools and aids during exams; their attitude improved slightly through the semester;
- spending excessive time preparing cheat-sheets does not help students do better on exams.

Most of these finding suggested that cheat-sheets are helpful in both learning and students' exam performance. Those findings echo Skidmore's work [10] and disagree with the idea that authorized cheat-sheets are "crutches" [6, 11]. As the survey responses indicated, the authorized cheat-sheet policy helped students learn before the exam and as memory aids. Unlike some other related researchers [8], our exam questions were designed mostly to test depth and breadth of understanding and applications with few recall questions. We found students' attitude toward the cheat-sheet policy improved slightly and students continued almost 100% usage as the semester progressed.

Our finding also showed that students who claimed that they spent a large amount of time preparing contents for cheat-sheets or preparing cheat-sheets did not do better than other students. This means that even though the cheat-sheet policy has a positive impact on students' grades, the bottom line here is still learning the material.

By comparing the use of cheat-sheets between graduate and undergraduate students, we found that different levels of students tend to use cheat-sheets differently. The undergraduate students relied more on the sample answers, while the graduate students used more graphs. Our data analysis showed that making cheat-sheets a "homework answer book" does not help students much on exams, and having more graphs does not have an impact on graduate students' grades.

A. *Suggestions*

We suggest that instructors should allow and encourage students to use authorized cheat-sheets on exams, but caution them to not replace needed understanding and learning. Weaker students especially should also be advised that the cheat-sheets should contain more than sample answers, and be warned about devoting excessive time to cheat-sheets.

We have designed our own cheat-sheet rating scheme, but it is based on our teaching experience and may not be applicable for other courses. Instructors can do similar analyses and develop their own guidelines for cheat-sheet preparation.

B. *Future work*

It is hard to do valid test-retest assessment to evaluate the helpfulness of cheat-sheets. However, we could ask students to answer another survey questions: "without this cheat-sheet, how many fewer points would you expect to get on this exam?" and see students' responses. We will also get data on students' networking background to see if that explains the low value of cheat-sheet usefulness of some students.

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