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A Comparison between Individually-Prepared and Team-Prepared Study Guides in a Sophomore Chemical Engineering Thermodynamics Course

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Study Guide Generation in Chemical Engineering Thermodynamics: A Comparison Between Individual and Group Preparation

Introduction and Background

Collaborative environments have been linked to improved student learning across many different variables, from early childhood education [1] to graduate level quantum physics [2]. Specifically within engineering, first-year engineering students showed a statistically significant increase when working collaboratively on tutorials in a calculus course based on exam performance relative to a control. [3]

Of course, collaborative environments define a large umbrella of approaches, and some implementation strategies have been explored much more often than others. For example, a simple search on the ASEE PEER system for the term "problem based learning" yields more than 2700 conference proceedings related to that topic over the past 25 years. At the other end of the spectrum, the literature is almost totally silent on the evaluation of collaborative environments associated with *student created* study guides (a.k.a. "cheat sheets") for quizzes and exams. As instructors will sometimes allow students to use their own study guides on exams, it is interesting to explore different creation methods (e.g., individual vs team created).

The use of study guides, whether student created or instructor/book created, has probably been around as long as instructors have been using quizzes and exams for assessment. Accordingly,

literature does exist within the field of study guides, exploring their effectiveness on reducing anxiety [4], [5] or impact on exam performance [6], for example. But very few works have analyzed the actual construction process. To address this gap, this study investigated the learning gains from collaborative study guide construction compared to individual study guide construction.

About 15 years ago, Visco et al. [7] examined individual student study guide construction in a qualitative work that explored what students put on their study guides and how they were used within a third-year undergraduate thermodynamics course in chemical engineering. Through individual interviews held after the exams, the researchers made several observations/conclusions: (1) a variety of completion strategies existed to prepare study guides, (2) there could be some value in providing direction to students on how to make a study guide, (3) most students were heavily influenced by what the instructor emphasized during the class and (4) there could be a benefit derived from peer-sharing of study guide creation efforts. It is this final point that motivated the current study in this work.

A typical approach for student study guide creation consists of an individual review of a student's notes, looking back through various course material that was covered up to that point in the semester (inclusive of handouts, homework, instructor points of emphasis, etc.) Of course, this approach is just one way to prepare a study guide. Reflecting both on the previous work [7] and the known benefits of teaming within STEM (e.g., [3]), students could work together in small teams to collaboratively prepare a study guide that each of the team members would use during a quiz or exam. This was the strategy taken in the current student and, accordingly, the

research question proposed in this work is as follows: “Does the construction method of a study guide affect study guide usage on exams?” We proposed this research question owing to the known effectiveness of collaborative learning [3], the benefits of a constructivist environment [8] and the suggestion on the benefits of peer-sharing in the creation of study guides. [7]

Methods

Thermodynamics is a course with many equations, and students need to make decisions on when to use the different equations based on environments that validate any simplifications, often with subtle underpinnings from math, physics, and chemistry courses. To assist students on exams in thermodynamics, instructors might decide to allow students to use a “study guide” to help recall rules, concepts, approaches, etc. One of the main faculty goals when they allow students to use study guides is that it allows students to avoid the need for extensive rote memorization and focus more on the nuanced concepts of the materials.

Additionally, how students use a study guide will vary based on the student. Timed exams penalize students who spend too much of their time scouring their books (or notes) for information. Study guides help mitigate this by allowing items to be focused for easy retrieval. However, a student who spends too much time looking at their study guide is still in danger of not finishing the exam in the time allotted. Thus, study guides are best seen as a “safety blanket” that mitigate both rote memorization and lengthy searches in materials for information.

In this work, we attempted to analyze *how* students used the material they put on their study guide and the value they assigned to their study guide, exploring this from both an individual and team preparation perspective. This study was implemented in an introductory Thermodynamics course, a second-semester, second-year course for 43 chemical engineering students. One of the authors (Visco) was the sole instructor for the course.

In this course, students were placed in teams of four (one group had only three students) at the beginning of the semester using default settings from CATME. [9] These teams sat together in class (at tables of four) and worked together on course projects, group-specific homework problems and in-class problems. The course had three in-class exams as well as a final exam. Data was collected over the first two exams only due to project time constraints.

Data Collection

The University of Akron Institutional Review Board (IRB) approved the use of questionnaires for this study. Students were able to opt out of answering any of the questionnaires used in this project and were provided with consent forms. Students were not given a bonus for completion of any portion of the questionnaires. Students were required to use only individually prepared study guides on Exam 1 and only their team generated study guides on Exam 2 as part of this project.

Exam 1 Procedures

Exam 1 was given during week 5 of the semester. Prior to the week of Exam 1, the following note was sent out to all students: "In addition to your textbook, you will be able to use a one-

page (two-sided, 8.5" x 11") study guide **that you create**. The study guide can have *anything* you would like to include on the sheet -- the choice is yours. Please create a study guide of your own to use on the upcoming exam." The students created their own study guides outside of class time, though it is unknown if they consulted with anyone during preparation of their study guide.

Students were required to submit their study guides a day before the exam to the instructor via the learning management system. After submitting their study guides, but prior to taking the exam, students were asked to complete a pre-exam questionnaire. Additionally, post-exam questionnaires were sent out following the exam and students had several days to complete the post-exam questionnaire. Exams scores were not known until after post-exam questionnaires were completed. All responses were recorded using Qualtrics. During the collection period reminders were sent once a day to students that did not complete the questionnaire.

Exam 2 Procedures

Exam 2 was given during week 10 of the semester. To help guarantee that study guide creation for this exam was a team-created effort, time was provided during class (50 minutes for team study guide creation). Students were told on a Friday (a week before the exam) that they would be working in teams to construct their exam study guides the following Monday and that they would use their team-constructed study guides on the exam (and not individual study guides, like the Exam 1). Students were strongly encouraged to bring a list of preprepared ideas/concepts to their team on Monday to help facilitate the discussion and, ultimately, the creation of the study guide.

During the team study-guide creation session on Monday, each team was provided with two blank sheets of paper, and it was emphasized to use only one side of each sheet. Such an approach allowed for quicker and easier preparation in a team setting (instead of constantly flipping the paper over). The instructor emphasized that both "fronts" of the paper would be combined to one sheet (2-sided) and this this would be their team-created study guide for use on the exam on Friday. It would be collected at the end of the session (50 minutes), photocopied and distributed back to the team later that same day by email for review. It was also emphasized that the instructor would provide the students with their team-created study guide on Friday (for the exam) to eliminate additional information being added to the study guide after the teaming session.

During this Monday session, the instructor walked around the room to encourage discussion and make sure the teams were on task. The instructor answered various questions upon request about methodology, etc. In situations where the class would benefit from the answer, the instructor would repeat the question so all could hear and then answer the question for the entire class. All student teams submitted a team-prepared study guide at the end of the Monday session. Following a similar approach to Exam 1, a pre-exam questionnaire and a post-exam questionnaire was utilized.

Questions Asked in Pre-Questionnaire

Five statements were provided on the pre-exam questionnaire (using a Likert scale), plus one free-response question. The statements were chosen to help isolate aspects of study guide construction and usage, per the research question. The statements are provided in Table 1.

Table 1: Likert statements and the free response question for the Pre-Exam questionnaires.

Likert Scale	1- disagree, 5- agree
Statement number	statement
1	I was able to fit all needed information on to my study guide.
2	Constructing a study guide helps me learn.
3	I studied my notes prior to making this study guide.
4	I prefer to study in groups.
5	I had an appropriate amount of time to construct a study guide.
Free Response 1	How did you decide what to put on the study guide?

Our choice of statement selections was as follows. For statement 1, we were evaluating appropriate size of the study guides. For statement 2, we were interested in the comparison between study guide construction methodologies and perceived impact on learning. For statement 3, we were interested in how the study guide was developed and the potential approach change between individual and team-created study guides. For statement 4, we were interested in the impact of teaming on preference. Finally, statement 5 was to flesh out in-class time restrictions, especially for the team-created guides. The free response question allowed us to explore creation strategies.

Questions Asked in Post-Questionnaire

Five statements were provided on the post-exam questionnaire (using a Likert scale), plus one free-response question (note: Exam 2 had a *second* free-response question). The statements were chosen to help isolate aspects of study guide construction and usage. The statements are provided in Table 2.

Table 2: Likert statements and the free response question for the Post-Exam questionnaires.

Likert Scale	1- disagree, 5- agree
Statement number	statement
1	I was able to find all needed information on my study guide in a timely manner.
2	I used my study guide extensively during the exam.
3	I followed examples on my study guide during the exam.
4	I had all equations and information I needed for this exam on my study guide.
5	I had enough time to finish the exam.
Free Response 1	What was most helpful about having the study guide available during the exam?
Free Response 2 (only Post-Exam2)	Which of the strategies to prepare the study guide (individual or group preparation) was most helpful to your learning and why?

Statement 1 fleshed out student feedback on organization of material, especially associated with their own organization (Exam 1) relative to team organization (Exam 2). Statement 2 evaluated usage of the study guide during the exam. Statement 3 explored use of examples during the exam as guides on the study guide. Statement 4 evaluated whether the decisions (individual or group) in what to put on the study guide was correct, from their perspective. Finally, statement 5

exploring the issues of timing in order to help flesh out value for the study guide as an efficiency mechanism.

Data Analysis

All data was collected in Qualtrics, with a data matching code for each respondent in order to link responses (pre and post). We were most interested in the *changes* for individuals relative to study guide preparation (individual vs. team). Accordingly, we decided to analyze changes for an individual between both exams, using both the pre-questionnaire and the post-questionnaire. However, not all students completed all the questionnaires and, sometimes, students didn't respond to a particular question within a questionnaire. Therefore, we focused on those questions where the same student answered them between both exams in order to have a matched data set. Thus, the N for each question is different (ranging from 13 to 20).

We report a "delta" value, which represents a change (either positive or negative) between Exam 1 and Exam 2. A positive delta value represents that this question received an increased (positive) response for the team-constructed study guide approach relative to the individually prepared study guide. Frequency of the delta value was also reported. Note that we have 10 unique questions to evaluate: five from the pre-questionnaire and five from the post-questionnaire.

The free response questions were analyzed inductively and coded for themes within the responses Codes created distilled versions of the free responses and these codes were then condensed into several themes. Typically multiple codes contributed to a theme. Two members

of the research team provided their own codes and themes individually, then met to discuss consistency of both codes and themes. In the limited instances where coding differences occurred, subsequent discussion led to a resolution (either to an existing code or the creation of a new code).

Data & Results

Likert Data for Pre-Exam

Table 3 provides the comparison for the pre-exam data. A few themes emerge when reviewing this data. First, students felt that team-prepared study guides were a negative for all statements, relative to individually prepared study guides. Second, the requirement of making a team-study guide encouraged students to consider their notes prior to making their study guides. Finally, a large majority of students felt that they did not have enough time to make their study guides via the team-prepared approach, relative to the individually prepared approach.

Table 3: Delta values from Pre-Exam questionnaires.

CHANGE	I was able to fit all needed information on to my study guide.	Constructing a study guide helps me learn.	I studied my notes prior to making this study guide.	I prefer to study in groups.	I had an appropriate amount of time to construct a study guide.
+4	0%	0%	0%	0%	0%
+3	0%	0%	11%	0%	0%
+2	0%	0%	15%	15%	0%
+1	17%	11%	21%	0%	0%
0	50%	63%	32%	38%	11%
-1	28%	21%	21%	31%	11%
-2	6%	5%	11%	15%	33%
-3	0%	0%	0%	0%	33%
-4	0%	0%	0%	0%	11%
N=	18	19	19	13	18

Likert Data for Post-Exam:

Table 4 provides the comparison for the post-exam data. For all five statements assessed, the average change for each statement was negative, indicating a preference for individually prepared study guides relative to the team prepared guides. Indeed, for the first statement concerning the ability to find the information on the study guide, none of the students indicated an improvement for the team-prepared study guide, relative to the individually prepared study guide. Additionally, students' feedback identified a large (negative) shift in the usage of

examples contained within the study guide for the team-prepared version. Such a result might indicate that problem solution strategies are more individualized in nature and, thus, a team developed approach either did not make it onto the study guide or, if it did, was likely not individualized enough to be useful. Note that free response question themes (discussed in a following section of this manuscript), would imply the latter.

Table 4: Delta values from Post-Exam questionnaires.

CHANGE	I was able to find all needed information on my study guide in a timely manner.	I used my study guide extensively during the exam.	I followed examples on my study guide during the exam.	I had all equations and information I needed for this exam on my study guide.	I had enough time to finish the exam.
+4	0%	0%	0%	0%	0%
+3	0%	0%	0%	0%	0%
+2	0%	10%	0%	0%	0%
+1	0%	10%	15%	6%	18%
0	22%	20%	15%	44%	0%
-1	44%	40%	15%	11%	47%
-2	22%	15%	23%	28%	12%
-3	6%	5%	23%	6%	24%
-4	6%	0%	8%	6%	0
N:	18	20	13	18	17

Pre-Exam Free Response Themes

The pre-exam free response question asked: "How did you decide what to put on the study guide?" As previously discussed, we developed codes from the free response answers and utilized those to identify themes. Five main themes emerged, which are listed in Table 5. It is noted that students may have listed multiple factors influencing study guide preparation, so the sum of each column in Table 5 is greater than 100%.

Table 5: Pre-exam theme frequency associated with decisions on what to include on the study guide.

Themes	**Frequency (n=25)** **Pre-Exam1**	**Frequency (n=21)** **Pre-Exam2**
Study guides are for formulas	36%	43%
Key Points / Examples	96%	91%
Material that was struggled with	28%	19%
Prediction of what will be on the exam	12%	19%
Group involvement	0%	43%

The most popular theme, regardless of the study guide preparation method, was the inclusion of key points and examples on the study guide. An increase was noted for prediction strategies and formula inclusion for team-based study guide preparation, relative to the study guides prepared by the individual students. Finally, students indicated "group involvement" as a factor for the team-prepared study guide.

Post-Exam Free Response Themes

The first post-exam free response question asked students to reflect on "What was most helpful about having the study guide available during the exam?" As in the pre-exam data analysis, we developed codes from the free response answers, which were condensed to identify themes. Five main themes emerged, which are listed in Table 6. Once again, it is noted that multiple themes could be present within a single response, so the sum of each column in Table 6 is greater than 100%.

Table 6: Post-exam theme frequency associated with what was most helpful about having a study guide available during the exam.

Themes:	**Frequency (n=20)** **Post-Exam1**	**Frequency (n=25)** **Post-Exam2**
Formulas	55%	40%
Examples	45%	24%
Organization of book	10%	0%
Unnecessary to memorize	30%	20%
Benefit of construction	0%	8%

For both individual and team-prepared study guides, students reported the ability to have formulas readily available on the study guide sheet as the most helpful. The value associated with having examples on the study guide decreased from the individually prepared study guides to the team-prepared versions. The theme of book organization, which captures using the study guide to identify where in the book certain information is provided, disappeared as a theme for

the team-prepared study guides. Finally, two students who responded to this question implied that there was value in constructing a study guide with a team.

The second post-exam free response question was only provided after Exam 2 and asked, "Which of the strategies to prepare the study guide (individual or group preparation) was most helpful to your learning and why?" Based on how the question was posed, the expectation was that the respondents would identify the positive aspects of the approach (individual or team) that they endorsed. However, several students identified the aspects of the two approaches that they liked and did not like. Accordingly, we classified the response (N = 24) in four ways based on whether the comment was positive or negative, and whether the comment was about the individually prepared study guide or the team-prepared study guide. Within each of those four classifications, themes emerged based on why they felt a particular approach was most (or least) helpful.

Table 7: Themes emerging associated with a preference for individual or team-prepared study guides, per free response question post-exam 2.

Classification	**Themes (%)**
Individual/Positive	Construction (33%) Helps me learn (29%) Time of preparation (8%)
Individual/Negative	Unsure of content (4%)
Team/Positive	Benefit of group construction (21%)
Team/Negative	Time of preparation (38%) Compromise (33%) Poor group dynamics (17%)

The top two positive themes were both from individual study guide preparation and are linked. The broad act of the individual constructing the guide was cited as helpful to learning for 33% of the respondents, while another 29% specifically mentioned phrases related to "helping me learn". On the other hand, the constrained in class preparation time for the team-developed study guide was viewed in a negative way (38%), as was the need to compromise on what to include in the study guide (33%). It is interesting to note, however, that despite the clear negatives identified associated with team-constructed study guides in this study, 21% of the respondents highlighted benefits of working in teams to construct the study guide.

Overall, 75% of respondents said they preferred individual study guides, 13% preferred group study guides, 4% specifically mentioned they had no preference between the two options, while 8% did not provide a preference.

Discussion

Based on the known benefits of collaborative environments, our research sought to explore whether the construction method of a study guide (individual or team-based) affected study guide usage on exams. The motivation being that the act of preparing the study guide in a team setting would create a study guide superior to individual efforts, resulting in less reliance on the study guide during the exam (and, ultimately, better student performance). Students' responses from the Likert scale survey and free response questions indicate that they preferred the individual study guide preparation over those prepared with their teams. However, based on how the survey and free response questions were answered, it seems likely that the reason for this preference was the time constraints of preparing the team-developed study guide. This was a confounding variable that limits interpretation of the results. Survey results also indicated that the key benefits of the study guides were associated with formula availability and use of examples on the study guides. This result is consistent with the previous findings from Visco et al. [7] where helpfulness of the study guide was linked to finding similar content on the exam.

The survey results can be viewed through three additional lenses: (1) whether there was a strategic element to study guide preparation, (2) how was the study guide ultimately used, and (3) what main value was derived from having the study guide. For the individual study guide preparation, the strategic element that existed for some students surrounded efficiency. In other words, how the study guide was used to organize the accessible content. This strategic element did not surface in team-based study guide preparation. For study guide usage, both preparation methods resulted in students using the guide for formula retrieval and example problems. Finally, as it relates to value, both construction methods point towards the need not to memorize information as the main value of the study guides, though this benefit decreased from individual

prepared study guides to team-prepared study guides. Such an outcome runs counter to the expected benefits of the collaborative environment. Whether this is an artifact of the time-constraint associated with the in-class preparation constraints or the planned usage (the exams are solved by individuals, not teams of students) is unclear.

From a performance standpoint, the same course (with the same instructor) was taught in 2021, 2022 and is currently being taught in 2023. In 2021, using individually prepared study guides, student performance between exam 1 and exam 2 decreased by 2.9 points (mean). In 2022 (the focus of the current study and analysis), student performance between exam 1 and exam 2 decreased by 2.5 points (mean). In 2023, students individually prepared study guides for exam 1 and exam 2 (similar to 2021), and the student performance between exam 1 and exam 2 decreased by 3.7 points (mean). Thus, no overall discernable student performance gain or loss, as measured through exam performance, was realized as a result of study guide preparation approaches.

Conclusions and Implications

A confounding aspect in the comparison of the study guide preparation methods was the feeling of diminished time availability associated with team study guide preparation. The instructor encouraged students to create a list of concepts to discuss with their teams prior to the team study guide preparation session. However, this was not a requirement and, thus, different students had differing levels of preparation for the activity. One way to address this would be to require students to create a draft study guide prior to the team preparation session and make those available to the other group members ahead of time (for review). Of course, such an approach

would also create challenges and may mitigate some of the benefits of the group discussions during the study guide creation that were cited as a positive aspect of the teaming activity.

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