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Efficacy of the Dual-Submission Homework Method

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Efficacy of the Dual-Submission Homework Method

A THESIS APPROVED FOR THE
INDUSTRIAL AND SYSTEMS ENGINEERING

BY THE COMMITTEE CONSISTING OF

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Abstract

The dual-submission homework method (DSHM) has become an increasingly popular form of self-assessment in recent years due to its low-stress engagement for students and the reduction of workload on instructors and students alike. However, to date, qualitative studies have been the primary form of investigation to ascertain the effectiveness of the DSHM. The purpose of this study is to investigate, with quantitative data, whether the dual-submission homework method leads to an increase in learning comprehension and retention of the material by the participants involved. Data collected from 59 students enrolled in a sophomore-level Digital Design course for Electrical Engineering majors was the focal point of this study.

The single-submission homework method (SSHM) resembles the structure traditionally used in classes. Students are assigned homework, to be submitted once, that will be graded based on accuracy and completion. The DSHM assignment, however, features two distinct portions. Students will complete their initial submission, which is graded based on effort and completion. The solution key for a DSHM assignment is released by the instructor after the initial submission. The students must then submit a corrected version of their initial assignment for the second portion of their homework grade. This corrected submission is then graded on effort, completion, and accuracy as well.

Subsequent exams included questions that closely resembled those from the SSHM and DSHM assignments, respectively. Performance measures for this study included grades on homework assignments and exams that were used to accurately measure the results of the DSHM compared to the SSHM. Measured by performance on the aforementioned criteria, ANOVA analysis demonstrated that student performance on DSHM exam-based questions was substantially greater than SSHM exam-based questions. As seen in previous self-assessment studies, feedback from participants and the course instructor indicated significant qualitative advantages to the DSHM; desire for implementation in future courses and the reduction of workload and anxiety about grades for instance. In essence, this study has provided the necessary quantitative and qualitative evidence to indicate, at the very least, that the Dual-Submission Homework Method is not a novelty concept and should be given serious consideration in implementation to the same degree as the traditional single-submission homework method.

Keywords

Dual-submission, single-submission, homework, self-assessment, comprehension

Introduction

Instructors use various methods of homework to interpret student engagement and how to best accommodate their needs [26]. In most courses, there are numerous homework assignments for students to complete that contribute a significant amount to the total course grade. Students who fall behind in homework can be easily tempted to engage in academic misconduct. Furthermore, the professor's ability to provide reliable grading could be a significant factor that further disenfranchises a student. Studies have suggested that a direct correlation exists between the quality of an instructor and the perceived learning from the student [18]. When applied incorrectly, homework implementation and instructor feedback can have a negative impact on student learning and engagement [14]. If a student cannot understand their critiques, how can they be reasonably expected to learn from their mistakes and apply themselves correctly?

Homework assignments are a crucial medium to practice and engage with the material before demonstrating comprehension on exams [27, 29]. However, performance on an assignment might not necessarily reflect a student's understanding of the specified topic or their participation in class. Traditionally, homework assignments have taken on many forms: projects, reading prompts (in selected articles or chapters from a textbook), or responses to question from a given source [3]. In recent years, however, many qualities of the homework format have been altered. These aspects include digital submissions or digital assignments entirely. Students have reported higher scores from these digital methods, but previous data analysis suggests there are no differences between this and the physical forms of homework [32]. Furthermore, these studies critique the simplicity of these digital characteristics [31, 32]. Clearly, there is strong debate over how the structure of the assignment itself may contribute to a student's response to the homework. In the age of the internet, the digital medium has become much more prevalent in higher education and must be considered.

The digital learning environment has seen unprecedented growth from technological advances and, in no small part, due to the ongoing crisis from the Covid-19 pandemic. Online sources like Chegg and CourseHero have become powerful tools at the students' disposal and have shifted the classroom dynamic. Students no longer need to engage with their material to the same degree as before when online tutors are simply standing by to be called upon. Traditional homework assessment methods appear to be highly susceptible to academic misconduct. Students simply scan the assigned problems and wait for a solution [20]. Although certain digital methods experience their fair share of misconduct, the ability to change details of a question between each submission is a significant boon. While no academic major is impervious to academic misconduct, engineering majors appear to be much more vulnerable [15]. A collaborative study between researchers at East Carolina University and the University of Applied Sciences Darmstadt revealed that over 40% of surveyed students admitted to using services like Chegg in their engineering coursework [22]. The digital learning environment has fostered these reactions by students, but they are not the only party to succumb to "shortcuts" such as these.

One common digital method that instructors use to ensure timely return of feedback is "auto-grading". Due to the overwhelming number of students enrolled in a course, many instructors have designed their homework assignments using digital sources that will grade a student's work as soon as they answer a question. Based on student survey responses, previous studies have indicated that this method of assessment may be more suitable for multiple choice questions rather than "problem solving" questions as the grading is focused primarily on the final answer,

not the solution steps [1, 17]. Engineering coursework is typically focused on the steps and processes required to arrive at the correct solution; rather than the solution itself. As such, agile assessment methods are lacking in comparison to a thorough evaluation. While "auto-grading" reduces the workload of the instructor, it may come at the cost of student satisfaction and comprehension.

The relationship of homework between instructors and students is very delicate. Students require a reliable, balanced system of homework assignments since their grades can depend on it. This dependence can be quite significant based on the contribution of homework performance towards the final course grade. Conversely, instructors struggle with the best method to administer homework as they must effectively convey the course principles, while providing valuable critiques to growing class sizes in a timely manner [28]. Students and instructors alike now frequently approach online sources for aide in the form of online tutors and "auto-grading", respectively. These "shortcuts" taken by both parties further exacerbate these issues creating, in essence, a negative feedback loop. Clearly, there is a resolute call for homework reform on behalf of students and professors alike that will improve the experience and performance by both parties. The dual-submission homework method (DSHM) is one of the leading alternatives to address these concerns.

Background

Traditionally, homework has taken the form of question and responses in a single-submission homework method (SSHM) for students to gain experience with the principles taught in a variety of selected situations [3]. In the past, this form was typically physical, however, it has now seen digital alterations. Instructors may provide a physical copy or source for students but require the submission to be digital with an uploaded scan of the completed assignment to a learning management system (LMS). This submission is usually graded on both accuracy and completion. In many courses, most assignments, quizzes, and exams follow this grading structure.

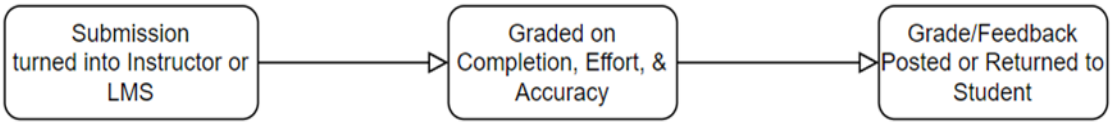


Figure 1. Flowchart for SSHM process

Due to growing class sizes and/or types of problems presented, grading can be extremely difficult for the instructor, or in many cases, the teaching assistant or grader [9]. Time spent grading is a significant factor. Unless the course has a significant number of graders, larger classes lead to less grading time per submission. As a result, the benefit of the feedback could vary from step-by-step critiques or a simple "x" indicating that something in the response is incorrect. The potential advantage the student may gain from quality feedback can be significantly affected by the effort and clarity provided by the grader. Furthermore, students may adjust their efforts, rather than understand the material itself, to adhere to a grader's bias for a

more favorable grade [5, 6]. The method of feedback is as essential as the feedback itself and assessment has proven to be a critical point in students' academic careers [5, 12].

Additionally, many students who are stressed about their grade or who do not understand the material enough to apply themselves are tempted to utilize online sources or solution manuals from previous classes to achieve a satisfactory grade [2, 11]. Surprisingly, perception of solution manual use differs between students and instructors. Many students use solution manuals as a study aide to evaluate their work before submission [24]. While this may be an "honest" use of resources, instructors must have the ability to account for the students that would simply copy the solutions as their own work to submit. Homework assignment grades and associated stress from workload, for both students and instructors alike, are some factors that have plagued this SSHM and substantiate concerns for assessment reformation [7].

To counter many of these issues, alternative evaluation methods ranging from peer assessment to self-assessment have emerged in the field of higher education with the latter gaining popularity within engineering courses [6, 8]. This innovative non-traditional method allows the students to assume the roles of both the learner and the evaluator. The DSHM has been explained in previous studies [2, 3] but will be briefly summarized here. The assignment features two submissions. The first is completed by the student and submitted to the instructor in person or online using a LMS similarly to the traditional method of homework. This submission is then graded based on completion and on the basis that the student gave a "good faith" effort on answering the questions correctly.

Shortly after the first submission is due, the instructor will post the solution key for the students. The second submission requires the students to evaluate and make any necessary corrections to their work. The student must identify how they were correct and incorrect on their initial submission. Where incorrect, students must identify their mistakes and what steps need to be adjusted in their work to arrive at the correct solution [2, 3]. The corrected submission is then graded based on accuracy and completion. For both submissions, the level of effort perceived by the grader factors into the student's grade. In essence, the DSHM combines student self-assessment and grader assessment into a holistic evaluation of student performance on assignments [21].

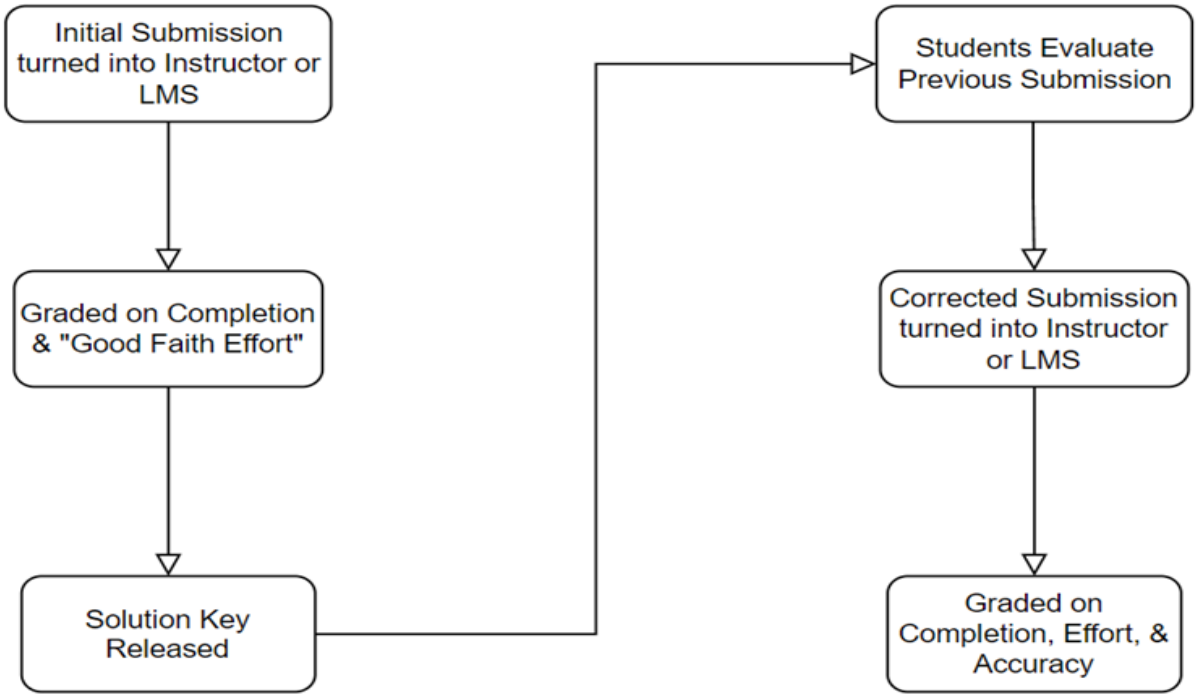


Figure 2. Flowchart for DSHM process

Motivation

Self-assessment establishes specific learning goals for students. Instructors can utilize the process of self-assessment to demonstrate that the student's objective should be to understand the material; not just to complete the assignment and remove it from their weekly checklist [21]. Although many benefits exist to this evaluation method, self-assessment creates a much larger role for the student to guide their academic career which can come at a cost. Students must be active in their feedback. Rather than just reading instructor comments, they must analyze each step to reach the solution and evaluate their own work. Their grade is much more dependent on the effort a student gives to both answer the question and understand their mistakes. Students that are motivated in their work have been shown to perform much better than those lacking such motivation [8]. With this new approach, a student's academic drive is more important than ever and can have compounding effects on their course performance.

Furthermore, self-assessment is a consistent form of validation and exercise of judgment in professional environments [10]. The DSHM not only focuses on the technical success of the course but expands the suite of skills necessary to actively conceptualize, analyze, and apply engineering concepts that expand beyond the scope of a classroom [30]. Self-assessment provides students the necessary skills to practice adequate engineering judgment; a core tenant of the third criterion, *Student Outcomes*, in the A.B.E.T. criteria for 2022-2023 [13]

With the traditional SSHM, many students look at their grade but rarely refer to their homework for future assignments and exams [4]. Previous studies showing comparisons between the DSHM and SSHM demonstrate that students referred to the homework 52% more frequently for DSHM material compared to SSHM material [2, 3]. Students take the time to not only evaluate

their work, but to reflect on the material at hand [8]. This process, an exercise of "metacognition", creates a deeper understanding of the material and an appreciation for the effort a student must demonstrate to truly excel in their course. Students must reflect on their submissions by asking themselves questions over why they find the concepts challenging or how satisfactory their responses were. Moreover, "metacognition" necessitates that a student contemplates which study habits lead to success and those that enable poor practices [3, 4]. Despite this intensive process, students reported spending significantly less time on the DSHM in comparison, while claiming they had a better understanding of the given material [2, 3]. Student productivity and engagement increases both in and out of the classroom.

The application of this new homework method significantly appeals to both students and instructors. For the instructors, significantly less time is dedicated to grading which, in turn, can be reinvested further into other aspects of the course [19]. For students, rapid valuable feedback is provided, their effort is reflected in their grade, and they are not penalized for inaccuracies [23]. While the workload is reduced per homework assignment, the frequency of assignments increases for the class. However, students have clarified that the time spent per submission has noticeably decreased. Instructors have noticed that self-evaluation and increased frequency of assignments has caused a noticeable increase in student engagement in and out of class [23, 29]. Finally, students and instructors alike have reported that the inclusion of self-assessment has led to an increase in homework assignment scores [2, 3, 4, 29].

To date, many of the studies revolving around the DSHM have primarily been qualitative in nature. In these studies, the DSHM has been implemented on homework assignments and the investigators provided a series of questionnaires and surveys for the participants to fill out that gauged their impressions of the new method upon course completion [29]. Additionally, administrative and instructor/grader feedback was recorded [29]. These results are then compared to previous implementations of the DSHM in other courses. These attempts to quantitatively assess this method have struggled to obtain meaningful data due to complications arising with the logistics of gathering class data without affecting the participants and by extension, their data [16]. While students and instructors have reported an increase in performance in previous studies, substantial quantitative data, such as recorded participant scores on course assignments, have yet to verify these conclusions.

The focal point for this study will be the quantitative data attained by the participating class with supplemental qualitative data included. Student performance data will be a decisive indicator to empirically assess how the DSHM impacts retention of material and assignment grades in comparison to the SSHM. The investigators intent was to implement a new homework method that could benefit both students and instructors without compromising the academic goals of the course as dictated by the institution and ABET.

Methodology

Students enrolled in the ABET accredited Digital Design electrical engineering class at the University of Oklahoma were the targeted participants in this study. The class was held in-person three sessions a week with online submissions for assignments using the Canvas LMS in addition to in-class physical submissions. The grade distributions for the course are provided below.

Table 1. Grade Distributions

Course Activity	Grade Percentage
Exams	40%
Homework	20%
Lab Assignments	20%
Final Exam	20%

There are three types of assignments within the homework category: Single-Submission Assignments, Dual-Submission Assignments, and Zybook Challenge Problems. Within the course, there are six exams based on the six chapters covered. Starting with chapter three, each chapter had one DSHM assignment followed by one SSHM assignment. Additionally, exams three through six featured one question that was based on a similar question present in each homework submission type: SSHM and DSHM. To avoid skewing data, the course instructor sought to make the difficulty level of SSHM and DSHM assignments similar. The difficulty level, however, was subjectively determined by the instructor. There was no formal process to determine question and topic difficulty. The instructor simply selected a question between the assignments that they felt were similarly challenging.

For SSHM assignments, the students were graded on both accuracy and completion. The SSHM assignments were given with the following parameters:

1. A digital submission of homework must be made before the solution posts.
2. Submissions of the homework must be uploaded as PDF documents.
3. Any submission made after the solutions are posted will receive no credit.

The SSHM assignment was subsequently graded by the teaching assistant for the class with feedback posted to the respective assignment on Canvas. Feedback was typically in the form of the incorrect solution being crossed out with the correct value marked in alternative ink.

With the DSHM assignments, homework was submitted in two stages. For the initial submission, the student scanned and uploaded their assignment just like the SSHM assignments. This initial DSHM submission was graded on completeness and "good faith" effort given by the student. Cases where the work was not the author's own, or where questions were left without any attempt were deemed unacceptable and received no credit. There was no dedicated process established by the grader or instructor for what represents a satisfactory effort by a student. The qualities that constituted a "good faith" effort were subject to the grader's interpretation. For instance, the grader reported that certain homework assignments were more difficult for students to comprehend than others, so the definition of effort varied as a result. Typically, if the student made an earnest attempt at the problem, final answer or not, credit was given. The parameters for the initial DSHM submission were as follows:

1. Digital submission of homework must be made before the solution posts.
2. Each problem will be evaluated based on effort and completeness for up to 50% credit.

3. A problem missing any sections, appropriate diagrams, or a good faith effort at the solution in the required homework format will receive no credit.
4. Initial submissions of the homework must be uploaded as PDF documents in Canvas.
5. The Canvas submission window will close automatically as the solution is published. Late Canvas submissions will not be accepted and will not be eligible for Self-Assessment.

For the corrected DSHM submission, the student digitally submitted a hard copy of their corrected initial submission to the grader during the next class period. This submission was assigned with the following criteria:

1. A digital hard-copy submission of self-assessed homework to be turned in three days after the solution posts. Canvas will list specific hard-copy due dates for each assignment.
2. The remaining 50% of the grade will be awarded for submitting a hard copy of the complete and self-assessed homework problem. An incomplete or incorrect hard-copy problem will receive no additional credit.
3. Assessment should provide clear, hand-written documentation of corrections made in a different color.
4. A minimum of a check mark in a different color next to the correct answer will be required.
5. Corrected hard-copy submissions of the homework must be uploaded as PDF documents in Canvas.

The corrected submission was graded on completion, effort and accuracy. The same reasoning for what constitutes a "good faith" effort from the initial submissions applied here. Again, no process was utilized to define this. It was at the grader's discretion. Since they had access to the solution key, students certainly had the ability to ensure their answers were completely accurate. As such, accuracy was crucial to this submission's grade. Students who still did not have the correct answer received no credit for the specific question. Both submissions were subject to the grading rubric below.

Table 2. DSHM Grading Rubric

Canvas Submission	Hardcopy Self-Assessment	Maximum Grade
One-time and Complete	One-time and Complete	100%
One-time and Complete	Late/No Submission	50%
Late/No Submission	n/a	0%

It should be noted that many of the previous implementations of the DSHM and similar methods included the application of "metacognition" [3, 4]. This was a specific portion of the resubmission process where students would describe their rational for arriving at the solution in their original submission, whether they were correct or not. The DSHM parameters for the

course in this study do not dictate this activity as a requirement for submission. Rather, it is seen as an implicit consequence of self-assessment.

Zybook is an online homework platform that hosts a variety of questions for instructors to utilize in their homework assignments. These submissions were automatically graded by the platform based on accuracy with no feedback other than being told the answer was incorrect. Students were allowed unlimited attempts for these questions, but the numbers and choices available were randomly generated with each attempt. Additionally, the Zybook problems could be attempted in any order or even skipped entirely. Students received no credit for attempting the Zybook assignments after their due date.

The participants were provided the following questionnaire to gauge their opinion of the DSHM as compared to the SSHM. The questions featured are similar to those in a previous study [25]. The students were surveyed at the end of the semester before the week of the Final Exam, but after completing all other assignments in the course.

Name: _____ ID:_____

Questionnaire for ECE 2214

(5-point Likert scale; Strongly Disagree – Disagree – Indifferent – Agree – Strongly Agree)

1. I learned the material better with the Dual-Submission Method compared to other homework methods.

Strongly Disagree Disagree Indifferent Agree Strongly Agree

2. I found the self-assessment portion of the Dual-Submission Method to be beneficial.

Strongly Disagree Disagree Indifferent Agree Strongly Agree

3. The time spent on the Dual-Submission Method homework was less than other homework methods.

Strongly Disagree Disagree Indifferent Agree Strongly Agree

4. The Dual-Submission Method made me less anxious about my grade for the assignment.

Strongly Disagree Disagree Indifferent Agree Strongly Agree

5. I did not feel as pressured to study for the exams in this class, because of the Dual Submission Method.

Strongly Disagree Disagree Indifferent Agree Strongly Agree

6. I would like to see the Dual-Submission Method implemented into future classes.

Strongly Disagree Disagree Indifferent Agree Strongly Agree

Figure 3. Questionnaire for ECE 2214

Equation 1 is the mixed two-way model for the study that was necessary to account for the variability caused by the participants. This experimental design was used to evaluate participating students' performance by the associated levels of the grading method for homework assignments and exam questions based on each. This mixed model included two main effects and the interaction of these effects. The main effects were the fixed factor for the grading method and the random factor due to the participants. The random factor for participants was a between-subjects factor as the participants only experienced one condition. The fixed factor of grading method was a within-subjects factors as the participants experienced both of the following levels:

- Grading Method: {SSHM, DSHM}

The dependent variable collected was:

- Student performance on grading method

$$Y_{ij} = \mu + A_i + P_j + A_iP_j + \varepsilon_{ijk}$$

Y_{ij} : Performance on *i*-th grading method from *j*-th participant

μ: True mean response

A: Grading Method effect at *i*-th levels {1, 2}

P: Participant effect at j-th levels {1, …, 59}

ε: Random Error

(1)

Results

Data analysis could not begin until shortly after the end of the Fall 2021 semester. Once final course grades were submitted by the instructor, the investigators were granted access to the course data. This data included student assessment (by the teaching assistants and course instructor in addition to the automatic grading from the Zybook platform) on the homework submissions and exams. The investigators had access to each student's submission to the respective assignment and answers to the questionnaire distributed to the participants. Several participants had conflicts with their data due to a variety of reasons such as missing assignments (due to late enrollment) and class drops. 59 of the original 79 participants' data were included in this analysis to present a complete dataset. Additionally, only the data from chapters three through six were used for analysis due to missing course data for the first two chapters of material taught in the course. Furthermore, only the DSHM and SSHM homework assignments were analyzed as the Zybook and other assignment data was not structured similarly enough to the other methods described to provide effective, interpretable results. Finally, ANOVA results for the random factor of the participant were omitted as it was not the objective of the study. It was necessary to include this random factor in the data analysis to account for the participant variability, but whether students' scores were equal to each other on the same homework assignment does not reflect the difference between the SSHM and the DSHM as seen in the tables below.

For each chapter, the average score for the DSHM assignment consisted of the average across both the initial and corrected submission for a student as each represented 50% of the total assignment grade. This provided a clear one-to-one comparison of a student's score on the SSHM assignment and the DSHM. With an alpha level of 0.05, ANOVA was conducted for each chapter with the following hypotheses:

- H_0: Average score of the DSHM Assignment = Average score of the SSHM Assignment
- H_1: Average score of the DSHM Assignment ≠ Average score of the SSHM Assignment

Table 3. Chapter 3 ANOVA Results

	ANOVA		
Factor	Statistic (F)	p-value	Conclusion
Grading Method	9.348	0.0028	Reject null hypothesis. Average score of DSHM Assignment is statistically different from the Average Score of SSHM Assignment.

Table 4. Chapter 4 ANOVA Results

	ANOVA		
Factor	Statistic (F)	p-value	Conclusion
Grading Method	1.524	0.22	Cannot reject null hypothesis. There is no statistical difference between the Average score of the DSHM Assignment and the Average Score of the SSHM Assignment.

Table 5. Chapter 5 ANOVA Results

	ANOVA		
Factor	Statistic (F)	p-value	Conclusion
Grading Method	1.929	0.168	Cannot reject null hypothesis. There is no statistical difference between the Average score of the DSHM Assignment and the Average Score of the SSHM Assignment.

Table 6. Chapter 6 ANOVA Results

	ANOVA		
Factor	Statistic (F)	p-value	Conclusion
Grading Method	0.001	0.980	Cannot reject null hypothesis. There is no statistical difference between the Average score of the DSHM Assignment and the Average Score of the SSHM Assignment.

Table 7. Assignment Averages based on Homework Method

	Averages	
Chapter	DSHM	SSHM
3	80.39	59.54
4	90.01	84.16
5	77.86	86.29
6	90.68	90.79

With the exception of chapter three, the p-value is less than the alpha level and the null hypothesis was rejected. In other words, the average score of the DSHM assignment was not statistically different from its SSHM counterpart for chapters four through six. This is not to say that the DSHM is generally inferior to the SSHM method for these chapters. Rather, the average scores for the DSHM assignments were similar enough with the average scores for the SSHM assignments that a statistical difference could not be determined for these chapters. The average score discrepancy for chapter three between the DSHM and SSHM assignments is surprising, however. For this chapter, the null hypothesis was rejected; indicating that there was a statistical difference between the average score of the DSHM and SSHM assignments. The first SSHM assignment for this course was presented in chapter three rather than the first chapter, and as a result, may have contributed to this discrepancy.

Again, for each midterm exam at the end of a chapter, ANOVA was conducted on the students' scores on the mid-term question based on the grading method, with an alpha level of 0.05, using these hypotheses:

- H_0: Average of the Exam Question based on DSHM Assignment = Average of the Exam Question based on SSHM Assignment
- H_1: Average of the Exam Question based on DSHM Assignment ≠ Average of the Exam Question based on SSHM Assignment

Table 8. Exam 3 ANOVA Results

	ANOVA		
Factor	Statistic (F)	p-value	Conclusion
Grading Method	4.07	0.046	Reject null hypothesis. Average score of DSHM Exam Question is statistically different from the Average Score of the SSHM Exam Question.

Table 9. Exam 4 ANOVA Results

	ANOVA		
Factor	Statistic (F)	p-value	Conclusion
Grading Method	9.164	0.00305	Reject null hypothesis. Average score of DSHM Exam Question is statistically different from the Average Score of the SSHM Exam Question.

Table 10. Exam 5 ANOVA Results

	ANOVA		
Factor	Statistic (F)	p-value	Conclusion
Grading Method	34.34	1.09×10^{-7}	Reject null hypothesis. Average score of DSHM Exam Question is statistically different from the Average Score of the SSHM Exam Question.

Table 11. Exam 6 ANOVA Results

	ANOVA		
Factor	Statistic (F)	p-value	Conclusion
Grading Method	12.26	0.00066	Reject null hypothesis. Average score of DSHM Exam Question is statistically different from the Average Score of the SSHM Exam Question.

Table 12. Exam Question Averages based on Homework Method

Exam	Averages	
	DSHM Question	SSHM Question
3	85.59	73.73
4	85.76	66.36
5	90.34	60.17
6	90.25	77.29

The null hypothesis was rejected for each chapter analyzed. The average score of the DSHM-based exam question was statistically different from the SSHM-based exam question in the midterms for chapters three through six. The difference in average scores, seen in table 12, for each question type ranged from twelve points to as much as thirty points per chapter. For chapters three through six, the average score was greater for the DSHM-based exam question than its SSHM counterpart. The ANOVA results and higher average scores together specifically suggest an increased retention of course material on the midterm with material previously assigned using the DSHM method

For each chapter, a correlational analysis was conducted for the score of the SSHM-based exam question and the total score for each midterm. This same analysis was applied to the DSHM-based exam question and the total score for each midterm as well.

Table 13. Chapter 3 Exam Correlation

	SSHM Question Score	Total Exam Score		DSHM Question Score	Total Exam Score
SSHM Question Score	1		DSHM Question Score	1	
Total Exam Score	0.2054	1	Total Exam Score	-0.0341	1

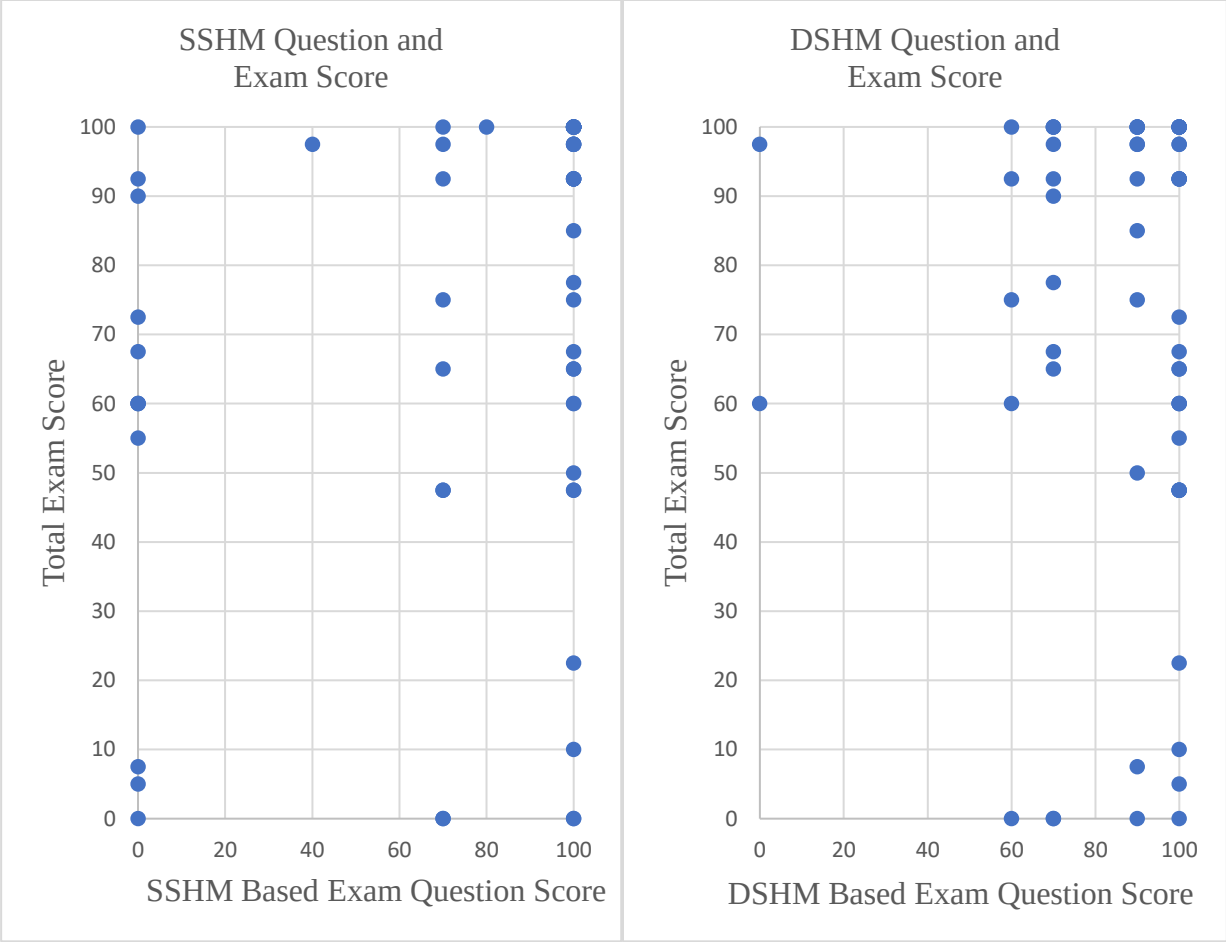


Figure 4. Chapter 3 Exam Correlation

Table 14. Chapter 4 Exam Correlation

	SSHM Question Score	Total Exam Score		DSHM Question Score	Total Exam Score
SSHM Question Score	1		DSHM Question Score	1	
Total Exam Score	0.7496	1	Total Exam Score	0.6508	1

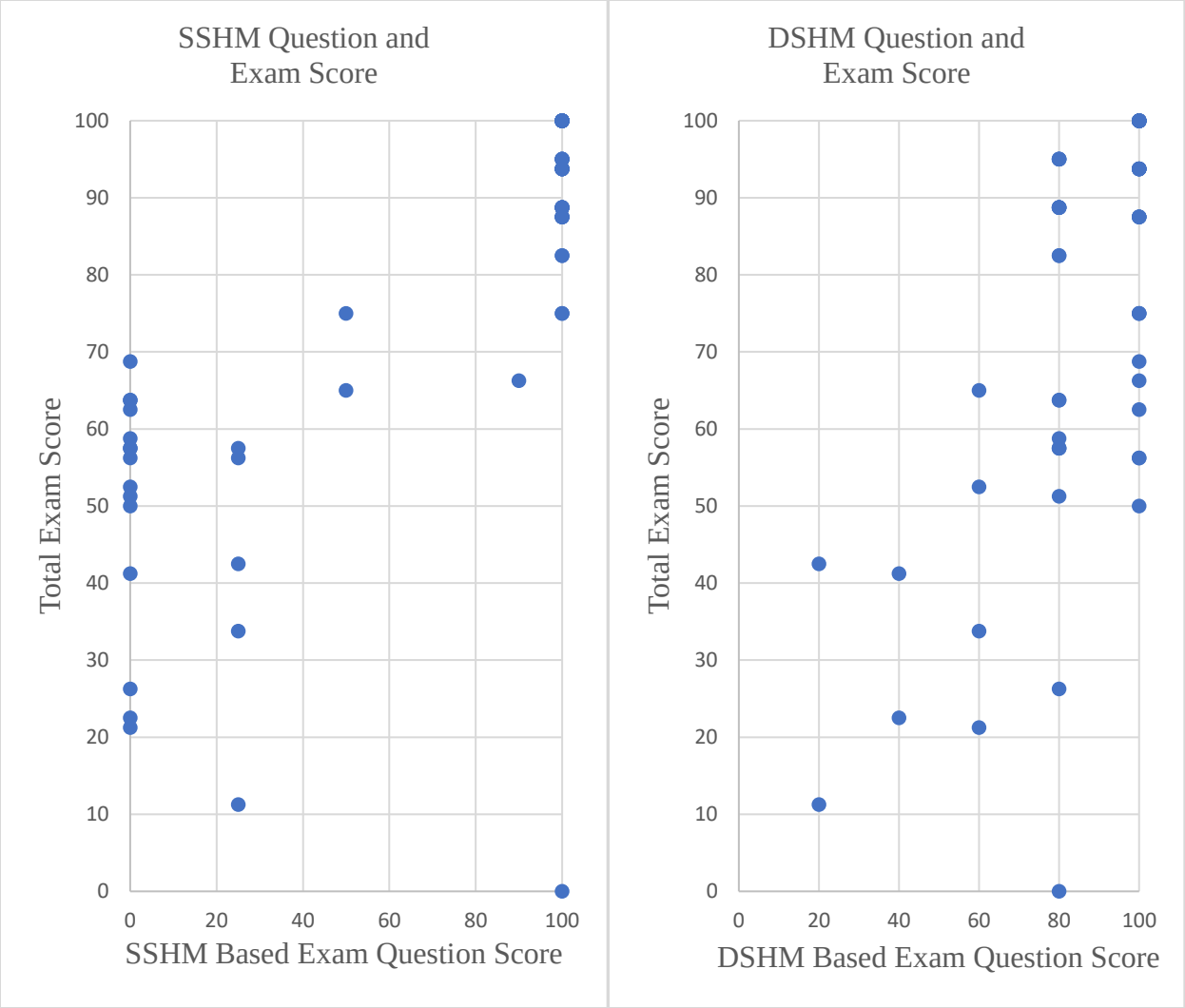


Figure 5. Chapter 4 Exam Correlation

Table 15. Chapter 5 Exam Correlation

	SSHM Question Score	Total Exam Score		DSHM Question Score	Total Exam Score
SSHM Question Score	1		DSHM Question Score	1	
Total Exam Score	0.7409	1	Total Exam Score	0.4877	1

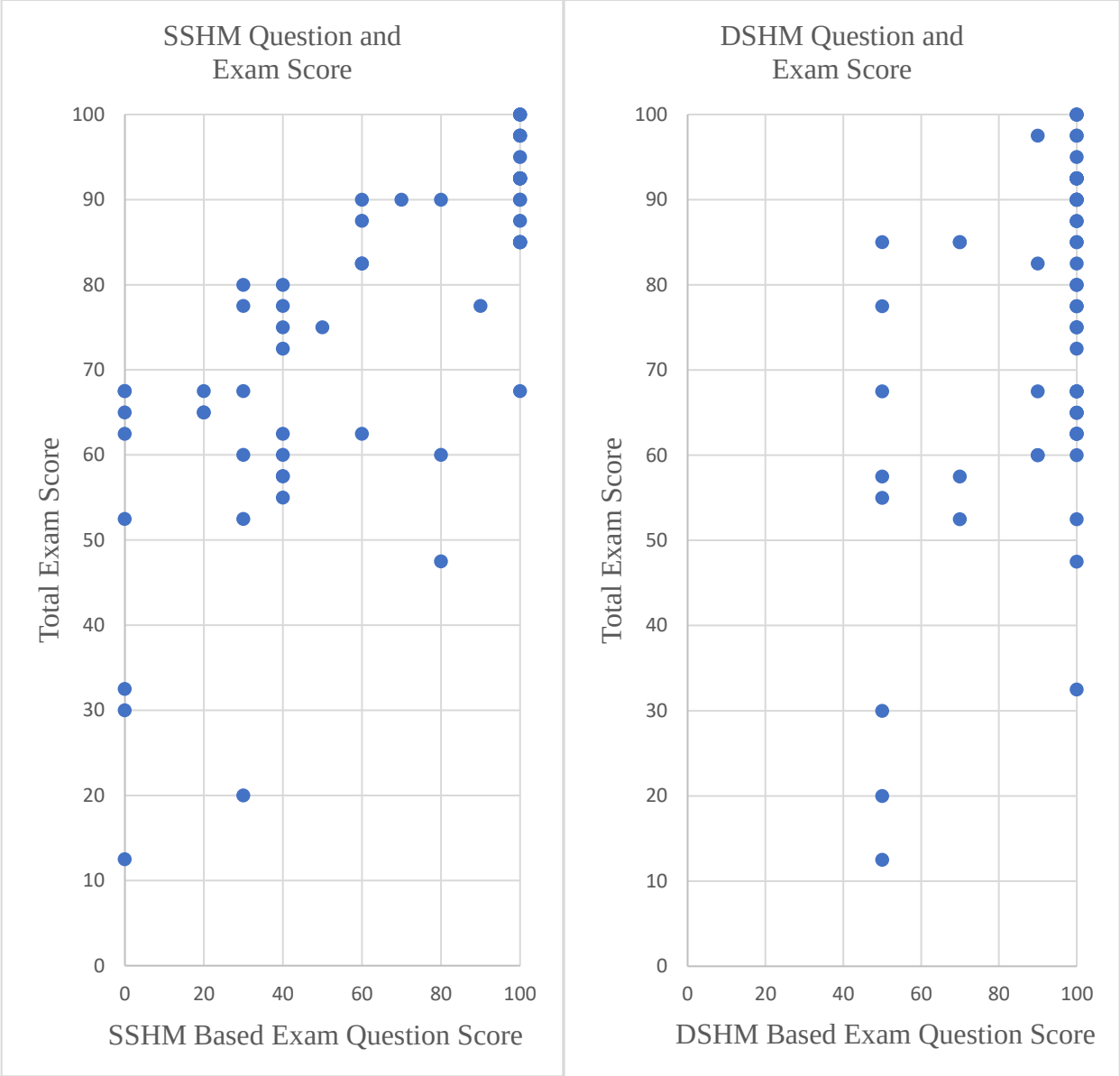


Figure 6. Chapter 5 Exam Correlation

Table 16. Chapter 6 Exam Correlation

	SSHM Question Score	Total Exam Score		DSHM Question Score	Total Exam Score
SSHM Question Score	1		DSHM Question Score	1	
Total Exam Score	0.7465	1	Total Exam Score	0.3256	1

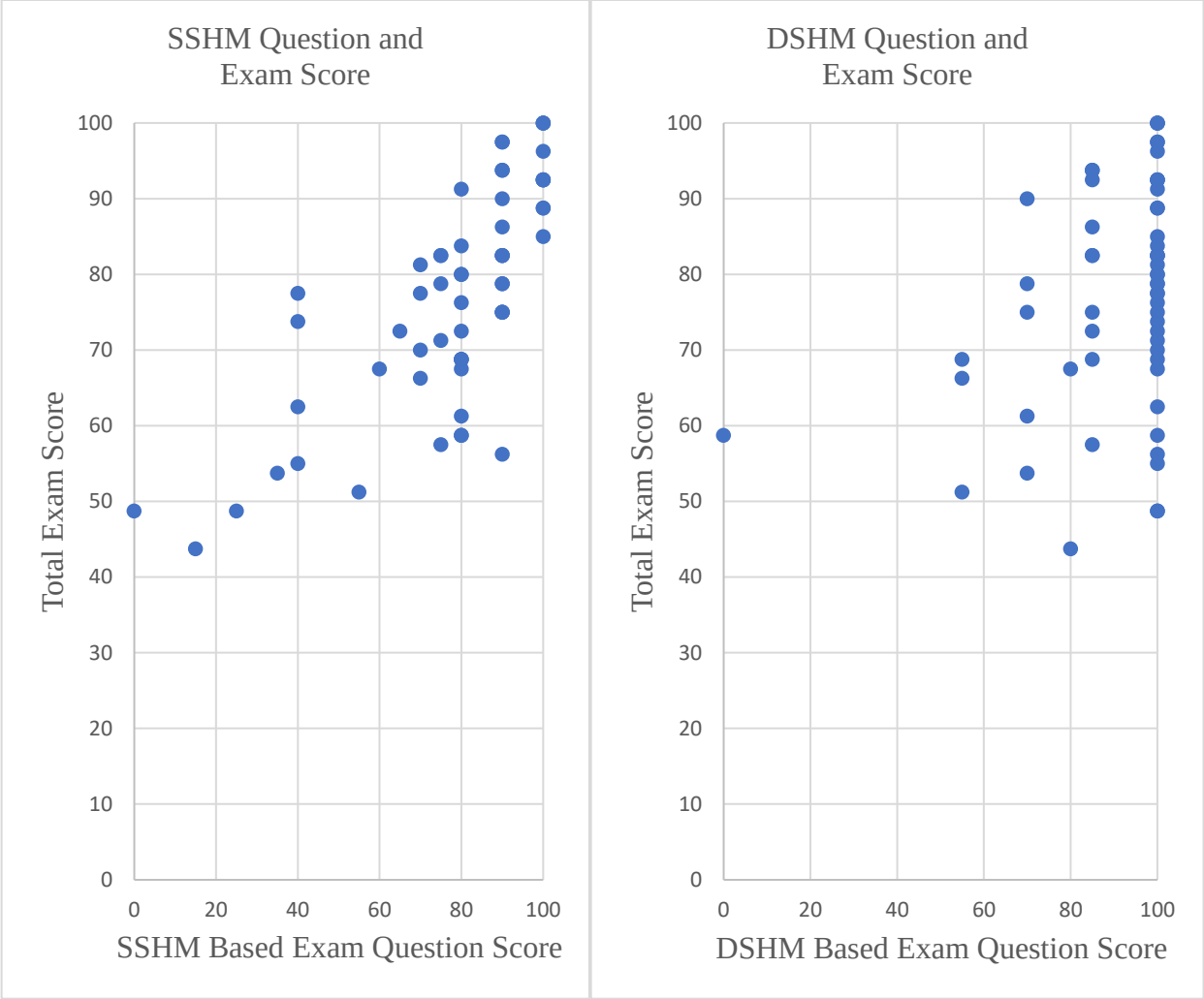


Figure 7. Chapter 6 Exam Correlation

Initially, there was a negative correlation with the DSHM-based exam question and the total score for the chapter three midterm. Meaning, there was a negative linear relationship between these variables. This could be due to the fact it was their first true chapter using the method in addition to the SSHM, so novelty may have potentially created a skewing effect on the data. However, the correlation did increase for chapter four, but consistently remained lower than the correlation for the SSHM. It appears that the DSHM was not necessarily a reliable indicator for total exam performance.

The positive correlation between the SSHM-based exam question and the total score for each midterm suggests that the SSHM positively impacted their exam performance. Since they were more familiar with this method in their academic careers, participant study habits may have been more favorable to the SSHM. However, four additional questions were featured in the exam whose origin came from a variety of course sources. Unfortunately, there was only one question based on each grading method from the chapter, so it is difficult to sufficiently determine whether this reasoning is valid.

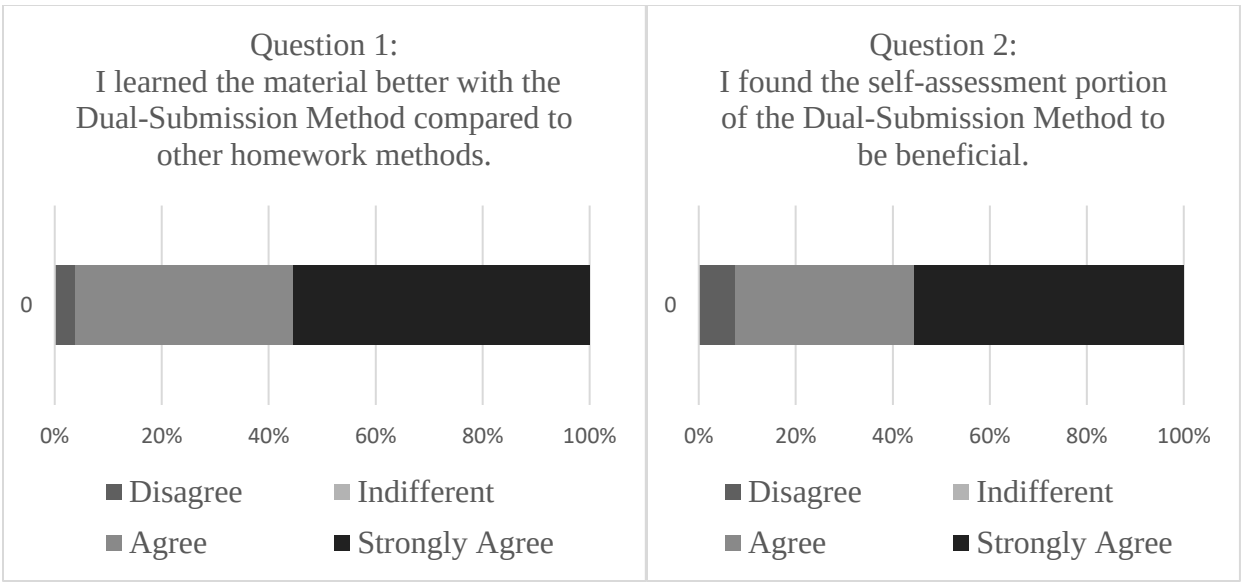


Figure 8. Questions 1-2 Results

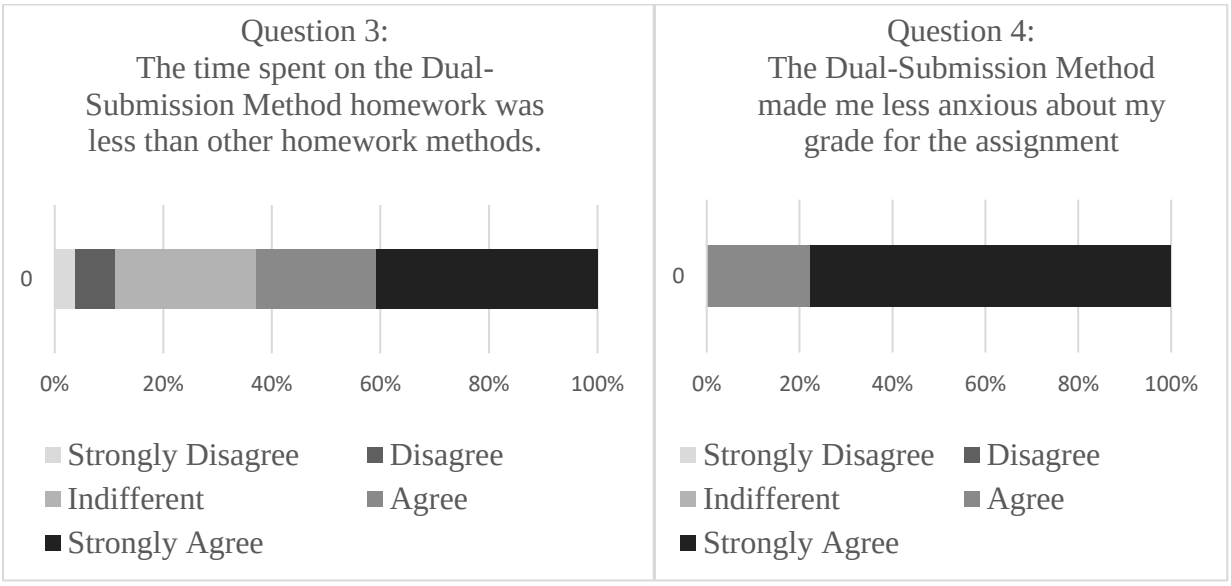


Figure 9. Questions 3-4 Results

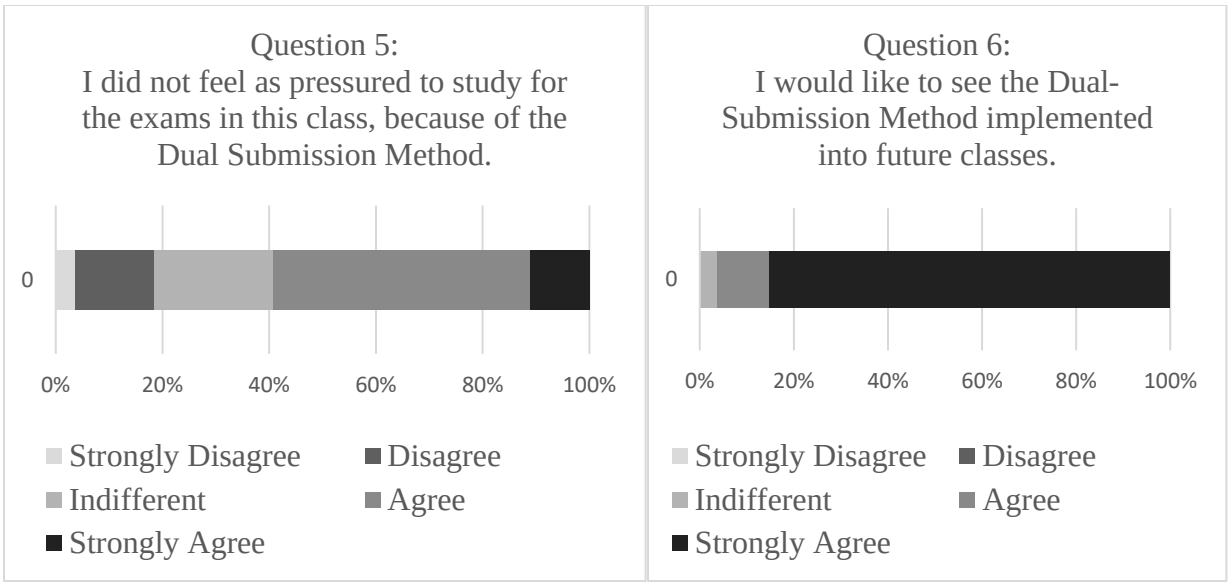


Figure 10. Questions 5-6 Results

Responses to the questionnaire reveal that the majority of participants preferred the DSHM assignments to the other homework assignments methods. Close to 50% of participant responses claimed improved learning comprehension from the DSHM in comparison. Students indicated that they generally found the DSHM to be beneficial with only a small number of participants indifferent to it. Nearly 60% of the participants reported spending less time on the DSHM assignments compared to Zybook and SSHM assignments. Furthermore, well over 75% of participants felt that the DSHM assignments reduced their anxiety for their assignment grades. Finally, an overwhelming majority of participants indicated that they would like to see the DSHM implemented in other courses.

The results from the fifth question featured in figure 10 above are somewhat surprising, however, since previous studies have shown that most students strongly agree that the DSHM created a less stressful environment when studying for future exams [2, 3, 8]. Perhaps, the difficulty of the course material itself pressured students to study for exams. Evident in table 1, exams poised a greater contribution, 60% exactly with the inclusion of the final, to a student's course grade for this study. The exam's weight, which is not a reflection of the DSHM, may have been enough to pressure a student's study habits. While they were not as favorable, negative responses were still in the minority; mirroring the same behavior present in the other questions. For the participants in this study, the DSHM assignments received favorable responses across the board and were significantly preferred to the Zybook and SSHM assignments.

Furthermore, the instructor of the course delivered remarkable praise of the DSHM; stating that students shifted their behavior to "use homework as it was intended by completing it in a thorough manner with more thoughtful work." Rather than just submitting an assignment with rough answers and vague ideas, the instructor reported that students desired to know more about course concepts and how their approaches can lead to a better understanding of the material. Finally, the grader reported spending less time to grade the DSHM assignments in comparison to the SSHM assignments. The grader did mention, however, that the corrected submission took

more time to grade than the initial submission; evaluating the work against the solution key and verifying the student was eligible for a corrected submission according to the parameters in table 2 were cited as reasons for this delay. Overall, the feedback received from all parties about the DSHM, and its perceived effects was similarly positive to that of previous efforts [4, 27, 29].

Analysis

Tables 3-7 provide evidence that participant performance was statistically different on assignments presented by the DSHM and SSHM formats for only chapter three. The third chapter was the first in the course to feature SSHM assignments which more than likely contributed to this outcome. The novelty of the DSHM, despite having two more assignments than the SSHM in the course, may have contributed to this outcome as well. Overall, student performance between each grading type was inconsistent. For participants with little to no experience in self-assessment, the course may have been exponentially more difficult as they would have learned the material and self-evaluation methodology simultaneously. This problem could have been further exacerbated by not specifically outlining the goals of self-assessment or the omission of a dedicated "metacognitive" reflection process.

The definition of "good faith" effort may be related to the ANOVA results for the grading method on assignments. Again, there was no structured rubric on the level of effort for the grader to compare a student's homework against. There were particular cases where it was clear no effort was given (i.e., questions with no responses), however, many students did not fall into this category. Given this, the process of grading was certainly subjective. The grader confirmed as much, specifically, with assignments that were deemed to be of a higher difficulty. This variability tempers the results in tables 3-7. Perhaps, the assignment scores were inflated for certain chapters due to the difficulty of the material and variable grading as a result. The SSHM did not have a subjective process for grading like the DSHM did for a "good faith effort". In the future, the qualities of a "good faith effort" should be stated explicitly to remove any potential variability from this subjective process.

Tables 13-16 and figures 4-7 portray a much different picture than the analysis of homework performance suggests. There was typically a much higher correlation for each chapter between performance on the SSHM-based exam question and the overall midterm score than the DSHM counterpart. This may not necessarily indicate that the SSHM is preferable to the DSHM for exam performance as latency between assignments and the four alternative questions could have caused confounding effects.

For chapters three, four, and six, the corrected DSHM and SSHM submissions had the same due date. The due dates of both submissions for chapter five were separated by one day. Both submissions, closed the day before the midterm for all four chapters in question. The initial submission, however, had a due date that was typically a week before the midterm for the respective course chapter. Participants were first exposed to SSHM assignments much later than DSHM material and closer to the midterm for the chapter. To further complicate this, certain chapters used the same material in both assignment types. So, a student could be introduced to the content in a DSHM assignment, complete it, and then work with that material again on the SSHM.

This set of events for each chapter may have led to a recency bias for SSHM-based exam questions which might explain the stronger correlation seen previously. This effect could be diminished or removed entirely by simply introducing each assignment and setting final due dates simultaneously, with separate content for each grading method. Although there will always be two submission opportunities for the DSHM, at least the material will initially be introduced with the SSHM at the same time.

Furthermore, the correlation may have been affected by the four additional questions that were based on alternative sources. While the other assignment types did not necessarily follow the parameters from the SSHM, the process for submission may have been similar enough to generate the correlation presented. To remove this possibility and provide a clearer picture of correlation, questions for exams, in future studies, should be split evenly between the DSHM and SSHM or any other method to be tested over. This is entirely dependent on instructor preference. Investigators can make this request, but ultimately, it is the instructor's decision on how they would prefer to structure their exams and the rest of the course.

The ANOVA results, present in tables 8-11, revealed how student average scores on exam questions based on the DSHM were statistically different to those based on the SSHM for every chapter in the course analyzed. The data in table 12 specifically indicates the average participant scores on DSHM-based exam questions were greater than the SSHM counterpart for all four midterms. In essence, it was determined that the DSHM contributed to an increase in student comprehension. As opposed to material graded using the SSHM, students were able to prove their understanding and retention of course topics on exam questions with a quantifiable increase from the DSHM. Students and instructors have reported this outcome in previous studies without performance data, but this is substantial empiric evidence to support their claims thus completing a primary objective for this study [2, 3, 4, 27, 29].

Unsurprisingly, both the participants and instructor for the course in this investigation favored the DSHM method compared to the SSHM method for a variety of reasons. Based upon the questionnaire responses and feedback from the instructor, the DSHM method improved the quality of life for both parties. The benefits seen in previous qualitative studies are present in figures 8-10. Workload, stress, and time spent with the material has been reduced for students and instructor alike; all of which have been reported as incentives of academic misconduct for students [4, 27, 29]. Although students and graders reported less time spent on work with the material, there was no data collection portion of this. A suggestion for future studies might be to record the time spent by the graders and students with the DSHM to quantify this claim. Additionally, the instructor believed the DSHM decreased a student's motivation to cheat as they would receive the answers anyway. While this is a welcome benefit, the primary objective of this study was to provide empirical support that the DSHM strengthens student learning and retention.

However, the instructor did not believe that the DSHM, in its homework form, evaluated a student's comprehension of the material as they could completely misunderstand the material and receive a passing grade on the assignment after submitting their evaluation. This may have been a fault of the parameters set for the initial submission, but the instructor clarified the role of homework, in their class, was never to assess a student's comprehension of the material. They maintained the position that the DSHM provided a thorough assessment of a student's effort and engagement with the material, while exams assessed their comprehension of the material.

Participants did notice benefits from the DSHM, present in the questionnaire responses, but these motivational improvements seem superficial compared to the change in work approach that "metacognition" has been shown to perpetuate [3, 4, 19]. Additionally, studies that did not explicitly have student engage in "metacognition" exercises still asked students to ponder the self-assessment process featured in the DSHM and how it has affected their work habits [2, 21]. Unfortunately, this study did not incorporate a direct "metacognition" or reflection component. As such, it remains unclear how student performance fares in conjunction with these underlying activities. Future studies should, perhaps, clarify the aspects, processes, and goals of "metacognition" as it relates to the DSHM with open feedback from all parties involved. Doing so may create the opportune environment for participants to gain a deeper appreciation for the fundamental and conceptual differences between the SSHM and DSHM. Students who are aware of these factors may be more inclined to invest their effort in the DSHM which could result in stronger responses.

The critical data for this study were the results of student performance from both types of assignments and corresponding questions within the exams in chapters three through six. This set featured the most complete data and allowed the investigators to create a one-to-one comparison of data points for analysis. The difficulty level for each homework assignment and exam were subjectively determined by the instructor. The purpose here was to make the difficulty level similar to avoid any resultant skewing effect. While it may be impossible to remove subjectivity entirely, future studies should seek to determine the difficulty level for questions and assignments as objectively as possible. SSHM questions that students have performed poorly on in previous sessions of a course may be a path of interest as well. Performance may change should these questions be implemented with the DSHM instead. This may provide an indication as to whether certain topics could benefit from assessment using the DSHM rather than the SSHM and could be a fruitful endeavor for any future investigators.

While this study suggests that the DSHM leads to increased retention on similar questions featured in midterms, it was unclear how this homework method affects performance when greater time is allotted between introduction of a topic and exam assessment. The time in which students were presented the material and examined over it varied from as little as twelve days to as high as nineteen days. Unfortunately, final exam performance was not included in this study since questions based on topics assessed using the SSHM or DSHM were not present. For each chapter in this course, students were introduced to the topics, given homework assignments over this, and, finally, evaluated over the material by a midterm. Data for future studies should include final exam questions that are like topics from previous chapters where the SSHM and DSHM assignments were implemented. Studies that incorporate this analysis may clarify the differing cognitive effects between short-term and long-term recollection from the DSHM.

Although data from Zybook and other assignments were collected, there was no one-to-one comparison available for this method; leaving its effectiveness compared to the SSHM and DSHM assignments in this course unknown. Despite the omission in this study, it is crucial to mention these additional assignment types. The DSHM can be evaluated against methods other than the SSHM and future investigators should take note of this. Perhaps another study with this same class should include Zybook problems as another factor level for the stated grading method independent variable.

Final grades were not involved in the analysis of the DSHM in this study either. The rational for this omission was due to the exclusion of final exam performance for the reasons mentioned previously and for the number of assignments for each method. The frequency of assignment type for the entire course is presented in the table below.

Table 17. Assignment Frequency

Assignment Type	Frequency
Exams	6
Final Exam	1
Labs	5
Zybook	36
DSHM	6
Challenge Problems	5
SSHM	4

SSHM and DSHM assignments together comprise close to 15% of the total number of the assignments in the class. With such a low figure in comparison, the effect of these methods on the total course score may not have been very distinguishable. That is not to say there is no effect. Rather, any conclusions on how the SSHM and DSHM assignments affect overall course grades may be misleading when there is only a single data point for each type (as is the case in chapters three through six). This affect may have been present in the correlational results. An increase of the frequency of the SSHM and DSHM assignments with alternative methods, while remaining equivalent to each other, may remedy this issue.

A common topic in previous studies has been a revolving discussion over where this method is suitable. In cases of lower-class sizes, it may not be beneficial to an instructor's or grader's time to go through the DSHM process as it could increase grading time. However, this may not be the case for larger class sizes where thorough grading already requires extended periods of time to complete [19]. This study featured seventy-nine participants, but there were still students who chose not to participate that were enrolled in the class. Additionally, the class featured was typically taken by sophomore students. At this level, students have experience with the material, but the course work might still be at a somewhat fundamental level. This may, perhaps, indicate that the DSHM is better suited to lower levels of assessment not featured in junior or senior year classes. Furthermore, only one engineering class, as opposed to multiple courses in previous analysis, was included in this study further isolating the DSHM [19]. These shortcomings may indicate a bias of the DSHM towards these factors. While this is certainly possible, future opportunities to study the DSHM should seek to include data from classes that vary in size, courses, and education level to further evaluate this method. Taking the time to study these factors in relation to the DSHM will provide clarity as to how and where it fits best in higher education.

Conclusion

Although it does not fundamentally necessitate a particular medium, the DSHM can certainly be implemented in both the physical and digital learning environments. Previous studies have maintained physical submissions, while this study utilized the Canvas LMS [3, 4]. Despite this apparent difference, the DSHM garnered similar positive feedback and impressionable quantitative support. While it is compatible, the DSHM is not impervious to the critiques that have plagued both conditions [31, 32]. Given its growing prevalence, it is crucial that the DSHM be amenable to the constraints and conveniences of both physical and digital learning environments. However, self-assessment is the foundation of the DSHM regardless of the medium. Whether a physical or digital method of homework, the objective for any implementation of the DSHM should be one that maintains this principal.

Self-assessment is not a common occurrence in engineering coursework, so students may need more guidance to understand how to best perform this process. As mentioned in the methodology, the process and goals for the "metacognition" aspect of the corrected submission were not explicitly stated to the participants in contrast to their inclusion in previous studies [3, 4, 19]. Students, especially those who have never participated in self-assessment, may not be aware of these subconscious exercises resulting from their self-assessment attempts. As such, an appreciation and understanding of the difference in problem solving approach from SSHM to DSHM submissions may not naturally occur.

Despite this omission, students indicated a shift in their coursework approach. The instructor detailed their experience with a particular student. The student, struggling with an assignment, stated their appreciation for how the DSHM encourages a true understanding of the material as opposed to reliance on online sources. While the topic never occurred in the classroom, the self-awareness demonstrated by this student was indicative of the strategy traits exhibited by "metacognition" reported previously [21]. The behavior here demonstrates how students became much more sincerely engaged with the material than in previous courses. Though this was only one experience mentioned, the instructor clarified that it was representative of the cognitive pattern exhibited by the majority of the additional students. The increased engagement prompted conscientious discussion and analysis with the instructor. Resulting from its implementation, the DSHM has led to a positive feedback loop between instructors and students. The instructor plans to continue the DSHM in all their future courses.

The goal for the DSHM should not be to replace other forms of homework entirely. Rather, instructors should view it as another sufficient method through which they can effectively assess and teach their classes. Whether the DSHM replaces single submission methods as the primary form of evaluation in class or a supplemental alternative to other homework methods, instructors and students can be assured of its effectiveness. The efficacy of the DSHM is clearly presented in the analysis of student performance on exam questions from tropics introduced with this method. Scores were higher for the DSHM-based exam question; indicative of this method's ability to increase student recollection. All the mentioned suggestions and adjustments for future iterations of this study will create a much more holistic set of empirical evidence, with prominent inclusion of qualitative analysis, to refine the assessment of the DSHM's impact on instructors and students. With this study, the Dual-Submission Homework Method has the substantial quantitative and qualitative foundation to support its continued implementation in courses across the field of higher education.

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