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The Efficacy of Student-Revised Homework Assignments in an Introductory Engineering Course

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Abstract

Traditional homework in engineering courses often involves “problem sets” – lengthy collections of problems students solve over a period of days or weeks. Time expenditure on these assignments is high, often numbering dozens of hours for each student over a semester-long course with a similar time spent by instructors to grade them and provide feedback. Instructors must therefore choose the most worthwhile assignments based on time available and impact on student learning and competence.

The purpose of this study is to build on previous research reported in the literature by examining the efficacy of self-revised problem sets in an introductory-level engineering course. Self-revised assignments are defined as those requiring an initial submission, the publication of a complete solution, and a subsequent student requirement to revise the initial submission by correcting any errors. Instructors grade the assignments by assessing most points to the initial work and a lower percentage to the revisions.

Two semesters of students enrolled in an introductory statics and mechanics of materials course (n=219 and 128 students, respectively) and 11 instructors are included in the study. We compare student achievement on select graded events to similar cohorts in past semesters that did not experience self-revised assignments. We also survey students and instructors on their impression of the self-revised assignments to evaluate the efficacy of these assignments in three areas:

1. Student academic performance on exams compared to previous cohorts
2. Student perception of the homework and learning experience
3. Instructor perception of the assignment style’s benefits to students and ease of grading

Outcomes proved neutral to slightly positive in each area. Student grades remained similar to previous cohorts, but struggling students demonstrated increased time spent engaging with the material during the revision process. Students reported neutral to positive perceptions of the method, and instructors generally favored the approach for its reduction in time spent grading. Overall, we recommend other engineering courses consider implementation of a similar dual-submission homework method, and we will continue to implement it in this course.

Introduction

The benefits of homework in academic courses at the secondary and undergraduate levels are well-established. Some amount of homework is correlated with student academic performance, attitudes towards learning, and development of self-regulation habits like independent studying [1]–[3]. However, research emphasizes that homework must be of high *quality* to sustain this correlation; homework quantity is not a suitable proxy [4].

Increasingly, educators are experimenting with "metacognitive" homework strategies that aim to preserve the benefits of traditional homework while encouraging student metacognition – the process of thinking about thinking. In practice, metacognitive homework strategies in engineering courses are those that encourage students to think about how they solve engineering problems. "Student-graded," "self-revised," and "dual-submission" homework methods all encourage student metacognition by requiring students to examine their work multiple times, though individual methods can vary widely in the specific ways students assess their problem solving [5]–[10]. Secondary benefits of homework methods that encourage metacognition can include decreased risks of cheating [11], [12], decreased instructor time spent grading homework assignments [12], and improved student attitudes towards homework [5], [6], though these are secondary in this study to demonstrated effects on student learning.

In this study, we specifically examine the efficacy of student-revised homework, one assessment method that targets student metacognition. We aim to expand upon other work analyzing metacognitive homework strategies, particularly that of Linford et al. [9] by implementing a similarly-structured homework scheme with several key differences:

- The strategy was implemented in a high-enrollment, *introductory* engineering course with a student population consisting of engineers and non-engineer majors.
- Problem sets throughout the semester were *either* traditional or self-revised, exposing students to both styles of homework in a single course.
- Students do not grade their work, instead they simply correct their errors based on comparison with a published solution. Instructors assign all grades.
- Student academic performance across semesters is examined by using relative performance on different sections of the course final examination.

The academic course discussed in this study is "MC300: Fundamentals of Engineering Mechanics and Design." The course includes content similar to a traditional engineering statics course (e.g., application of static equilibrium, truss analysis, and frame analysis) with the addition of basic mechanics concepts (e.g., stress, strain, material properties, and shear force and bending moment diagrams). MC300 is taught in both fall and spring semesters and is considered introductory level. Its only co-requisite is Physics I (covering classical mechanics), which itself has a co-requisite of Calculus I. This study examined MC300 during Academic Year 2023 (AY23) during its fall and spring semesters (AY23-1 and AY23-2, respectively).

The student population in MC300 consists of three distinct sub-populations as shown in Table 1:

- Civil and mechanical engineering majors, who must take the course during their sophomore year.
- Other math/science/engineering (MSE) majors who choose to take the course as an elective, typically between the second semester of their sophomore year and the second semester of their junior year. This subgroup is a mixture of systems engineers, nuclear engineers, chemical engineers, and engineering management majors.
- Non-MSE majors who are required to take the course as part of their three-course "engineering sequence," which is required at West Point to earn a Bachelor of Science degree. MC300 is the first course in the "Infrastructure Engineering" sequence, which also includes infrastructure engineering and construction management.

Table 1 MC300 Student Body Demographics

	Fall Enrollment (AY23-1)	**Spring Enrollment (AY23-2)**	**Total Enrollment (AY23)**
Civil and mechanical engineering majors	120	5	125
Other MSE majors	41	62	103
Non-MSE "sequence" majors	58	61	119
All populations	219	128	347

Methods

The execution of the student-revised homework method used in this study was closely based on the method described by Linford et al. [9]. This method is similar to other "dual-submission" methods outlined in the literature [7], [13]. Students were required to turn in an "initial" submission of their work on a given due date. A detailed instructor-generated solution was published on the course Learning Management System (LMS) at the same time. Students then had additional time (approximately four days) to add revisions to their work, consulting the solution to identify any errors and make associated corrections. They were required to leave their initial work untouched and to make their revisions distinct from that initial work (by working in a contrasting color ink). They then turned in the second "revision" submission on its due date. MC300 employs a no-tolerance late policy; unexcused late submissions are awarded no credit, strongly encouraging students to abide by published deadlines.

Students did not assign any grades to their work, instead simply making corrections and ensuring they worked each problem through until discovering the correct answer. Instructors conducted all grading of these assignments. 70% of the points associated with the student-revised assignment were allocated to the initial submission, while 30% were allocated to the revisions. The grading process for the initial submission was typically quicker than traditional problem sets because most students had identified their errors during the revision process. Full points were awarded for the revised submission if students had identified all their errors and corrected both the errors and all subsequent work (students were required to re-work the problem to arrive at the correct final answer). Students who achieved correct answers on their initial submissions were still required to submit revised documents and were awarded full points if their revisions demonstrated they had checked their answers against the solution (commonly with a small red checkmark).

Instructors still provided comments on student work, often to identify the true source of an error a student had identified but could not resolve. Instructors generally did not consult initial submissions except to verify they had been turned in before the original deadline or when there was any suspicion a student had changed portions of an initial submission during the revision process. Points for both the initial and revised submission were assessed and awarded on the revised submission.

Detailed instructions were published on the course LMS describing this process to students. These instructions included an example of properly-formatted initial and revised submissions, adopting a two-column approach to help students delineate their initial work from their revisions (Figure 1). This thorough structuring of the method was received positively across the course and seemed to improve both student and instructor experiences. We have since begun publishing problem sets documents pre-formatted with initial and revision columns.

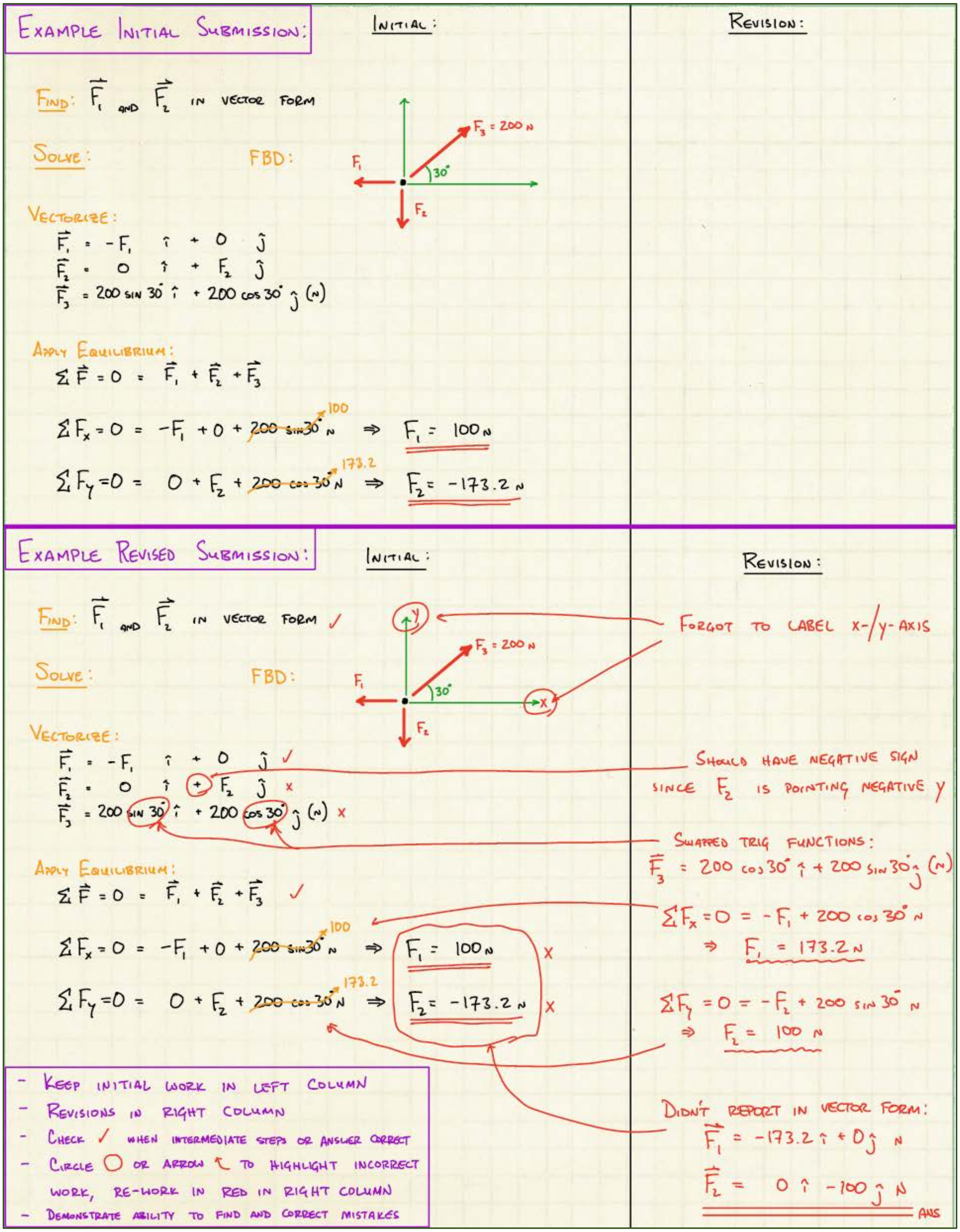

Figure 1 Initial and Revision Submission Examples

Results and Discussion

Assessment of Student Performance

We assessed student performance and the effect of self-revised homework in two ways:

1. Student grades and associated time spent on the self-revised problem set in AY23-1
2. Student grades on the AY23-1 course final compared to grades on the final in AY22-1

MC300 students during AY23-1 completed four problem sets, of which only the third used the self-revised method. This problem set contained questions on 2D and 3D truss analysis in addition to frame analysis. The scope of the problem set was unchanged in comparison to AY22 versions and – while the questions themselves had changed – the overall complexity of the questions was unchanged. Grades for the initial submission of this problem set in AY23-1 were similar to overall instructor-assigned grades for the same problem set in AY22 (Table 2), indicating relative consistency in problem difficulty and instructor grading across semesters.

Table 2 Problem Set 3 Grade Data

Semester	Mean Problem Set Grade
AY22-1 (n=269)	85.5%
AY22-2 (n=158)	86.7%
AY23-1 (n=219) (Initial Submission)	88.2%

Figure 2 shows the distribution of grades for the initial submission of this problem set in AY23-1, in addition to self-reported data from students on time spent completing each of the two portions of the assignment (the initial and revision submissions).

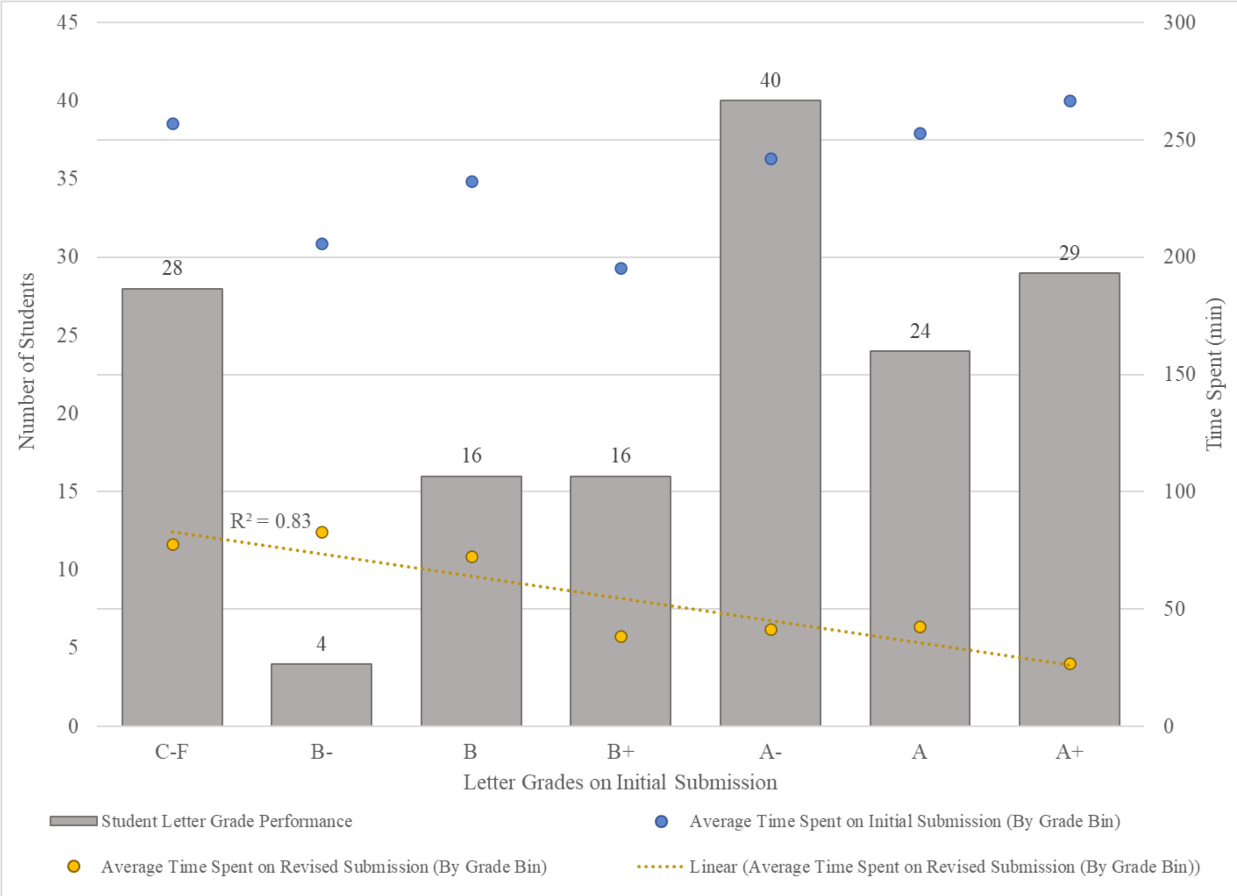

Figure 2 Problem Set 3 Grade and Time Data, AY23-1

The time data (the yellow and blue plots) displays an interesting trend. Students who received an initial grade of a "B" or lower on the problem set reported spending as much time as other students on the initial submission but approximately 45 more minutes on revisions than their peers who earned a B+ or better on the initial submission. This suggests that the self-revised homework method incentivizes students with below-average initial understanding of the course material to spend additional time engaging with their work through revisions.

Time spent on the initial submission of this problem set (the blue points) is comparable to surveyed time spent on the same problem set in previous semesters. This suggests time spent on revised submissions is an overall increase in student time spent on the problem sets, beyond what has previously been spent on problem sets.

Figure 3 shows the relative performance on the course comprehensive final examination between students in AY22-1 and AY23-1. These two semesters were selected for direct comparison due to the similarities in the student population (specifically the concentration of students majoring in civil and mechanical engineering). Incoming student GPA in AY22-1 and AY23-1 was 3.15 and 3.18, respectively, indicating student populations of similar academic ability. In contrast to problem sets, finals in the Civil and Mechanical Engineering Department at West Point are not returned to the student upon completion and are instead retained as a record of student performance between semesters. As such, the content on the final remains largely unchanged from semester to semester and can serve as a reliable indicator of student performance across cohorts. The MC300 final in AY23-1 was identical to the AY22-1 final.

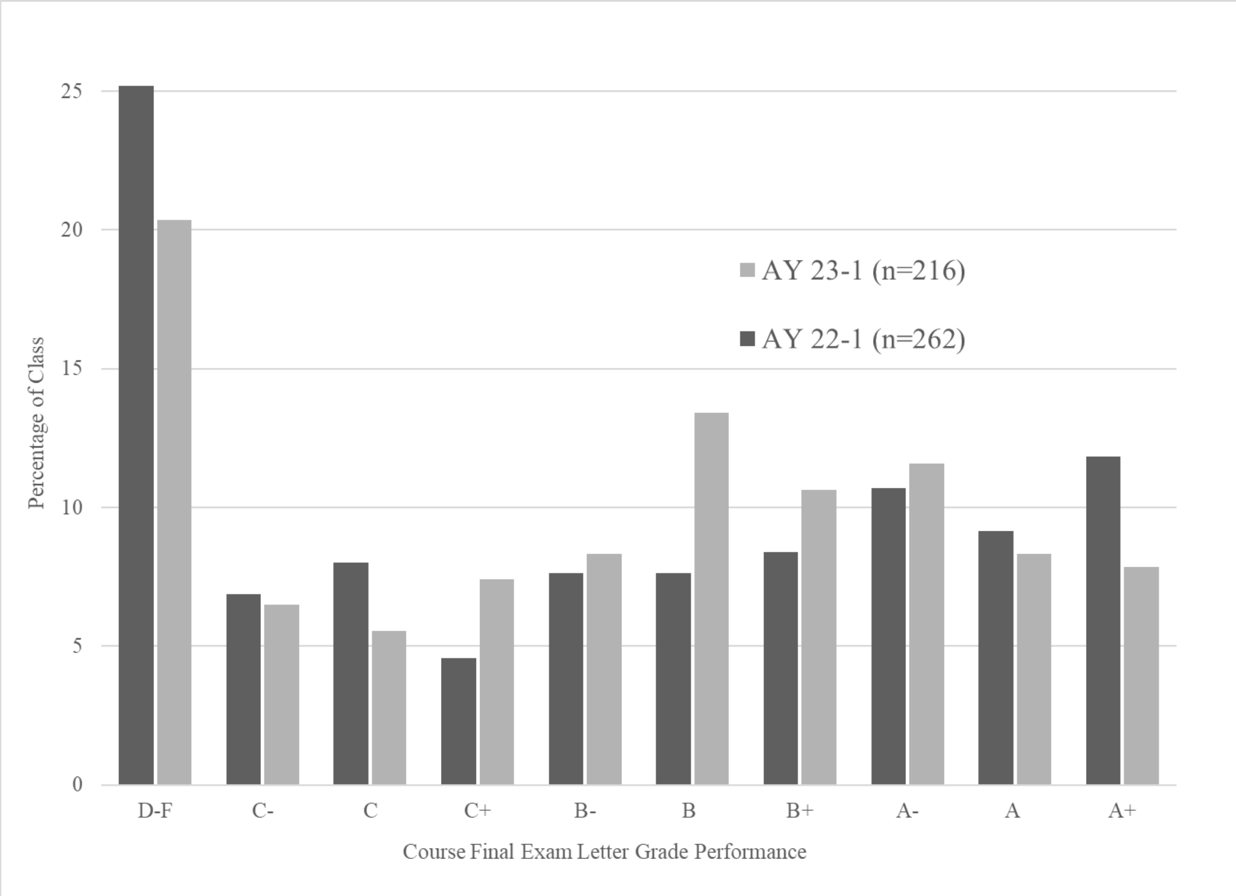

Figure 3 MC300 Final Exam Performance, AY22-1 and AY23-1

Overall student performance on the final in the A-C grade range showed some slight changes between semesters. Grades in the C and A ranges became less common, and more students scored in the B range. However, approximately 5% fewer students in AY23-1 received grades of D or F on the final than students in AY22-1. This result could indicate that the prospective benefits of the self-revised method are concentrated in the portion of the student population scoring worse than average.

The self-revised problem set focused on material constituting half of the total content on the final exam: truss analysis, frame analysis, and 3D equilibrium. Students demonstrated modest performance improvements on truss analysis and 3D equilibrium and a modest decrease in frame analysis (Table 3). Student performance moderately increased on other topics that had not been addressed in the self-revised problem set. Overall mean performance remained very close between the two semesters. This suggests that the self-revised method may have caused improvements in some topic areas but may not have influenced changes in student performance as much as other factors.

Table 3 Final Exam Performance by Topic

Topic	AY22-1 Mean Performance	AY23-1 Mean Performance
Truss Analysis	84%	87%
Frame Analysis	81%	77%
3D Equilibrium	75%	81%
Other Topics (Material and Shape Properties, Simple Connections)	76%	81%
Overall grade on final	80%	81%

One drawback of the method used in this study is that it does not provide a convenient way to measure academic gains from each individual step in the revision process, only a way to measure the overall efficacy of the method. We therefore assessed these step-by-step gains using the quantitative and qualitative survey data below, particularly Question 8 in the student survey.

Assessment of Student Perception

Instructors conducted anonymized student surveys at two points in AY23-1 to collect qualitative data on their perception of student-revised problem sets. The first survey occurred approximately one week after the due date of the first student-revised problem set aiming to collect feedback as soon after assignment completion as possible (shown below as "mid-semester"). Notably, students responded to this survey before many of them had received instructor feedback on their revision submissions. The second survey was embedded within the anonymous course end feedback process, but before students had taken the final.

Both surveys included the same set of single-select questions on student perception of the self-revised problem set. Responses were recorded on a numerical Likert scale from "1" ("Strongly Disagree") to "5" ("Strongly Agree"). The seven survey questions and the students' responses are shown in Table 4. Questions 1-6 were inspired by the question wording and associated reasoning used by Linford et al. [9]. Question 7 specifically aimed to assess whether students were aware of any metacognitive efforts. Question 8 was introduced to assess whether students spent the majority of their time correcting conceptual or technical errors in their work. These questions used a modified Likert scale, in which "1" was "almost entirely technical errors" and "5" was "almost entirely conceptual errors."

Table 4 Student Survey Results, AY23-1

Question	Average (scale 1-5) n=140 (mid-semester)	Average (scale 1-5) n=182 (end of semester)
Q1: The Self-Revised Method helped me learn the material better.	3.7	3.7
Q2: The Self-Revised Method increased my motivation to complete the problems correctly the first time.	3.5	3.7
Q3: The Self-Revised Method was a good use of my time.	3.6	3.7
Q4: The Self-Revised Method helped me review topics that I need to know.	3.6	3.8
Q5: The Self-Revised Method reduced my anxiety about grades.	3.3	3.6
Q6: The Self-Revised Method reduced the time required to study for exams.	3.1	3.2
Q7: The Self-Revised Method made me aware of my own problem-solving thought process.	3.7	3.7
Q8: I corrected conceptual errors (e.g., fundamental understanding, problem setup, strategy, and steps) during my revisions, as opposed to technical errors (e.g., math errors, units, notation).	3.1	2.2

Responses to Questions 1 and 7, related to the efficacy of the method for learning the material and improving metacognition, remained consistent and generally positive throughout the semester. Responses to Questions 2-6, related to various specific benefits of the method, remained the same or showed slight improvement throughout the semester. Interestingly, responses to Question 8 demonstrated that students perceived their time to be spent evenly between conceptual and technical errors in the middle of the semester but felt at the end of the semester they had actually spent most of their revision time correcting technical errors. Metacognitive strategies aim to increase student time spent thinking about the problem-solving process [9], and these results show that they may have spent more time instead focused on non-conceptual technical errors, which is not desired.

Each survey additionally provided an opportunity for students to submit narrative feedback, prompting them after Questions 1-8 to “expand on the above by indicating why you did or did not prefer the self-revised method.”

Students were generally neutral to positive in their comments about the method in the first survey. Many comments suggest the method incentivized student metacognition, even if they identified other shortcomings in the method or incentive scheme:

> *It’s nice to see the correct solution compared to our answer and identify the errors ourselves then learn from correcting it.*

I preferred the self-revised method, in most regards because it helped me to take notes on my problem-solving process, however, I do think that the notes the instructors leave are more precise and they have a big picture perspective.

I thought that the self-revised method was helpful in understanding the material better/made me want to work harder to get the right answer as there was an incentive in that I would not need to do more work after.

I think the self-revised method helped ease my stress about the assignment while still giving me a solid opportunity to test my knowledge if the skills we had learned.

Other students were more critical of the method, characterizing the revision process as redundant, a waste of time, or excessively focused on mechanical errors rather than conceptual misunderstanding:

It encouraged me to be more lazy about my work knowing I could fix the mistakes later.

I always put effort into trying to understand the problems and get the full credit, so the corrections were just another step. I think making it optional would be better.

I felt like I was just correcting mathematical errors, perhaps this method will improve my scrutiny over time but it is hard to tell from one problem set.

Students were similarly neutral to positive in their comments at the end of the semester, though far fewer focused on the mechanics of working through the self-revision process. Most students focused their comments instead on the outcomes of the process:

The self-revised method reduced study time and helped me work through my thought process on mistakes, helping me to solidify how to overcome those particular problems.

I was better able to reflect on my mistakes using this method. This is because, for the regular problem sets, I rarely look at the answer key after submission. This self-revised method forces me to look at correct work improve my understanding of course concepts.

Since I knew that I would be saving my future self some time by doing the problem set right on the first submission, I made sure to be careful with the initial submission. I cared more about not giving myself a headache down the line than I did about my grade.

Several students remained ambivalent or critical of the method:

It made no difference to me because I usually go over what I got wrong on problem sets. I found that peers were less likely to help because it was just an initial submission when doing the 2x submission.

> *I did not* [prefer the self-revised method] *because I would have made the same mistakes regardless, but having my instructor comments on my sheet helped show me where I went wrong instead of having to correct it myself and hope that I was correcting it the right way.*

Implementation of the same method in additional homework assignments within the same semester would likely improve student familiarity with the method and resolve some of the negative comments, but other students simply seemed opposed to the core concept of the method in comparison to traditionally graded assignments.

Assessment of Instructor Perception

Six faculty members that taught the course and graded at least one self-revised problem set during AY23 were surveyed to assess their experience on the assessment method. All six faculty members reported that the self-revised method was a good use of student time and the method made grading more efficient. All but one of the faculty members preferred the self-revised method over the traditional problem set format.

Half of the faculty members believed the self-revised method helped the students learn the material better than the traditional problem set; the other half of the faculty were neutral on which method helped the students learn the material the best. Four out of the six faculty members reported that the self-revised method reduced their overall grading time. The remaining two faculty members reported an equal amount of time spent between the two assessment methods. Both of those faculty members graded only one assignment using the self-revised method and included the time needed to learn the new online grading platform in their time assessment. Both faculty members acknowledged the potential time savings of the self-revised method in their survey comments.

Only half of the faculty felt that the self-revised method improved the ease of providing student feedback; the other half were neutral on which assessment method was better for providing feedback. Overall, the faculty survey produced mostly positive responses towards the self-grading method and no negative comments towards the assessment method.

Assessment of Other Areas

While not directly part of the areas of efficacy identified in this study, the self-revised assignment encouraged students to develop other skills. Many students reported to instructors that these assignments had been their first experience making revisions to their work outside of essay revisions in history or literature courses. Others recalled spending in excess of thirty minutes attempting to find a single error within a problem, remarking on the frustration in that experience. While that sort of targeted error correction would undoubtedly prove frustrating, it may also provide instructors a useful opportunity to emphasize the real-life importance of finding minor errors, bugs, or glitches in complicated engineering systems.

Observations on Method Implementation for Others

We recommend implementing this method only for problem sets and homework assignments comprised of questions that generally have a single answer and a relatively limited set of ways to solve for that answer. The instructor-published solution must be exceptionally detailed, ideally accounting for alternative methods for reaching a given answer. It should follow any problem-solving methodologies taught in class, clearly labeling steps to improve the ability of students to follow along. While we endeavored to provide finely-detailed solutions to the assignments included in this study, some students remarked on the difficulty in completing revisions when their problem-solving method differed from the version published in the solution:

> *On one of the problems, I deviated from the exact way the instructor completed the problem, and it was really difficult to correct my mistake without doing the problem exactly how the instructor completed it. I would have rather had instructor notes on my paper letting me know where I went wrong.*

The self-revised dual-submission method also makes granting extensions more problematic. Since the instructor solution is published immediately after the initial submission is due, any students who require an extension on the initial submission would have access to the solution (assuming it is published through an LMS) before they are required to turn in their initial submission. We denied extension requests, gave students alternate assignments, or simply ordered students not to look at published solutions, but no one method addressed this problem.

Additionally, this method seems to pose some risk of problem set grade inflation. Initial grades are similar to previous semesters, but grades on revised assignments consistently measured in the A/A+ range due to the relative ease of completing the revisions when consulting a published solution. This grade inflation effect could be mitigated by increasing the share of points for the initial submission (perhaps to 80% or 85% of the total points) or even by publishing just the answers to the problems rather than a full solution (thereby making the revision process more difficult).

Table 5 MC300 Problem Set 3 Combined Grades

Semester	Mean Initial Grade	Mean Revision Grade	Mean Final Grade
AY22-1 (n=269)	85.5%	N/A	85.5%
AY22-2 (n=158)	86.7%	N/A	86.7%
AY23-1 (n=219)	88.2%	95.4%	90.4%

Conclusions

This study aimed to implement a student-revised homework strategy in an introductory engineering course to assess outcomes in three areas: student learning, student attitudes, and instructor perceptions. Effects on student learning seem positive, specifically for those students struggling with course material. These students demonstrated increased time spent on the self-revised assignments versus their peers, though overall performance on the final examination did not show conclusive changes in their performance. Feedback from students on their perceptions of the student-revised homework method was mixed, but generally neutral to positive. Some data seemed to indicate students spent more time than desirable correcting technical errors rather than the conceptual errors central to metacognitive homework strategies. Instructor feedback was similarly neutral to positive, with most instructors praising the method for time saved on grading even if the method itself was unfamiliar.

We recommend other technical engineering courses experiment with implementation of self-revised and dual-submission homework strategies. This method was employed in MC300, an introductory course with an academically varied population of students, and we experienced no significant issues with implementation of the method or cooperation of the students. The method has some shortcomings, but we will likely continue to implement it in this course in future semesters.

Disclaimer

The views expressed in this work are those of the authors and do not necessarily reflect the official policy or position of the United States Military Academy, Department of the Army, Department of Defense, or U.S. Government.

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