The Future of Engineering Education
2024 Annual Conference & Exposition
Oregon Convention Center
Portland, OR . June 23 - 26, 2024
Paper ID #43567

A Secure, Scalable Approach to Student-Graded Homework for Self-Reflection

Dr. Matthew Jordan Ford, University of Washington

Matthew J. Ford (he/him) received his B.S. in Mechanical Engineering and Materials Science from the University of California, Berkeley, and went on to complete his Ph.D. in Mechanical Engineering at Northwestern University. After completing a postdoc with the Cornell Active Learning Initiative, he joined the School of Engineering and Technology at UW Tacoma to help establish its new mechanical engineering program. His teaching and research interests include solid mechanics, engineering design, and inquiry-guided learning. He has supervised undergraduate and master's student research projects and capstone design teams.

Dr. Heather Dillon, University of Washington

Dr. Heather Dillon is Professor and Chair of Mechanical Engineering at the University of Washington Tacoma. Her research team is working on energy efficiency, renewable energy, fundamental heat transfer, and engineering education.

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Abstract

A large body of research shows that deliberate practice is essential to developing expertise in any skill. The essential elements of deliberate practice are: (1) motivation, (2) intentional plan of practice, (3) repetition, and (4) timely feedback. We assign homework to provide students with repetitive, intentionally designed practice opportunities, but ensuring that students receive timely, effective feedback is resource-intensive and does not scale well to large classes. In addition, our experience with traditional homework grading suggests that many students do not even view detailed feedback when it is provided. One solution to both problems is for students to grade their own homework assignments.

Direct evidence of effectiveness of student-grading for learning is scant, but suggests that self-grading is more effective than peer-grading for achieving learning objectives[1]. A search of the engineering literature on student-graded assignments turned up a handful of studies[2,3,4,5,6]. The most common concerns are (1) scalability and instructor workload, (2) accuracy and reliability of student scores, (3) student perception and experience, and (4) academic integrity.

We present a methodology for student-graded homework which addresses these 4 concerns, and data demonstrating its effectiveness. Our specific contributions are (1) a scalable workflow using our Learning Management System API (Application Programming Interface), (2) a generic, flexible rubric which maps to ABET student outcomes, and (3) a straightforward approach to encourage academic integrity. We have collected data from three mechanical engineering courses for juniors and seniors: Machine Design, System Dynamics and Controls, and Heat Transfer. Our results indicate that students' self-assessments are accurate and reliable, with an average bias $<+6\%$ and RMS error $< 15\%$. Qualitative data from surveys and reflective journals suggest that students find the process intuitive and useful, and that self-grading prompts deeper reflection on their work.

Introduction

The benefits of self-grading are well established in the literature. First, the practice supports student development of expertise[1,7]. Experts tend to organize domain knowledge around general principles, making it possible to apply the knowledge in new contexts[8]. Students lacking expertise may organize knowledge around superficial connections rather than general principles. Litzinger et al. make the important point that current practice in engineering education may not be well aligned with the development of expertise for many students[1]. Self-grading offers students the opportunity to more deeply understand the way an expert instructor has organized knowledge, and compare that to their own application.

Self-grading also provides very timely feedback to the students, often faster than a grader or instructor might be able to provide. Timely, specific feedback is a crucial component of deliberate practice[9]. In many engineering courses the feedback for students may be delayed until after the next quiz or exam, often several weeks. Self-grading provides feedback immediately after submission. The most compelling reason to introduce self-grading is the opportunity for student reflection and metacognition. Metacognition is the practice of thinking about one's own process or learning[10]. Many studies of engineering students have confirmed the benefits of providing students with structured opportunities to reflect and develop a habit of metacognition[11,12,13]. In this study, we implemented student self-grading to improve student metacognition, provide timely feedback to students, and support student development of expertise. We also aligned our practices with research on alternative grading methods[14,15,16,17] that guided the way we structured the student scores.

The following research questions frame our work:

1. How does the accuracy of self-grading compare to instructor-graded assignments?
2. In what ways do students benefit from self-grading and the process of metacognition?
3. How does the instructor and student workload compare to instructor-graded assignments?

Background

Self-grading has been explored by prior authors in different contexts as shown in Table 1. Gehringer[2] provides a summary of many of the recent papers, including confirmation that most studies report slight overrating of performance by self-grading students. Lower-performing students are more likely to overrate their own performance, but the variations may be due to differences in rubrics and how the self-grading is connected to the course grade[2]. This result was refuted by other authors including Kearsley and Klein[3].

Several studies found clear advantages for self-grading compared to peer grading[4,5]. In fact, the authors expressed concern that peer grading may require more training for student graders about equity to be fair to all populations.

Plett and Peter[6] tested self-grading for engineering students with several important differences from our study. They allowed students to resubmit homework assignments to receive full credit and published the solutions at the time of the assignment, which provides a second step of required paperwork for the instructor. Kearsley and Klein used a similar approach but also confirmed the benefits of the metacognition for the students[3].

Badir and O'Neill[18] took an approach similar to our own, but limited the study to one course. Our work tested self-grading in one cohort of mechanical engineering students as they progressed through the curriculum with a survey at the end of the three term experience. Our project is unique in the three course series examined for mechanical engineering students in one cohort and the examination of both grade accuracy and student surveys.

Table 1: Summary of prior work relevant to student self-grading.

Author/Citation	Year	Population	Intervention	Data Collection
Plett and Peter[6]	2007	Engineering students (n=99)	Self-graded homework + resubmission	Surveys
Haddad and Kalaani[19]	2015	Electrical Engineering students (n=9)	Self-graded homework	Grade accuracy
Kearsley and Klein[3]	2016	Electrical Engineering students (n=34)	Self-graded homework + resubmission	Grade accuracy and metacognition survey
Badir and O'Neill[18]	2017	Civil engineering students (n=27)	Self-graded homework	Surveys and grade accuracy
Jackson et al.[4]	2018	Biology students (n=550)	Peer and self-graded practice exams	Grade accuracy
Present Work	2024	Mechanical Engineering students (n=26)	Self-grading with rubrics (no resubmission)	Surveys and grade accuracy

Methodology

Context

This study takes place in a regional public university in the western United States. The Mechanical Engineering program, which started in Fall 2021, is capped at 45 students per cohort. The faculty have worked to create a culture of community and peer-learning through a student-taught seminar and robust support for student clubs, however we do not have a graduate program in mechanical engineering and thus have no support from teaching assistants.

We implemented student-graded homework assignments in three required mechanical engineering courses: (A) Mechanical Design, (B) System Dynamics & Controls, both junior-level classes, and (C) Heat Transfer, a senior-level class. Due to the course sequencing in the program, most of the students that participated in the study were from the same cohort, and experienced student-grading through multiple courses and instructors.

Table 2: Courses involved in the study.

Course	Level	Term	Enrollment	Number of assignments
Mechanical Design (A)	Junior	Winter 2023	26	5
System Dynamics & Controls (B)	Junior	Spring 2023	25	3
Heat Transfer (C)	Senior	Fall 2023	26	11

Table 3: Comparison of elements of deliberate practice.

	Traditional Instructor/TA Grading	Student Self-Grading
Student Motivations	Maximize homework score and minimize study time. May lead students to consult online databases or copy.	Maximize documentation and understanding during time spent on homework. Develop a sense of ownership over the learning process.
Instructor Motivations	Provide feedback to students about methods and techniques. Often not reviewed by students in a meaningful way since the score has already been assigned.	Provide feedback to students about methods and techniques. Solutions are reviewed by each student in detail.
Intentional Plan of Practice	Provides a structured practice.	Provides motivation for more intentional practice with fear of external grading penalties lessened.
Repetition	Supports repetition of shallow solution strategies.	Students practice ethical self-evaluation of their own process and understanding.
Timely Feedback	Provides feedback after several days.	Provides feedback immediately.

Design principles

The essential elements of deliberate practice are: (1) motivation, (2) intentional plan of practice, (3) repetition, and (4) timely feedback. Our homework strategy naturally addresses these elements, while also ensuring consistency and accountability. A comparison of these elements is given in Table 3.

These essential elements inform several design principles of our homework system:

1. **Accountability and ownership:** Our experience with traditionally-graded homework revealed that students rarely looked at our grading feedback. In fact, Gradescope records whether students have looked at their submission after grading, and we discovered that only about half of students were looking at their submissions at all, let alone actively reflecting on their work. Our self-grading strategy makes students accountable not only for their product, but for the evaluation of their process. Students also develop a sense of ownership over their grades and begin to shift away from the mindset of grades as “granted” by the instructor. In a previous iteration of our system, students would enter their scores directly into the Canvas gradebook through a “quiz” with multiple-choice multiple-select problems in which every answer option was correct.

2. **Consistency:** Students are given explicit guidance on grading through structured rubrics. We use a common-form rubric for assessing all problems, but the rubric may be tweaked for individual problems. Students gain experience applying this rubric over time.

3. **Integrity:** The teaching team chooses one problem to grade for all students, and may look at other problems if a student’s score is dramatically different. The students are not told

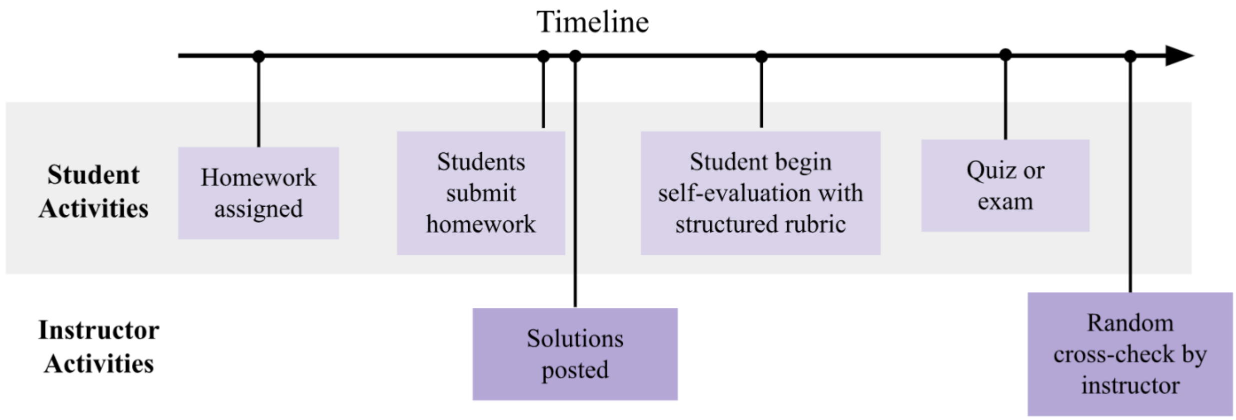

Figure 1: Timeline of events for a single homework assignment.

which problem will be checked ahead of time. This makes it risky to game the system, and also reassures students of the integrity of the process.

4. **Timeliness:** In order to ensure timely and useful feedback, and allow for adequate practice and repetition of skills practice, our system is organized so that students have adequate time to study the homework solutions prior to the unit quiz. The grading workflow should also be scalable so that the teaching team can give feedback to students on their grading accuracy quickly.

Logistics and workflow for junior-level courses

Homework assignments are roughly synchronized with low-stakes semiweekly quizzes. The process for each assignment is as follows:

1. Homework is assigned by the instructor through the course website (Canvas).
2. Students submit completed assignments to the grading platform (Gradescope) by 11:59pm of Day 0 (Monday).
3. On the morning of Day 1 the solutions are released to students through Canvas, along with a grading rubric for each problem. Students begin filling out the rubric as they grade their own assignment.
4. On Day 2 students take a quiz on the material covered in the homework assignment.
5. Students submit their own self-determined scores via a Canvas "quiz" by 11:59pm of Day 4 (Friday).
6. The instructor chooses one problem and grades all student submissions on Gradescope.
7. The instructor replaces the student-determined score with the instructor-determined score for one problem, looks for suspicious entries, and enters final scores into the Canvas gradebook. This final step is automated using a Python script and the Canvas API.

Table 4: Standard analytic rubric structure.

Category	2 Points	1 Point	0 Points
Diagram(s)	Clear, correct, labeled free-body diagram(s) with all forces shown	Incorrect free-body diagram(s) and/or missing forces	Missing diagrams
Equations and variables	Correct equations/laws presented clearly in variable form	Equations present, but don't match diagram or solution method, or unclear variables	Missing, incorrect, or incomplete
Solution method	Correct method, neatly documented	Incomplete or incorrect method	Missing or unclear method
Calculations	Error-free and neat. Includes correct units	Missing or incorrect units, or minor errors	Significant errors in calculation
Communication	Clear work and relevant reflection	Readable work with marginally relevant reflection	Messy or missing reflection

Assessment

Students are provided with a grading rubric for each problem. We use a standard analytic rubric (Table 4), which we modify or clarify for each problem, depending on specific context. Students are given explicit instructions in each homework statement to follow a common solution format—including diagrams and a reflection on the solution and its implications—that roughly matches the standard analytic rubric. The detailed rubric includes instructor comments and additional guidance on grading each part. An example is shown in Table 5.

Students fill out the rubric template in a Word document, and then enter their problem scores in a Canvas quiz, along with their completed rubric. The quiz includes an academic integrity attestation. This quiz is worth zero points, but stores the students' numeric responses.

The instructor then chooses one problem to grade as a consistency and integrity check, and the instructor or grader scores student submissions in Gradescope. These scores are synced to an assignment placed in a grading category worth 0% of students' total grade. The instructor then runs a Python script which extracts students' self-scores from the quiz compares their self-score and instructor score for the specified check problem, and generates a report of student and instructor scores for each student. The instructor may then follow up on any submissions with large score discrepancies. Final student scores are determined by substituting the instructor score for the check problem, and then entered automatically into an assignment in the gradebook.

Table 5: Example rubric for a specific homework problem.

Category	Notes	Score
Diagram(s)	Free-body diagram of bolt-plate assembly showing internal forces	/2
Equations and variables	Equilibrium equation, Hooke's law, and compatibility requirement, or other relevant equations.	/2
Solution method	Clear, relevant connection between analysis and justification (e.g., bolt should not loosen). This question can be answered without numerical calculations.	/2
Communication		/2
Total		/8

Results and discussion

Accuracy and reliability

We assessed student self-grading accuracy by comparing students' own scores to instructor-assigned scores on one problem per assignment. The instructor and students used the same solution and rubric. The instructor did not see the students' scores prior to grading, and vice-versa. Students did not know which problem would be checked for consistency prior to submitting their own scores. Grading comparisons are shown in Figure 2.

We analyzed three metrics of consistency: bias, number of outliers, and RMS error. Bias is the mean of the percent error (student score - instructor score)/(max possible score). A positive bias indicates that students are assigning themselves higher scores than the instructor. Outliers are defined as students whose self-score differed from the instructor score by more than 25% of the maximum possible score for the problem. RMS error is the root mean square score difference (normalized by maximum possible score). A larger RMS error indicates less agreement between students and instructor.

The average bias across all assignments was +5.5% and the average RMS error was 15%. Overall, only 7% of student scores differed from the instructor score by more than 25%. Given the inherent subjectivity of scoring rubrics which award points for process and correctness, we find these results very satisfactory. Furthermore, there is evidence that consistency improves over time. Figure 3 shows all three accuracy metrics by assignment. There is a clear general trend towards closer agreement as students get more experience grading their own work.

Student perceptions

We surveyed students at the end of the Fall 2023 quarter after they had experienced three consecutive courses with self-grading. The survey consisted of one open-ended question: "How was your experience with self-graded homework in this class? Do you have any suggestions to improve the process?", one question about time spent grading each assignment, followed by a series of four Likert-scale questions about metacognitive behaviors in comparison to traditional homework. We received 23 responses (88% response rate). The overall quantity of feedback from

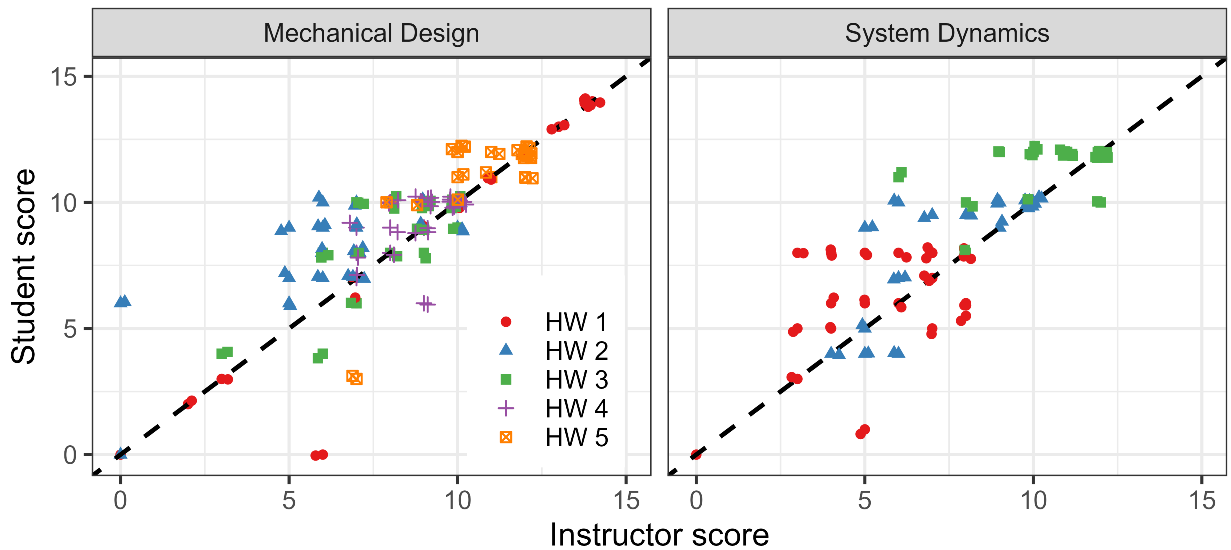

Figure 2: Comparison of student score and instructor score. The dashed black line indicates perfect agreement. Data points are jittered slightly to reveal overlaps.

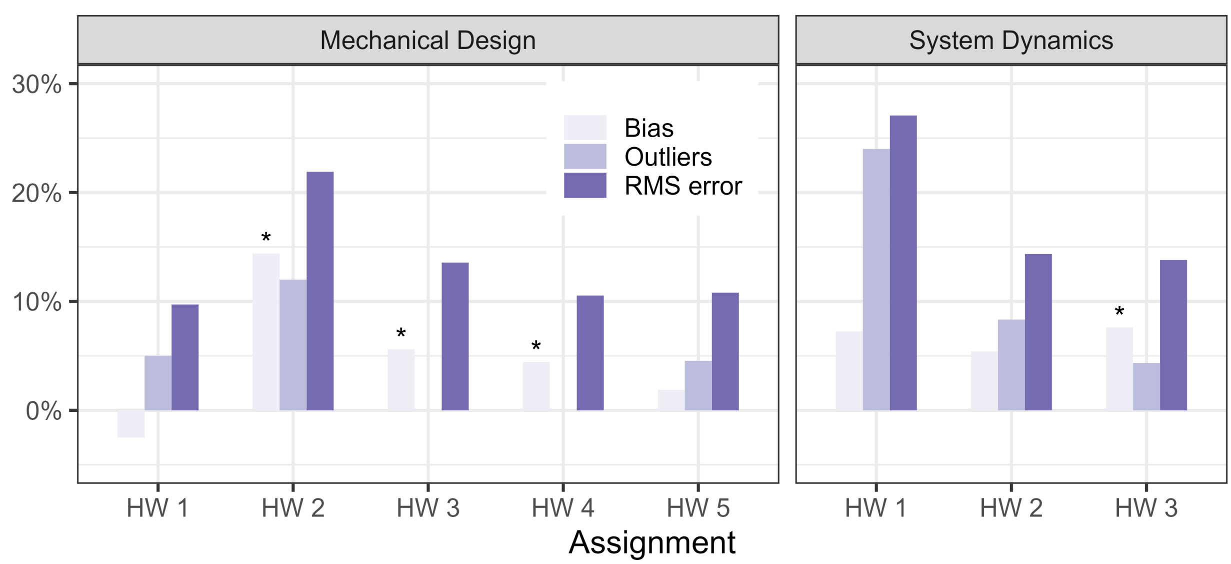

Figure 3: Accuracy metrics for each assignment. Asterisks indicate assignments for which the bias is statistically distinguishable from zero (p-value $< .05$).

students was high, with no blank responses and an average length of open-ended response of 38 words.

Student perception of value was generally positive. We categorized the overall tone of each open-ended response as Positive, Negative or Neutral. Responses with positive words ("like," "good," "helpful," etc) were marked Positive. Responses with mixed sentiment or neutral phrases ("fine," "OK," "no issues," etc) were marked Neutral. 65% of responses were Positive, while 30% were Neutral. Only one response was coded as Negative because the student only reported logistical difficulties with the self-grading process.

Students reported spending an average of 20 minutes on self-grading per assignment, with 87% of students spending between 10 and 30 minutes. No respondents spent more than 60 minutes per assignment. One respondent mentioned that they did not like filling out the rubrics, but the same respondent liked the overall system.

A few students raised concerns or offered suggestions for improvement. Two respondents reported minor logistical difficulties with the process. One respondent asked for more guidance for self-grading specifically, while another expressed a desire for more feedback from the instructor on problem-solving. Only one respondent expressed concerns about academic integrity ("I understand that this is a method that can be taken advantage of by others."), but went on to say that the experience was very valuable for their own learning.

Metacognition and self-reflection

Our survey results indicate that students engage in more reflective and metacognitive activities—asking questions, preparation for assessment, reflecting on mistakes—compared with traditional homework. Reported agreement with questions regarding reflection activities are shown in Figure 4. Agreement level ranged from 61% ("I review my past homework assignments...") to 65% ("I ask myself more questions..."). Disagreement level ranged from 4% to 22%.

These results are further supported by the open-ended responses. We coded the open-ended responses for common themes. The results are summarized in Table 4. The most frequently-coded theme was "Learning from mistakes," exemplified by the comment below.

> "I like that it **forces you to take a second look** at your work and see what things you understand and areas where you need to improve. **With traditional homework I often wouldn't review my homework after submitting it** unless I was surprised to receive a poor grade or to study before a test." (emphasis added)

Several other students admitted that they would not look at posted homework solutions under traditional grading schemes, unless they were surprised or disappointed by their score. This underlines another important theme in our open-ended responses: a shift from surface-level learning, motivated by performance goals, to deeper learning, motivated by mastery goals.

> "...it allows me to focus on learning rather than just completing the assignment to get points!"

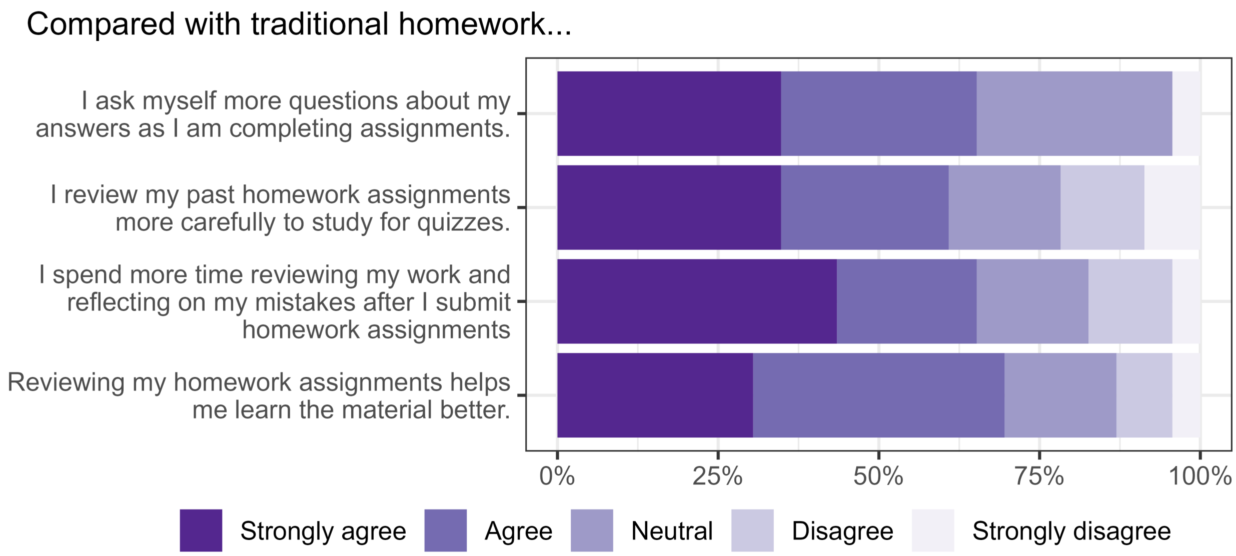

Figure 4: Survey responses for metacognitive behaviors.

> "...taking away the pressure [of external grades] really helped me to focus more on my understanding of the material."

Three students mentioned the opportunity for self-reflection, while three students specifically mentioned a shift towards learning and deeper understanding.

Our results do indicate, unsurprisingly, that self-grading increases students' total time spent on assignments. Students estimated an average of 20 additional minutes per assignment, and 65% of students endorsed the statement "I spend more time reviewing my work..." Any additional time on task is expected to be beneficial for learning, but we believe that the additional time spent reviewing their own work is more valuable for learning than the equivalent time added by increasing the length of a homework set. Indeed, students still struggle with homework in our system, but, as one student put it: "it became clear that struggling with the homework was the only way to have consistently good quiz grades."

Table 6: Themes from open-ended response.

Theme	Number of responses
Learning from mistakes	7
Self-reflection	3
Deep learning	3
Want more guidance from instructor	2
Opportunity for feedback	1
Productive struggle	1
Traditional homework is equally good	1

Instructor perceptions

Two different instructors participated in the self-grading activities over three courses. Both instructors observed themes consistent with the student reported observations:

- Students spent more time reviewing instructor solutions than past classes. For example, in the heat transfer course, students found a few typos that had been present in the instructor solutions for many years.
- Students expressed lower levels of anxiety around homework than prior years, but also demonstrated spending significant time on the problems with questions and clarifications.
- Exam/quiz performance was consistent with, or slightly improved from prior cohorts of students taking the course. We do not have results from an identical learning assessment, nor do we have anything resembling a control group because our program is so new, so we stop short of claiming direct evidence of learning gains.
- Time spent grading was reduced for at least one instructor that already had detailed homework solutions available to share with students.
- A few students did not fill out self-grading rubrics honestly later in the term. Once the instructor corrected their grades (down) the word spread and no further issues were observed.

In general the benefits of self-grading are significant and both instructors plan to continue the practice. The primary benefit observed is the self-reflection about the problem process observed in the students.

Conclusions

The study provides insight into each of the proposed research questions.

RQ1: How does the accuracy of self-grading compare to instructor-graded assignments? When provided with a structured rubric, students' own grade assessments are consistent with instructor assessments. The average bias (<+5.5%) and RMS error (<15%) are acceptable, given the inherent subjectivity involved in scoring problem sets. The consistency check decreases the risk of cheating, and also effectively reassures students that their peers are being held accountable. The number of outlier scores is small (<7% of scores differ by more than 25%), and those students quickly learn how to apply the rubric in accordance with our standards, leading to an improvement in grading accuracy over time.

RQ2: In what ways do students benefit from self-grading and the process of metacognition? Students report spending an average of 20 additional minutes reviewing their work under our self-grading model. In one course (Heat Transfer), students also revise and resubmit their solutions, offering another opportunity for practice. The self-grading workflow guides students through an important metacognitive exercise that increases the value of the practice (the original assignment) itself.

The self-grading process also increases the value of feedback by making it more prompt (solutions are available right after the homework deadline), and specific (students look at their actual work). A majority of students report reviewing their assignments more carefully when preparing for quizzes, which increases motivation. The most common theme from student comments is the ability to learn from mistakes.

Students also report an increase in metacognitive behavior (self-questioning) while completing homework assignments, knowing that they will be grading their own work. Our own experience suggests that students also engage in self-evaluation prior to the homework deadline by reviewing their work and asking themselves how it might match up against the grading rubric. This also presents us with an opportunity to encourage other positive metacognitive behavior by structuring our grading rubric to reward certain strategies.

RQ3: How does the instructor and student workload compare to instructor-graded assignments? The instructors noted a modest reduction in workload for student-graded assignments. The fixed costs of providing more carefully-guided rubrics would have an even larger payoff for large-enrollment courses. The logistical burden of reconciling instructor and student grades is significantly lessened through the use of a Python script interfacing with our learning management system's API.

Reviewing the student self-graded assignments did require additional student time, but the benefit to the students was significant and worth the effort. Students confirmed the benefits in several ways, and the practice is recommended for future upper division courses.

Acknowledgements

Special thanks to Niki Schultz for the original version of some of the rubrics used in this study, and for many patient conversations about homework rubrics over the years. Special thanks to Professor Brian Kirby for inspiring us with his approach to self-graded homework.

Code availability

The Python script for comparing and entering final homework grades is available at `https://github.com/dashdotrobot/self-grading`.

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