

Self-Corrected Homework for Incentivizing Metacognition

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Abstract

A homework grading model is presented where students grade and correct their own homework, and they are evaluated on their own ability to subsequently grade and correct. It is well-known that a large percentage of students regularly consult online solution manuals when completing homework, and the homework model presented in this study seeks to adapt the incentive mechanisms to enhance utility of homework as a form of formative assessment while encouraging higher-order thinking and metacognition. An analysis of data collected from student-graded and instructor-graded homework is presented, as are survey results which suggest self-corrected homework encourages students to be more aware of their learning.

Introduction

With the widespread availability of online solution manuals, ever more intelligent search engines, and repositories containing solutions from previous course offerings, the utility of traditional homework as a form of summative or formative assessment is increasingly unclear¹. Traditional homework models reward correct answers, incentivizing students to consult online sources for answers; studies have shown that 90% of students consult (questionably obtained) online solution manuals when completing homework^{2,3}. While there are means to counteract this somewhat (e.g., creating new problems or variations each course offering), it would seem that with the rampant use of solution manuals by students, traditional graded homework assignments are an unreliable indicator of student learning.

In this study, which was conducted in two junior/senior-level electrical engineering classes as well as a third freshmen-level introduction to engineering course, we explore the use of a self-grading and self-correcting homework model as means for encouraging metacognition. While previous studies have investigated the use of self-grading^{4,5,6,7,8,9,10,11} and self-correcting^{12,13}, most of them have left traditional incentive mechanisms in place. This work considers an alternate incentive mechanism with the aim of encouraging students to attempt problems on their own while removing the incentive to plagiarize. Instead of assigning students a grade on the accuracy of their homework, we grade them on their own ability to evaluate and correct their homework. Under this model, which was independently developed but bears similarities to one very recent work¹⁴, students submit homework twice: the initial submission where there is no penalty for wrong but complete attempts, and a second submission after detailed solutions are provided by the instructor where students grade and correct their own homework. The recorded grade they ultimately earn for the assignment is based on how well they grade and correct their homework, encouraging a self-reflective analysis of their own learning.

The first question we attempt to verify in this study is how well students in engineering courses grade their own homework when a self-graded homework model is in place. This is a question that has been addressed previously in the literature in other disciplines^{4,5,6,7,8,9,10,11} where it has been demonstrated repeatedly that most – but not all – students tend to assign themselves slightly lower grades than instructors, and we seek to compare our results with others. To do so, we graded a photocopied version of each student's initial homework submission without the students' knowledge; meanwhile, the students used an answer key and grading rubric to grade their own initial homework submission, which they subsequently resubmitted, and the results were compared. Our findings are largely in agreement with the majority of the literature on self-graded homework assignments, confirming that the widely reported results from other disciplines appear to also be relevant to self-graded homework in electrical engineering courses. The second question we attempt to address regards the students' perceptions of the self-graded and self-corrected homework model, compared to the traditional model. Our intention is to assess whether self-reflection via self-correction encourages deeper personal involvement and awareness of the learning process. Metacognition is a complex construct that is not directly observable¹⁵, and in this study we resort to the common but limiting approach of self-reported survey results from students as a means to assess metacognition. Results from the survey show that students do indeed report a higher awareness of their learning process, suggesting that this alternative grading model incentivizes metacognition.

Methodology

Subjects and setting

The Department of Engineering and Design at Western Washington University (WWU), established in 2014 as part of a state-funded transition from Engineering Technology, has approximately 400 undergraduate students with about 100 students enrolled in the electrical engineering program. In the conception of the new engineering programs, project-based learning was identified as a key component of the curriculum, and consequently the majority of courses in the department have a weekly lab component. While the labs provide an opportunity for hands-on learning, problem solving at all levels is primarily practiced through weekly homework problems, in introductory courses up through senior-level courses on more advanced topics.

This case study of self-graded and self-corrected homework problems was conducted in three classes within WWU's Engineering and Design Department, taught by two different instructors, and includes a freshman (100-level) introductory course, a required junior (300-level) electrical engineering course, and an advanced senior (400-level) concentration-specific course on communication systems. Specifically, the three courses in this study and their terms offered include:

- ENGR 104 – Introduction to Engineering and Design (Fall 2015),
- EE 360 – Communication Systems (Winter 2016),
- EE 460 – Digital Communications (Fall 2015).

The number of self-graded and self-corrected assignments that students in each of these classes

had completed at the time data was collected for the study varied widely. Students in ENGR 104 had completed four such assignments when data was collected, students in EE 360 had completed a single assignment, and students in EE 460 were part of a cohort of students that had been exposed to self-graded and self-corrected assignments for three consecutive quarter-long classes comprising 27 total homework assignments. Thus, the study includes students with a diversity of progress toward degree completion, as well as a diversity of exposure to self-graded and self-corrected assignments.

ENGR 104 is a freshman-level course not required for electrical engineering majors that introduces students to the broad field of engineering, the design process, and how to communicate ideas with graphics. Coursework includes team design projects, orthographic drawing instruction, and history of engineering. EE 360 is a junior-level course required of all electrical engineering students, and serves as an introduction to communication systems. The course relies heavily on principles of signals and systems and is fairly mathematical, thus requiring extensive problem solving practice. EE 460 is a follow-on senior-level course that explores digital communication systems in more depth, and is required only of electrical engineering students who have chosen the “electronics” concentration.

Homework grading procedure

When the self-graded and self-corrected assignments were first introduced to the students, the instructors each devoted class time to perform instructional scaffolding to explain the motivation and rationale for self-graded and self-corrected assignments, as well as a review of the grading rubric and procedure. As mentioned above, the three courses in this study were taught by two different instructors; thus, while most of the homework submission and grading procedures were identical for the three courses, there were minor variations between instructors as described in the following homework submission and grading procedure:

1. **Weekly homework assigned by instructor.** Homework problems were assigned each week, and due the following week.
2. **Initial submission by student.** Students completed the homework within 7 days. In ENGR 104 the instructor reviewed assignments for completion and signed off accordingly. In EE 360 and EE 460, students scanned their homework (either with a smartphone app or with a flatbed scanner in the lab), and submitted it electronically. This step provided proof to the instructors that all of the problems had been attempted.
3. **Solutions distributed by instructor.** Immediately after the review of the initial submission, detailed solutions were distributed by the instructors.
4. **Homework self-graded by student.** The students then had three additional days to review the solutions and assign themselves a grade for each problem by following the provided grading rubric. Students were instructed to use a different color pen than that used to complete the homework.
5. **Homework self-corrected by student.** In addition to grading their homework, the students were also asked to correct any incorrect answers. Rather than simply copy the distributed solutions, students were asked to reflect, identify, and correct their specific logical, mathematical, or formatting/drawing errors.

6. **Second submission by student.** Three days after the initial homework submission, students re-submitted a hard copy of their graded/corrected homework for evaluation.
7. **Grade recorded by instructor.** The instructor provided a final grade based on the quality and accuracy of the corrected, final submission. In the entry-level ENGR 104 course, the instructor used a scale from 0 to 100. In the more advanced EE courses, a “coarse” grading scheme was used, with the students receiving one of three possible scores:
 - 100% – when the student had attempted all problems and done a satisfactory job grading and correcting.
 - 50% – when most but not all problems were attempted, or the assignment was self-graded and self-corrected incompletely or inadequately.
 - 0% – when a significant amount problems were not completed, or the self-grading and correcting was woefully incomplete.

A time-line showing two consecutive weeks of this homework assignment and grading procedure appears in Fig. 1. In the figure, student tasks are shown on the top, while instructor tasks are shown on the bottom.

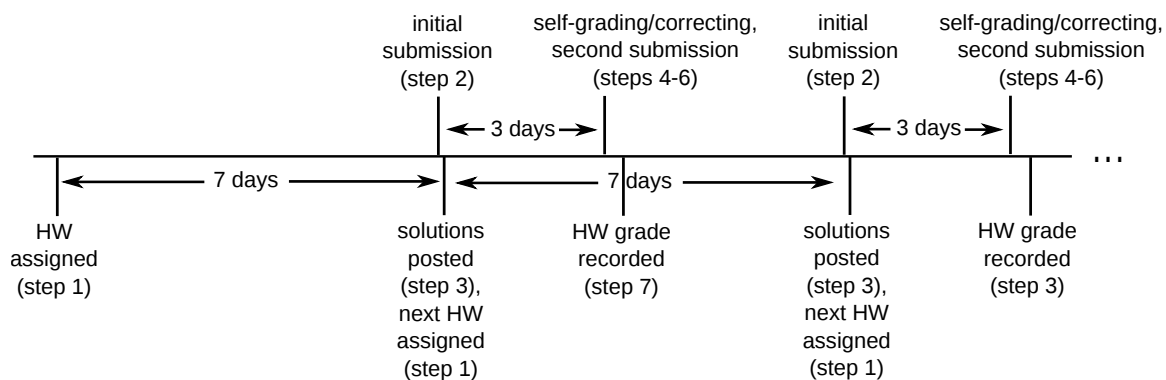


Figure 1: Time-line showing tasks required of student (top) and instructor (bottom) over a two-week period

Since the students submit each homework assignment twice, it appears at first glance that this homework grading approach results in more time and work for both the student and the instructor. Even with traditional instructor-graded homework, however, the students ideally spend time reviewing solutions; thus, while reviewing the solutions and correcting mistakes is a required activity under this scheme, it is an activity students should be conducting informally in all classes. As for the time requirements on the instructor, we have found it to be similar or less than that of traditional graded homework. As other studies have found¹⁶, the majority of the work in self-grading schemes involves preparing detailed solutions the students can use to grade and correct their homework. If homework solutions are reused from year-to-year, or if sufficiently detailed textbook solutions are available, the time requirements of this scheme have been found by the authors to be significantly less than the traditional approach. Compared to grading each problem in the traditional manner, steps 2 (verification of completion) and 7 (coarse assessment of student self-correcting/grading) can be completed relatively quickly.

Data collection

To assess the accuracy of student self-grading and self-correcting for comparison with previous studies^{4,7}, we conducted a blind grading experiment. For one assignment in each class, the students' initial submissions (in step 2 above) were graded "traditionally" in parallel by the instructor without the students' knowledge. The instructor scores were then compared with the students' scores for this one assignment. In ENGR 104, the assignment used for the study involved dimensioning standard 3 view orthographic drawings as per ANSI standards. In EE 360, the assignment was a primarily mathematical assignment reviewing concepts of impulse responses, frequency responses, and LTI system behavior. Finally, in EE 460, the assignment contained a combination of mathematical analysis of carrier recovery in digital communications, and included some MATLAB programming exercises.

Because metacognition is a complex construct that is not directly observable, assessment of metacognition is particularly challenging¹⁵. While test instruments have been developed to assess metacognitive knowledge in the first six years of life¹⁵, metacognitive knowledge of university students and adults are typically assessed by self-report measures¹⁷. Thus, to gauge students' perceptions of self-graded and self-corrected homework compared to traditional instructor-graded homework, and to attempt to assess their metacognitive processes, an anonymous survey was administered. The survey contained 6 questions on a 5-point Likert scale, and students were encouraged to leave additional, qualitative feedback. The survey was anonymous, the instructor left the room while the students completed the survey, and one of the students volunteered to collect the completed surveys in an envelope.

Data analysis

Comparison of instructor and student grades

As mentioned above in the data collection section, one homework assignment was selected from each course to be graded in the traditional "instructor-graded" manner for comparison with the students' scores from their self-graded assignments. While the students had signed an informed consent form, and were therefore aware that they were part of the study, they did not know this particular homework was being graded in parallel by the instructor. Again, at the time this study was conducted, this was the 4th self-graded/corrected assignment for students in ENGR 104, it was the 1st such assignment for students in EE 360, and it was the 27th assignment for students in EE 460. Thus, the prior exposure to self-grading and self-correcting varied widely among the three groups.

A comparison of the instructor and student scores are shown in the scatter plot in Fig. 2. In the figure, "perfect agreement" between student and instructor is indicated by the dashed line, so points below this line correspond to cases where the instructor gave a higher score, and points above the line correspond to cases where the students gave a higher score. Averaging over all submitted homework assignments in all courses, we found students awarded themselves slightly lower grades (-2.30 points) compared to the instructor. Linear regression using a least-squares fit was performed, and the best fit was found to be $y = 1.0659x - 7.8816$ where x is the instructor

score, and y is the student score. The coefficient of determination was found to be $R^2 = 0.9002$, which is very similar to results reported elsewhere⁴. As part of the study, there were 26 submitted homeworks in ENGR 104, 25 submitted homeworks in EE 360, and 9 submitted homeworks in EE 460 for a total of $N = 60$ data points.

Previous studies on self-grading have observed that lower performing students tend to inflate their grades slightly, while higher performing students tend to modestly deflate their grades⁹.

To verify whether this effect was present in our data, we plotted the difference between student and instructor versus the instructor score, and the result is shown in Fig. 3. From the Figure, we do observe that the higher performing students did tend to give themselves lower scores when compared with the instructor, but different from the previous studies, we

noted that the lower performing students *also* graded themselves lower than the instructor. The standard deviation of score differences for students in ENGR 104, EE 360, and EE 460 were 7.10, 5.46, and 2.73, respectively. This suggests that student scores in EE 460 (represented by the green stars in Fig. 3) are, overall, more in agreement with the instructor; this can perhaps be explained by the fact that students in this class had far more experience with self-grading and self-correcting. We note that 78.3% of the student scores were within ± 5 points (roughly one letter grade) of the instructor scores, 18.3% of the student scores were more than 5 points below the instructor scores, and only 3.3% of the student scores were more than 5 points above the instructor scores. These statistics are generally in agreement with previous studies on self-grading of university-level homework³.

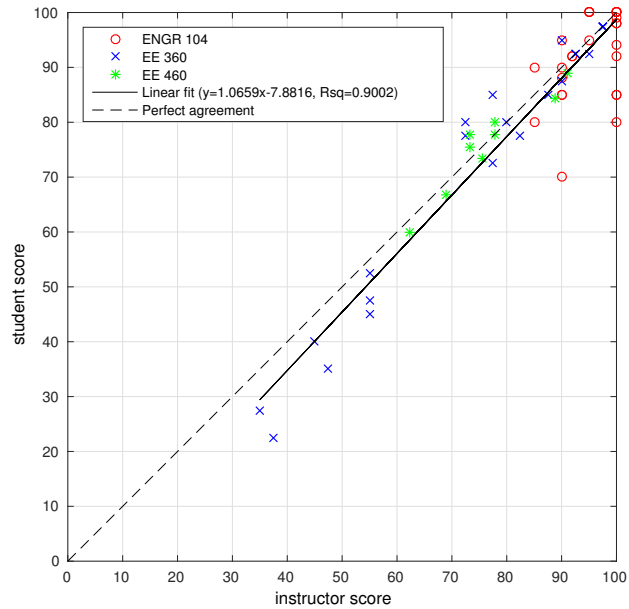


Figure 2: Scatter plot comparing instructor and student grades ($N = 60$)

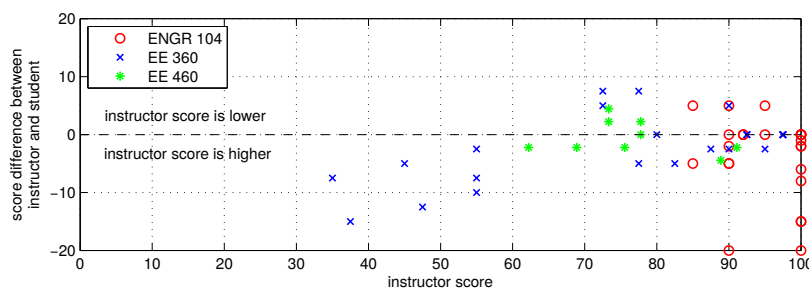


Figure 3: Student grading accuracy versus instructor score

Quantitative survey results

The six survey questions and the students' responses are shown in Figs. 4 and 5. Note that all of the survey questions began with the phrase "Compared to instructor graded assignments, please indicate...". The population surveyed included 34 students from the Fall 2015 offering of ENGR

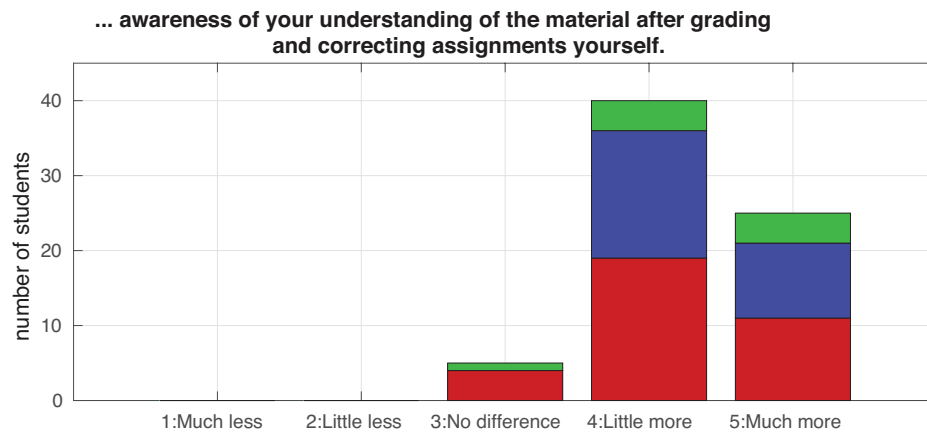
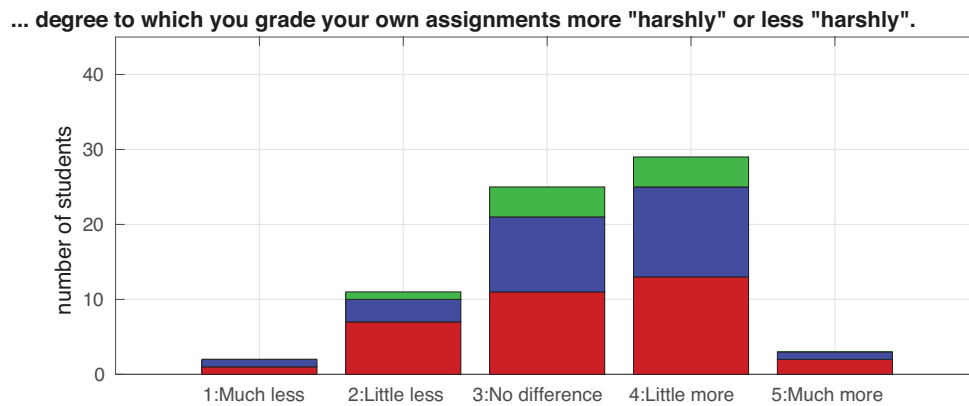
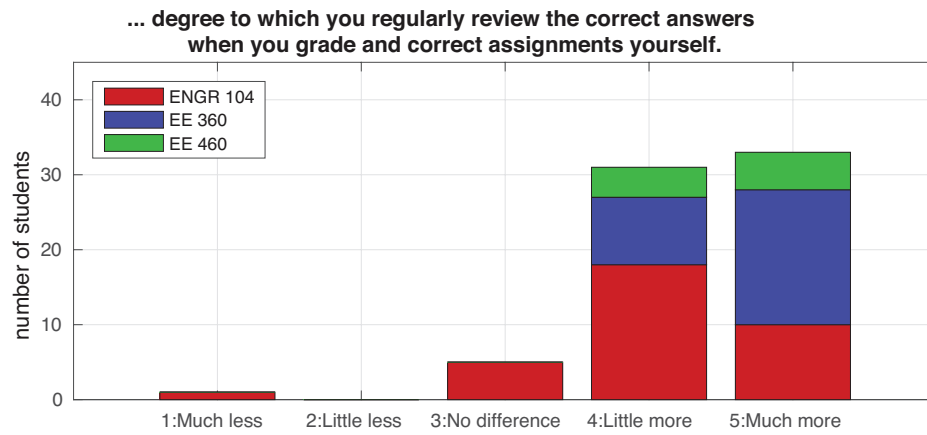


Figure 4: Survey results of questions 1-3.

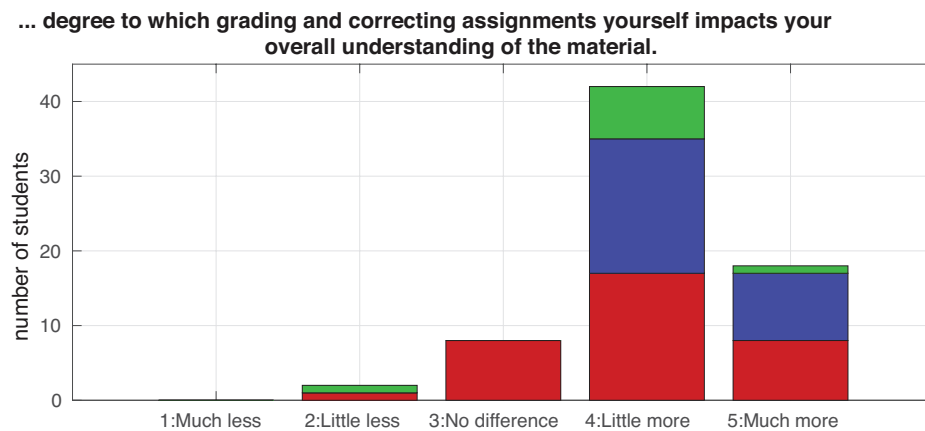
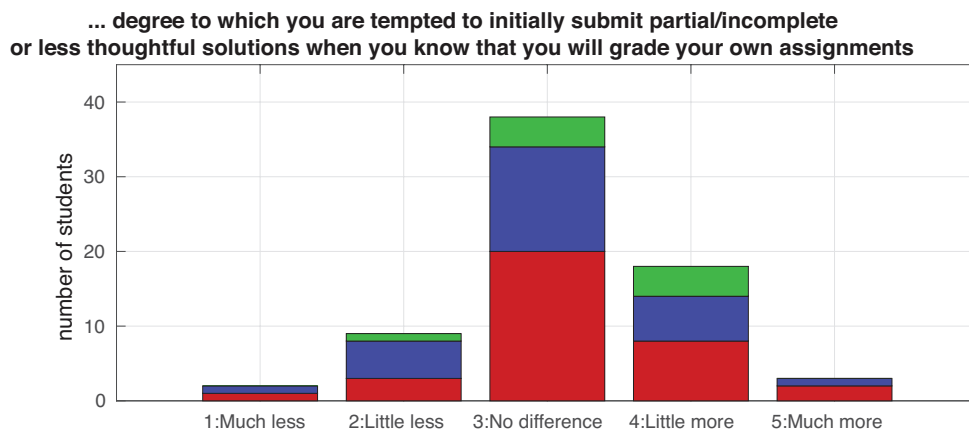
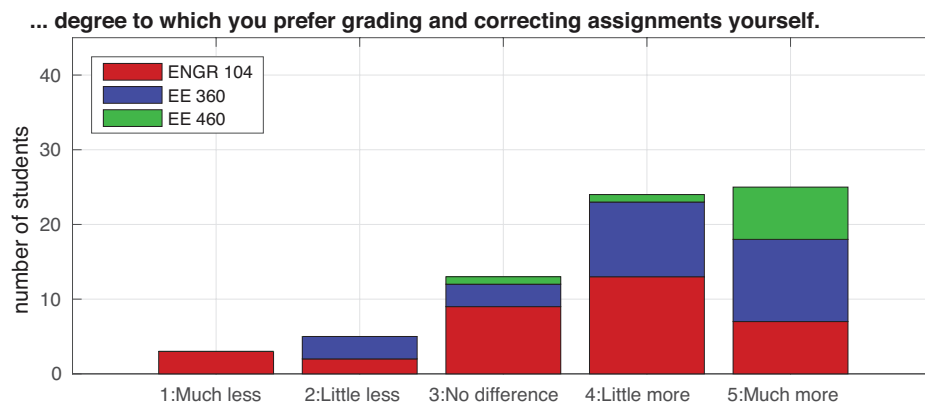


Figure 5: Survey results of questions 4-6.

Question	ENGR 104 mean ($N = 34$)	EE 360 mean ($N = 27$)	EE 460 mean ($N = 9$)	Total mean ($N = 70$)
... the degree to which you regularly review the correct answers when you grade and correct assignments yourself	4.06	4.67	4.56	4.36
... the degree to which you grade your own assignments more “harshly” or less “harshly”	3.24	3.33	3.33	3.29
... your <i>awareness</i> of your understanding of the material after grading and correcting assignments yourself	4.21	4.37	4.33	4.29
... the degree to which you prefer grading and correcting assignments yourself	3.56	4.07	4.67	3.90
... the degree to which you are tempted to initially submit partial/incomplete or less thoughtful solutions when you know that you will grade your own assignments	3.21	3.04	3.33	3.16
... the degree to which grading and correcting assignments yourself impacts your overall understanding of the material	3.94	4.33	3.89	4.09

Table 1: Mean survey results by subpopulation

104, 27 students from the Winter 2016 offering of EE 360, and 9 students from the Fall 2015 offering of EE 460 for a total of $N = 70$ completed surveys. The mean response on each question by subpopulation is shown in Table 1.

The means are quite consistent across each subpopulation, with one notable exception: the students who have had more prior experience self-grading and self-correcting (i.e. those in EE 460) report that they prefer it significantly more than the students with less experience. These self-reported results suggest that students generally review the solutions more (with 47.1% indicating much more, and 44.3% indicating a little more). In addition, 35.7% indicated much higher awareness of their understanding, 57.1% indicated a little higher awareness, and 7.1% indicated no difference; no students indicated *less* awareness under this homework grading scheme.

The self-reported survey trend regarding how “harshly” students perceive they grade their own homework compared to an instructor is in agreement with the score comparisons of the previous section. That is, a larger proportion of students believe they grade more harshly, which agrees with the instructor versus student data.

Qualitative survey results

Given the complex and subjective nature of metacognition, the survey included space for additional student comments. Twelve responses were collected from ENGR 104, 9 from EE 360, and 7 from EE 460, for a total of 28 comments. In these comments, 6 students offered suggestions for improvement to the process and 22 students emphasized their preference for the self-assessment model. Many students appreciate the increased involvement in their own learning, spending more time with their homework, and gaining a deeper understanding of course material. Comments of this nature allude to increased metacognitive reflection.

The most significant comments come from the EE 460 cohort. Having used this same method for 27 assignments across three consecutive quarters, 6 of the seven comments referred to their personal understanding or lack thereof, indicating a degree of self-reflection in accordance with the quantitative results of the survey. Here are example comments from three different students:

I like the self-grading because it forces me to go back to the solutions and break down what I did and did not know.

Having to correct my homework myself makes me set aside time to see how well I did on the homework and helps me to understand everything I did wrong before as well as how to do things correctly.

I really like being given the chance to grade and correct my own homework because it allows me to really see the topics I do and do not fully grasp.

Again, we acknowledge the difficulties associated with measuring metacognitive processes, but comments like these from students with extensive experience with this self-corrected homework model provide a strong suggestion that the self-corrected homework model incentivizes metacognition.

In hindsight, we regret that we did not include a survey question asking students if they still consulted solution manuals. It is impossible to completely eliminate the unauthorized use of solution manuals, but the incentive to use them is likely minimized under this grading approach which does not reward correct answers. When the self-corrected / self-graded homework model was introduced to the students, it was emphasized that copying solutions only minimizes their own learning and does nothing to improve their homework grade. Comments from students on the anonymous surveys suggested that they were quite aware of the importance of completing the homework on their own.

Conclusion

In this paper, a homework grading model was presented wherein students grade and correct their own homework, and they are subsequently evaluated on their own ability to grade and correct. In light of recent research suggesting that a large percentage of students regularly consult online solution manuals when completing homework – which calls into question the usefulness of traditional homework as a tool for formative or summative assessment – the homework model proposed in this study sought to adapt the incentive mechanisms to restore usefulness to homework as a form of formative assessment while encouraging higher-order thinking and metacognition. A comparison of student-graded and instructor-graded homework confirmed results from previous studies that suggested students tend to grade themselves similarly to instructors, giving themselves slightly lower scores on average. Because metacognition is a complex construct that is not directly observable, an anonymous survey was administered and students were asked to self-report on their awareness of their higher-order cognitive thinking. While such self-reporting surveys have limitations, the results of this initial work in progress suggest that under this model, students are more aware of their learning, they spend more time reviewing and evaluating their solutions, and they report that self-grading and self-correcting leads to an improved understanding of the material. Future work will expand this initial case study into a longitudinal study designed to test the impact of this model on student learning when compared to a control group.

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