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Metacognitive Strategies for Homework Grading: Improving Learning while Saving Time and Decreasing Cheating

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Abstract

In recent years, two trends have combined to cause engineering faculty to look for better ways to assign homework. The first is the Science of Teaching and Learning (SoTL) and its emphasis on the role of metacognition in learning. The second is the growth of online answer sites like Chegg and CourseHero, which allow students to get answers to homework without actually doing the problems. Over the past decade, several approaches have been devised to deal with the fallout. They typically have students submit homework twice: the first time to provide their answers to problems, and the second time to engage in some reflective activity comparing their approach or their answers with solutions provided by the instructor. This study identifies 14 such approaches, looks at what they have in common and how they differ, and summarizes their research findings.

1. Introduction

As almost everyone in academia now knows, web sites like Chegg and CourseHero enable students to download homework answers, rather than doing the problems themselves. This makes it challenging for instructors to get their students to undertake enough practice to learn concepts thoroughly. Several recent ASEE conference papers report on strategies that incorporate metacognitive activities into homework assignments, so that students cannot get credit for simply providing answers to problems without also explaining how they have derived those answers. Depending on how tasks are structured, this can (1) decrease cheating, by making it easy to spot students who have not actually worked problems, (2) save grading time, because it is faster to grade reflections on solving problems than to grade the homework problems themselves, and (3) promote deeper learning, because students not only have to solve problems, but also have to think about and describe how they have solved them.

All of these approaches are based on homework that is submitted twice. The first submission is typically the homework answers; the second is generally self-grading and corrections of the first submission. Most of the approaches require students to submit reflections on their work along with the second submission, but some require reflective components to both submissions.

It was not easy to devise a search strategy to return all papers on this topic. We started by searching ProQuest's Education Database, and then broadened the search to all ProQuest databases. A search for ("two submission" OR "double submission") returned no results. A search for (metacogni* AND homework) in the abstract returned 149 results, of which only three were relevant. Two of the three were from ASEE conferences, which suggested searching also

in peer.asee.org. Unfortunately, it was not possible on this platform to limit the search to the abstract, and a search for (metacogni* AND homework) in fulltext returned 495 results. Most of these could be eliminated by reading just the title or the first paragraph of the abstract. In a few dozen cases, the entire abstract was read before being discarded. After that, about 20 papers remained. Reading through the full papers allowed the list to be culled to just 14 papers, all but one of which came from ASEE Annual Conferences. The strategy was not perfect; at least one relevant paper [15] cited by a paper from the group of 14 did not make the cut because it used the term "self-reflection" instead of "metacognition." Sadly, there was not enough time to redo the search with the new term.

A common reason for removing papers from consideration was that they focused on two-submission approaches for exams, not homework, Thus, papers on exam wrappers [16] were excluded from the study, while papers on "homework wrappers" were included. Two papers [11, 14] report on both exam and homework wrappers, but we consider only the homework-wrapper portion.

The rest of this paper is organized as follows. After describing the fourteen papers that make up the study (Sections 2 and 3), the next three sections report on various research questions: Does the metacognitive approach require more time (Section 4)? Do students and/or faculty prefer it (Section 5)? Is there evidence of learning gains (Section 6)? Section 7 summarizes the results.

2. The Corpus

As stated in the papers, the homework strategies have two major goals: promoting students' metacognition (7 papers) and preventing students from simply submitting downloaded answers (5 papers). The papers in the former group tend to be older (average publication date 2016) than papers focused on preventing cheating (average publication date 2019). The remaining two papers express their goals differently. Linford et al. [4] are aiming to ensure that students look at their feedback in a timely manner. Lura et al. [7] are trying to get students to appreciate the relevance and importance of homework. Overall, the oldest paper is from 2013 and the newest from 2020.

Most of the treatment groups are quite small; 8 of the 14 involve fewer than 100 students. The largest includes 560 students, and it is larger than the second and third largest put together. In 13 of the 14 studies, all co-authors hail from a single institution. The exception is the Breid et al. paper [3] that explicitly sought to transfer an approach used at a small college (St. Vincent College) to a major university (Ohio State). Except for that paper and its predecessor from St. Vincent, and two papers by Goldberg et al. from Hofstra, each paper was from a different institution. Henceforth, we will refer to the approaches by the institution they come from. This will probably be easier for most readers to remember than referring to the works by title or author. The reference list gives the institutions that each paper comes from, along with the abbreviation (e.g., "WWU" for "Western Washington University").

3. The Approaches

To avoid confusion between submitted answers and solutions returned by the instructor, we will use the term "answers" for anything submitted by the student, and "solutions" for the answer key provided by the instructor. In all of these strategies, first-round submissions include the answers and last-round submissions include some kind of metacognitive reflection. One of the approaches [14] has three rounds of submissions: answers, quiz, and corrections.

Generically, the approach can be described as: student submits answers, possibly accompanied by some kind of initial reflection (such as an explanation of how they solved the problem). Instructor returns solutions, possibly accompanied by a simply-calculated grade. Student submits some kind of self-reflection or self-evaluation, possibly accompanied by a reflection or evaluation of a few other students' work. Then a final grade is assigned, which depends heavily (though often not entirely) on the reflective submission.

In all but two cases, homework submission and reflection/revision is solely an individual activity. In the Harvard [8] methodology, students first discuss their work with their team and make corrections; only then do they consult the solutions and make whatever additional corrections are necessary—a classic Mazur peer-instruction approach. The Elizabethtown approach has students respond on a message board to other students' explanations of how they solved problems.

Details of the approaches are summarized in Table 1.

Initial submission. In all cases, students submit their answers to homework problems in the first round. In about half the strategies, only the answers are submitted. Other items that may be submitted in Round 1 are supporting work (Ohio State [3]), discussion of methodology (Elizabethtown [6]), reflection on any confusion (Hofstra 2014 [9]), a reflection on the learning process and difficulty (UMBC [12]), and a cover sheet answering questions like, "Did you follow directions? find an answer?" (Citadel [5]).

First feedback. The most common follow-up to the student's initial submission is to provide solutions [1, 2, 4, 5, 6, 10]. In lieu of solutions, at Ohio State [3] the initial submission was autograded. Instead of being graded for correctness, students' answers were frequently graded for completion [1, 2, 7] or effort [8, 10]. A few approaches, though, graded some [7] or all [13, 14] problems in the traditional manner. A very different approach was undertaken at Elizabethtown [6], where students were required to post on a graded Canvas discussion board. They explained their answers and how they had obtained them, and responded to other students' posts. This was followed by a class discussion.

Second submission. Second submissions were usually metacognitive activities, such as corrections [1, 3, 5, 8, 9, 14], self-grading [4, 12], reflections on the solution process [2, 9, 12, 13], and homework "wrappers" [10, 11, 14]. Homework wrappers were inspired by the more

Table 1. Characteristics of Dual-Submission Approaches to Homework

Main Author	Purpose	# students in inter-vention	Initial submission	First feedback	Second submission	Final grade
1. Kearsley (WWU)	Prevent using downloaded solutions	70	Answers	Graded for completion Detailed solutions	Self-graded and corrected	The instructor provided a final grade based on the quality and accuracy of the corrected, final submission
2. Breid (SVC)	Prevent using downloaded solutions	27	Answers	Graded for completion & effort Solutions	Metacognitive evaluation	Corrections and metacognitive reflection (very similar to Kearsley)
3. Wilson (OSU)	Prevent using downloaded solutions	100	Answers + supporting work	Automated scoring for correctness, supporting work graded by instructor	Corrections & reflections, based on automated feedback	Completion grading of corrections and metacognitive reflection
4. Linford (USMA)	Ensure that students look at feedback in a timely manner	251	Answers	No grades Solutions	Self-graded (holistic letter grade) and corrected answers	Graded on thoroughness of revision (2/3 orig. student grade, 1/3 final instructor grade)
5. Wood (Citadel)	Prevent using downloaded solutions	560	Answers + cover sheet: did you follow directions, find an answer?	No grades Solutions	Corrections + cover sheet: Correct solution? Topics mastered?	60% for just doing it, 100% for on time, complete & correct
6. DeGoede (Elizabethtown)	Prevent using downloaded solutions	"3 classes"	Answers & explanation/discussion of method	After students post, they see solns. + other students' posts on a graded Canvas discussion board.	Respond to other students' posts, followed by discussion in class	The extent to which posts indicate engagement with the assigned problems toward developing req'd skills
7. Lura (FGCU)	Help students understand the relevance & importance of hw.	137	Answers	Graded for completion & some problems graded for accuracy (all probs were graded in Q sections)	Quiz, consisting of rephrased hw. or hw. with #s changed	Quiz graded for completion & accuracy
8. Mota (Harvard)	Promote students' metacognition	65	Students work problems individually, using a specified strategy	Evaluation based on effort, not correctness	Corrections, based on discussion with team, then on comparison w/solns.	Accuracy of self-evaluation, based on a scale of 0-3
9. Goldberg (Hofstra 2014)	Promote students' metacognition	72	Answers + reflection on any confusion	In-class demonstration and self-correction by students	Explain how you got the errors and revise solution	Score, plus feedback on whether understanding of errors was accurate
10. Lund (UB)	Promote students' metacognition	267	Answers	Most submissions graded only for effort Solutions, inc. problem-type ID	Homework wrappers	Wrappers were not included in the grade

Table 1 (cont.). Characteristics of Dual-Submission Approaches to Homework

Main Author	Purpose	# students in inter-vention	Initial submission	First feedback	Second submission	Final grade
11. Chew (Stanford)	Promote students' metacognition	75	Answers	[Not specified]	Homework wrappers	Instructor grade for answers
12. Castellanos (UMBC)	Promote students' metacognition	53	Answers, plus reflection (reflections are weekly, probably not submitted along with answers)	[Not specified]	Self-graded reflection (6% of grade)	Evidently, instructor grade. Also, feedback from "instructor for every written paragraph"
13. Goldberg (Hofstra 2015)	Promote students' metacognition	66	Answers	Not specified. Presumably a hw. grade, because writing was worth 20% of the hw. grade.	Responding to writing prompt for 1 problem (out of 3–5 on the problem set)	Whether the student completed the assignment "in a thorough manner," e.g., answering with ≥ 3 sentences when asked to do so.
14. Chen (Cal Poly)	Promote students' metacognition	110	Answers, ff. by quiz over hw. assignment	If student scored > 80%, hw. was simply returned to student. If student scored ≤ 80%, only score was ret'd. & student was given oppor-tunity to compete a quiz correction	Figure out mistakes & correct them; fill out the quiz "wrapper"	Original score + ≤ 1/2 of the missed portion of the original score

established practice of exam wrappers [16–19]. They are essentially a debriefing of students on how they attempted the work and how they performed on it (how did they study, what procedures did they follow, which practices were effective and which were not). One observation is that students should not be asked to do too much. Students at Ohio State [3] objected to being asked to submit both answers and supporting work in the first round, and corrections and reflections in the second. The FGCU students [7] thought that frequent quizzes were a source of stress. Hofstra 2014 [9] was one of several studies [12, 14] that reported poor compliance by students in doing the reflection (42% skipped 2 or more reflection assignments). Hofstra 2015 [13] improved on that by having students write all responses in class (87.4% were completed).

Most second submissions had students reflect on (only) their own work, but there were a few exceptions. The Elizabethtown approach [6], as noted above, had students reflect on *other* students' explanations on a message board. The Harvard approach [8] had students discuss their answers with their team before being allowed to see the instructor's solutions. A couple of approaches used quizzes in the second round. At FGCU [7], students took a quiz over rephrased homework problems, or homework problems with the numbers changed. The Cal Poly scheme [14] had students submit homework (round 1) and then take a quiz over it (round 2). The quiz was graded by the instructor. If the student scored more than 80%, then they simply received their homework back. Students who scored 80% or less were given the opportunity to complete a "quiz correction" (round 3), in which they corrected their mistakes (using any approach) and then filled out a "quiz wrapper." Their score was their original score plus up to one-half of the points they missed on the first quiz attempt. This was the only approach that offered more than two rounds of submissions. The author tried it in only one semester, and reported that quiz corrections did not seem to be efficacious.

Final grade. In contrast to the earlier phases, where the various approaches showed similarities, final grades were assigned in a great diversity of ways. The approaches targeted at improving students' metacognition tended to grade in a nearly traditional manner. Several [9, 11, 12] graded homework for correctness as usual. The strategies that administered quizzes [7, 14] used the quiz grade. The WWU approach [1] used the final, corrected answers to compute the grade. Some strategies included the quality of metacognitive reflections in the grade [2, 3, 8]. A couple used some sort of completion grading as a component of the grade, where they just checked that the student submitted the reflection [3, 5]. Perceived effort was an important metric for Hofstra 2015 [13]. The USMA methodology [4] combined the student self-grade with an instructor grade for the final revision. The odd strategy out was Elizabethtown [6], which graded the student's discussion posts based on engagement and the degree to which they reflected developing required skills.

4. Time Expenditure

RQ1a. Does the metacognitive approach require more time from the faculty?

When considering undertaking this kind of intervention, faculty naturally want to know whether it will demand more of their time. Most of the papers in the sample have something to say about that. Those approaches that grade only the reflection typically result in less instructor time. The Citadel authors report [5]: "The instructor engages primarily with the reflection worksheet decreasing the instructor's grading time." Lund (UB) [10] is even more emphatic: "Grading assignments on the basis of effort greatly reduces the time it takes to grade an assignment. Using the effort-based grading scale described here, grading an assignment takes no more than a minute." The approaches that grade the first-round submissions for completion and the second-round corrections [1, 2] still find that it saves time. Breid (SVC) [2] reports, "even though grading now occurs twice, both rounds are relatively quick, resulting in an overall decrease of grading time."

The USMA authors [4] state that the time factor could go either way. Their approach requires high-quality solutions to problems, more detailed than one would typically find in a solution manual. Experienced problem-solvers will often skip steps, which confuses beginners. The time spent developing solutions offsets the decrease in grading time. They estimate that it would save time if the class consisted of more than 20 students. Additionally, the solutions can be reused year after year. Certainly it is less time-consuming than developing new problems *and* solutions for each new class. (And, as DeGoede [6] points out, those new problems will soon find their way to Chegg and its ilk.) The high-quality solutions provided also set a high standard for student work, and motivates students to submit more complete work.

An important factor in how long grading takes is inspecting the corrected work to discover whether students have truly identified what they misunderstood about the homework problem [13]. If this time is too great, the instructor could forgo it in favor of simply grading the reflection.

The Ohio State authors [3] found that for them, the time burden increased. Formerly, they had been using an autograded homework system, but now they had the extra task of grading the reflections.

In summary, the answer to RQ1a is that if the strategy simply substitutes grading the reflection for grading the answers, it will save faculty time. If it calls for other activities (e.g., producing detailed solutions, determining if reflections accurately assess student knowledge) it may consume more faculty time.

RQ1b. Does the metacognitive approach result in less time spent by students?

The flip side of the time question is how much time the new approach takes the students. The fear is that if they are not going to be graded on their solutions, they will breeze through the work. The two Breid papers [2, 3] reported that most students spent at least as much time on homework after as before the intervention; that was true at both SVC and OSU.

RQ1c. Does the metacognitive approach consume more class time?

The Stanford [11] and Cal Poly [14] authors were concerned about whether the wrappers would use up valuable class time. Both of them concluded that minimal time was expended.

5. Student and Instructor Reaction

RQ2a. Do faculty prefer the metacognitive approach?

Only two papers reported on instructors' reaction to this style of homework. These were two of the three largest studies, and thus could survey a broad instructor base. The Citadel instructors [5] found that the method saved them time, while increasing "cognitive interaction with students." The USMA project [4] conducted an instructor survey, which found high agreement (better than 4/5) to statements such as, "The Self-Correcting Method helped my students review topics that they need to know," "The Self-Correcting Method was a good use of my students' time," and "The Self-Correcting Method helped my students learn better than traditional homework grading methods." Thus, the projects that were large enough to produce meaningful evidence of faculty reaction reported that faculty preferred this approach.

RQ2b. Do students prefer the metacognitive approach?

One of the most promising findings from this set of experiments is that students almost universally prefer this approach to homework. They report that it improves their understanding [1], found homework easier to complete [2], and felt that they learned the material better than they otherwise would have [2, 9, 11]. They found it very helpful in identifying their errors [9]. They felt that they were more engaged in the dual-submission process [5]. What they liked best was self-grading [5]. Their attitudes toward the methodology improved from early in the semester to later on [4]. Students who completed homework wrappers [13] said they made them more likely to think about what confused them about a problem. In the Harvard peer-instruction approach, they "greatly value[d] the team discussions in improving their skills." The only reactions that were less than glowing came from the UMBC students [12], who had just a slight positive perception of writing their reflection paragraphs, but even they were more positive than negative.

6. Learning Gains

RQ3a. Does the metcaognitive style of homework improve students' awareness of their understanding?

The point of the metacognitive strategies, of course, is to induce students to think about the work that they were undertaking, and in so doing, deepen their understanding of the material. The Harvard paper [8] reports that the number of metacognitive comments increased as the semester progressed. It also showed that students' self-evaluations became more accurate with experience. The UMBC team [12] found that students whose self-evaluations were more accurate also performed better in the course. Thus, both studies that addressed the issue reported better awareness by students who did homework and then reflective exercises.

RQ3b. Does the metcaognitive style of homework improve student learning?

The bottom line, though, is whether students actually learn more when metacognitive homework sequences are used. Only 8 of the 14 papers report any results in this area, and none of them report a clear benefit. The USMA project [4] reported that homework scores increased (recall that both self-grading and instructor grading were used to derive grades in this approach), but that test scores either did not increase at all, or increased less than 3%. Neither the FGCU project [7], the Hofstra 2014 study [9], the UB intervention [10], or the Cal Poly project [14] found any change in exam scores after the intervention. The Hofstra 2015 study [15] did, but they also noted that prerequisite grades were higher for the students in the intervention group. On the bright side, they found that students who completed the reflection questionnaires fared better, as did students with a stronger math background.

The Lund (UB) paper looked at it from a different angle. If students are not graded for accuracy on their initial homework submissions, they might invest less effort in them. If their later reflective activity did not make up for this (and recall that many students simply did not do the reflection), then their overall learning might decrease. He was pleased to note that exam scores did not *decline* after the intervention. However, that is perhaps a narrow perspective. In many courses, open-ended, open-book homework projects and exams test different kinds of skills. The fact that exam scores held up may or may not indicate that students are still learning as much from their homework. Thus, there is no clear answer to the question of whether metacognitive homework strategies lead to learning gains.

7. Conclusion

Dual-submission homework strategies (answers + metacognitive reflection) have popped up more and more frequently in recent years. These methods are used to combat copying and to deepen students' thinking about the homework tasks they undertake.

This paper examined several research questions posed by a survey of these strategies.

The first three research questions addressed the issue of time. *RQ1a. Does the metacognitive approach require more time from the faculty?* Most studies discussed this issue. The answer seems to depend on whether the instructor is required to do anything more than grade the reflection. If not, the approach saves faculty time; otherwise it might consume more time. *RQ1b.*

Does the metacognitive approach result in less time spent by students? Only two studies reported on this question; neither of them found that the strategy led students to devote less time to homework. *RQ1c. Does the metacognitive approach consume more class time?* Two studies considered this issue; both observed that the strategy had minimal impact on class time.

The next two research questions related to preferences. *RQ2a. Do faculty prefer the metacognitive approach?* Only two studies were large enough to answer this question; both reported that faculty preferred it. *RQ2b. Do students prefer the metacognitive approach?* Most studies dealt with this issue, and all reported that they students preferred the metacognitive style at least a little, with most reporting a strong preference for it.

The final two questions dealt with learning. *RQ3a. Does the metcaognitive style of homework improve students' awareness of their understanding?* The two studies that attempted to answer this question reported an improvement in students' assessment of their own knowledge. *RQ3b. Does the metcaognitive style of homework improve student learning?* About half the papers attempted to answer this question. None of them was able to answer it unambiguously.

In summary, there is strong evidence that both students and faculty find this approach less stressful and prefer it. There is also evidence that it really does improve students' metacognition: they invest more thought in their answers, and improve their self-evaluation skills. These factors *should* lead to an increase in learning, but so far, none has been demonstrated. In any case, a practice favored by both students and instructors is unlikely to fade away, so the future may bring more evidence of its effectiveness.

8. References

[Unless otherwise indicated, all references are from the ASEE Annual Conference proceedings (Annual Conference and Exposition, 2013–2019, Virtual Annual Conference, 2020–2021). Note the abbreviations for institutions in parentheses, which are used in some places in the paper.]

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